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Incremental revenue estimates derived from iron ore mining Mid West Energy Project (Southern Stage)

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1 Executive summary

This report presents estimates and analysis of the anticipated incremental revenue earned by Western Power in return for connecting several new iron ore mines located in the North Country Region. The estimated incremental revenue ranges between from $162 million to $194 million.

The estimated range of incremental revenue is based on detailed analysis of the potential new demand for electricity in the North Country Region. This analysis includes economic modelling using a risk-based discounted cash flow model. The adopted method explicitly recognises the uncertainty that is inherent in commodity markets. It is this uncertainty that largely causes the range of possible outcomes. It should also be noted that the estimates presented in this report do not constitute a forecast. Instead, the intention is to explicitly assess the risks associated with supplying electricity to relatively remote block loads.

The value of the risk assessment is that it clearly identifies the major risk factors associated with supplying new iron ore customers and therefore provides an opportunity for the development of risk mitigation strategies. A secondary benefit is that it explicitly documents what is currently known about these mines.

The value of the analysis contained in this report is that it provides a way of assessing the likelihood of Western Power's Central and High forecasts occurring. The model results presented in this report indicate that, given current information, the High forecast is more likely to occur than the Central.

2 Introduction

This report presents estimates and analysis of the incremental revenue that is anticipated to be earned by Western Power for connecting a small number of new block loads[1] in the North Country Region (NCR).

It is necessary to produce estimates of anticipated incremental revenue as part of Western Power's obligations under the New Facilities Investment Test, which is defined in section 6.52 of the *Electricity Networks Access Code 2004*.

Producing robust estimates of anticipated incremental revenue requires detailed analysis of the new demand for electricity connections. Much of this report is focused on this analysis. In brief, the main source of new demand is the prospective development of up to seven iron ore mines located in the NCR. Of these seven prospective mines, two represent a combined customer maximum demand (CMD) of approximately 400 MW.[2]

The result is an estimated range (low, medium and high) of anticipated incremental revenue. The key issues relevant to calculating incremental revenue are:

- Whether the mines will actually commence mining operations
- When the mines are likely to commence

[1] Block loads refers to individual operations that represent a significant portion of total market demand for electricity. From Western Power's point of view, an individual new demand centre (or new load) is considered significant if long-term network investment plans need to be accelerated in order to safely connect the new load to the network.

[2] Based on Western Power's "High scenario", see DM# 6429512, actual number is 395.5 MW.

- The stability of demand once mining operations are underway.

This report presents the evidence collated and used by Western Power to develop its estimate of incremental revenue. The evidence is presented in a number of sections beginning with a background description of recent mining activity in the NCR in Section 3.

The method of quantitative assessment is then briefly described in Section 4. Broadly, the assessment methodology is framed as a probabilistic discounted cash-flow model. The probabilistic approach taken in this report acknowledges the uncertain nature of the demand. This is followed by a discussion of the key modelling assumptions in Section 5.

Model results are presented in Section 6, which includes detailed sensitivity analysis. The sensitivity analysis serves to identify the variables that are most important to determining the level of demand and provides an assessment of the impact of changes in these assumptions on the anticipated incremental revenue.

Section 7 discusses the differences between estimates developed in the risk-based modelling and Western Power's official forecasts. Finally Section 8 provides a summary of the analysis and concluding remarks.

3 Background

3.1 Introduction

Western Power received an application for connection to the South West Interconnected System (SWIS) from a prospective iron ore mining company located in the NCR. In response to that connection application, Western Power has conducted an investigation to determine the most efficient approach to connecting the customer.

Invariably, connecting a new customer requires some level of network reinforcement. In scoping a reinforcement option, it is prudent to consider the long-run demand for electricity both in terms of the potential long-run size of the NCR electricity market and how quickly the market is likely to achieve that long-run size. Conducting this assessment helps to identify optimisation opportunities. For example, rather than upgrading the network via separate works to connect several customers over one or two years, it may be more efficient to build sufficient capacity in a single project to connect all new customers; thereby exploiting economies of scale through avoidance of cost duplication.

3.2 Prospective block load connections

Western Power's forecast branch has identified a total of 309 MW of potential new block loads connecting between 2010 and 2014.[3] The majority of individual block loads are within the agriculture and mining industries. Of this, approximately 92% is related to iron ore mining. However, this estimate does not include all of the potential block loads.

Further investigation has revealed the following prospective Mid West iron ore mines:

- Asia Iron's Mount Gibson project
- Cashmere Iron's Cashmere Downs project
- Crosslands Resources' Jack Hills project

[3] Based on Western Power's "High scenario", see DM# 6429512

- Gindalbie Mining Limited's Karara project
- Golden West Resources' Wiluna West project
- Mount Gibson, Extension Hill project
- Sinosteel's Blue Hills/Koolanooka and Weld Range projects

Advice provided by industry experts indicates that these prospective iron ore projects can be broadly classified as either hematite or magnetite projects. Importantly for electricity demand, hematite iron ore mines require relatively little electricity as they are largely direct shipping ore (DSO) operations. In contrast, magnetite operations require substantially more electricity due to the need to increase the iron content before exporting product from the mine site.

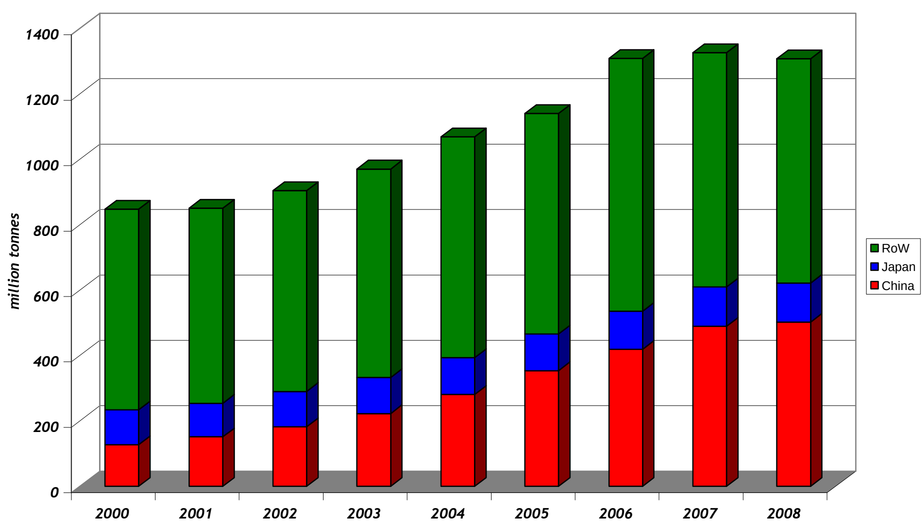
Collectively, these mines represent a substantial increase in the demand for electricity. However, not all of these mines are likely to seek connection to the SWIS. Of those that appear likely to seek connection, a total of 401 MW of CMD of which 72% can be attributed to magnetite iron ore mining. The total demand exceeds the available capacity in that part of the SWIS by a substantial margin.

Regardless of which option is least cost, all are dependent on the prospective iron ore mines actually commencing operations. This will depend on the likelihood of these mines earning at least a normal economic return. In turn, this will depend fundamentally on whether global demand continues to grow faster than the supply of iron ore.

3.3 Global iron ore outlook

The growth in the global demand for iron ore is summarised in Figure 1. Since 2000 global demand has grown from 800 million tonnes to 1,300 million tonnes in 2008. This increase corresponds to a compound average growth rate of 5.6% per annum.

Figure 1 World demand for iron ore



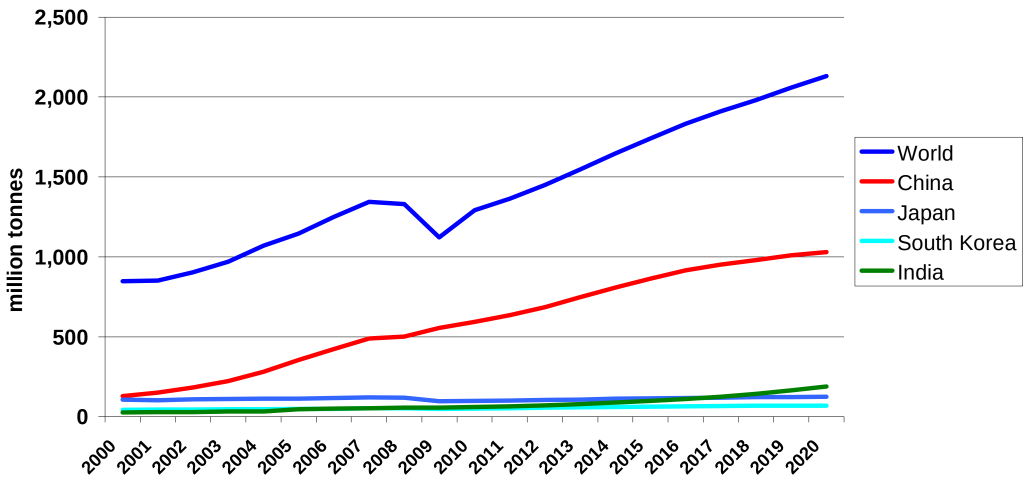
RoW: Rest of World

Source: Department of State Development, Iron Ore Forecasts For Western Australia, January 2010

The figure clearly shows that the primary source of the growth in iron ore demand can be attributed to China. Indeed, Chinese growth corresponds to a compound average growth rate of 18.7% per annum for this period.

A forecast for global demand to 2020 is provided in Figure 2. A key assumption underpinning this forecast is that world demand for iron ore is likely to return to its long-run rate of growth relatively quickly. A notable feature of the historic data (2000-2010) is that despite world demand for iron ore declining during 2008-09, China's demand continued to grow.

Figure 2 Forecast for global iron ore demand to 2020



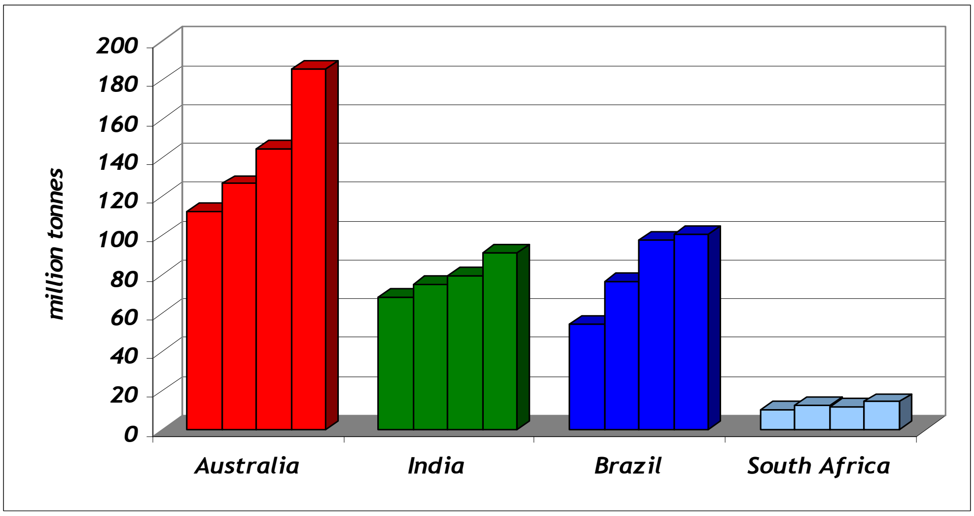
Source: Department of State Development, Iron Ore Forecasts For Western Australia, January 2010

If this forecast holds, then demand is likely to underpin ongoing increases in world iron ore production for the foreseeable future.

3.4 Implications for Western Australia's iron ore industry

In terms of satisfying Chinese demand, Western Australia has a competitive advantage based on substantial world-class iron ore deposits and its relative proximity to China when compared with other major iron ore producing countries. Given the bulky nature of iron ore, proximity translates to savings in transport costs, which can be substantial.

Figure 3 Market share of Chinese iron ore imports



Source: Department of State Development, Iron Ore Forecasts For Western Australia, January 2010

Indeed, Figure 3 shows that Australia (which is predominantly Western Australia) is the single largest supplier of iron ore to China. Moreover, it is maintaining market share, which averages approximately 45%.

Whether or not Western Australia can maintain or increase its market share depends on the size and quality of its yet-to-be-exploited iron ore resources. According to the Department of State Development, there are over 30 billion tonnes of defined and marketable direct shipping ore (DSO). In addition, Western Australia has a total of 12-14 billion tonnes of magnetite resources.

Figure 4 Projected supply of WA iron ore (million tonnes per annum)

Production Potential	2008	2010	2012	2014	2016	2018	2020
Pilbara	331	379	501	730	945	992	1,040
Mid West	4	5	11	43	76	96	93
Yilgarn & South Coast	7	8	11	20	31	34	30
Total	342	392	523	793	1,052	1,122	1,163
Demand	313	356	439	504	610	665	706
Over-supply	29	36	84	289	442	457	457

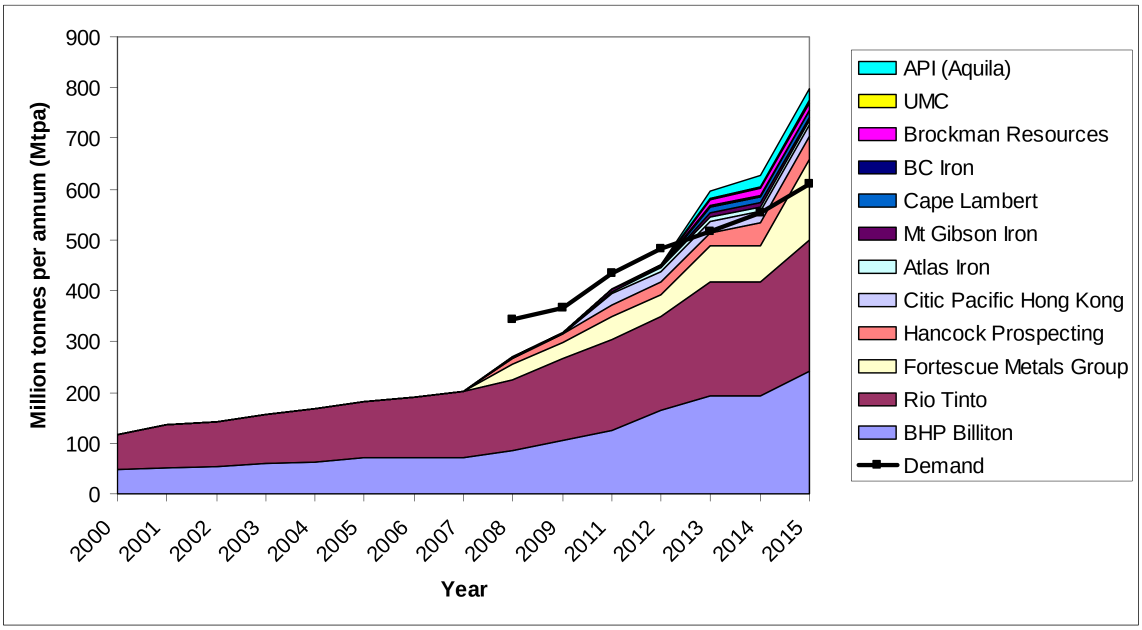
Note: potential over-supply based on a modest increase in Western Australia's market share of Chinese iron ore imports.
Source: Department of State Development, Iron Ore Forecasts For Western Australia, January 2010

Figure 4 shows how this production potential could translate into reality. Based on plans announced by current and prospective iron ore miners and current demand expectations, there is potential over-supply of iron-ore. If this materialised, it would be likely to have a dampening effect on iron ore prices.

Another implication of the data provided in Figure 4 is that the productive capacity in the Pilbara region is likely to exceed the growth in demand for iron ore. The projected over-supply in 2010 is 18 million tonnes and is likely to grow to 334 million tonnes by 2020.

Figure 5 presents a breakdown of Pilbara iron ore production capacity based on proponents' announced plans. The level of production is scaled down by 15% to allow for normal production capacity levels. Miners tend to operate at capacity utilisation levels of 85% of nameplate capacity.

Figure 5 Adjusted Pilbara iron ore production capacity



Note: based on reported nameplate capacity. Capacity reduced by 15% to allow for normal level of capacity utilisation

Given the potential for over-supply, a more in-depth investigation of proposed Pilbara iron ore mine expansions was conducted. The results are presented in Figure 6 to 9. These figures show incremental expansions for BHP Billiton, Rio Tinto, Fortescue Metals Group (FMG) and remaining suppliers collectively labelled as "Other suppliers". BHP Billiton and Rio Tinto are regarded as highly certain to implement announced plans since their funding is largely sourced internally and the expansions are "brown-fields" expansions. FMG is also regarded as certain to proceed, although qualitatively ranked lower than BHP Billiton or Rio Tinto. The remainder of the proposed iron ore expansions/new projects are regarded as less certain. For these, additional investigation identified which of these are actually proceeding and which are still at various levels of planning.

Figure 6 BHP Billiton and Rio Tinto Iron Ore Expansion Projects

Company	Project	Incremental capacity (Mtpa)	Cumulative capacity (Mtpa)	Start year	Completion year
BHP Billiton	RGP4	26	155		2010
	RGP5	50	205	2010	2012
	RGP6	35	240		2013
Rio Tinto	Mesa A	0			2010
	Brockman 4	22			2010
	Western Turner Syncline	29			2010
	Hope Downs 4	15			2013
	Brockman 4, Phase II	14			
	Western Turner Syncline II	16			
	Nammuldi Expansion (Phase I)	16			
	Marandoo (Phase II)	14			
	Paraburdoo	6			

Source: BHP Billiton (March 2010), http://www.bhpbilliton.com/bbContentRepository/docs/ianAshbyPresentationMarch23.pdf; Rio Tinto, http://www.riotinto.com/documents/PR580g_Rio_Tinto_invests_US2_4_billion_in_two_new_iron_ore_mines_in_the_Pilbara.pdf; http://www.riotinto.com/documents/Media/PR652g_Rio_Tinto_invests_US_667_million_in_infrastructure_and_mine_studies_towards_320_Mt_iron_ore_capacity_by_2012.pdf, http://www.riotinto.com/documents/Media-Speeches/3___Warwick_Smith_140608_v2_presentation.pdf, http://www.riotinto.com/media/18435_media_releases_19541.asp,

Notes: Mesa A replaces other mines. This will maintain Robe Valley pisolite ore at 32 Mtpa over the next 10 years. Completion year refers to completion of project construction and commencement of mining.

Figure 7 Rio Tinto Pilbara Iron Ore Production Capacity

Capacity (Mtpa)	Year	Status
220	2011	Committed
230	2012	Committed
283	2013	Committed
333	2015	Feasibility

Source: Rio Tinto (18 January 2011), Fourth quarter 2010 operations review, http://www.riotinto.com/documents/110118_Fourth_quarter_2010_operations_review.pdf

Figure 8 FMG Iron Ore Expansion Plans

Project	Incremental capacity (Mtpa)	Cumulative capacity (Mtpa)	Completion year
Cloudbreak	40	40	
Chichester Hub	55	95	2011
Rocket	35	130	
BC Iron Brockman	5	135	
Solomon Brockman BID + DID	20	155	2012
Solomon Channel Iron CID	40	195	

Source: Fortescue Metals Group, http://www.fmgl.com.au/IRM/Company/ShowPage.aspx?CPID=2195&EID=88866351&PageName=Fortescue Annual General Meeting 2010; FMG Annual Report (p. 2), http://www.fmgl.com.au/IRM/Company/ShowPage.aspx?CPID=2168&EID=36160324&PageName=2010 Annual Report;

Notes: Completion year refers to completion of project construction and commencement of mining.

Figure 9 Other planned iron ore expansion plans

Company	**Project**	**Incremental capacity (Mtpa)**	**Cumulative capacity (Mtpa)**	**Start year**	**Completion year**	**Life of mine (years)**
Atlas Iron	Pardoo DSO	6			2010	
	Wodgina DSO	6	12		2012	
	Dalton & McPhee Creek DSO	10	22		2015	
	Ridley	6	28		feasibility	

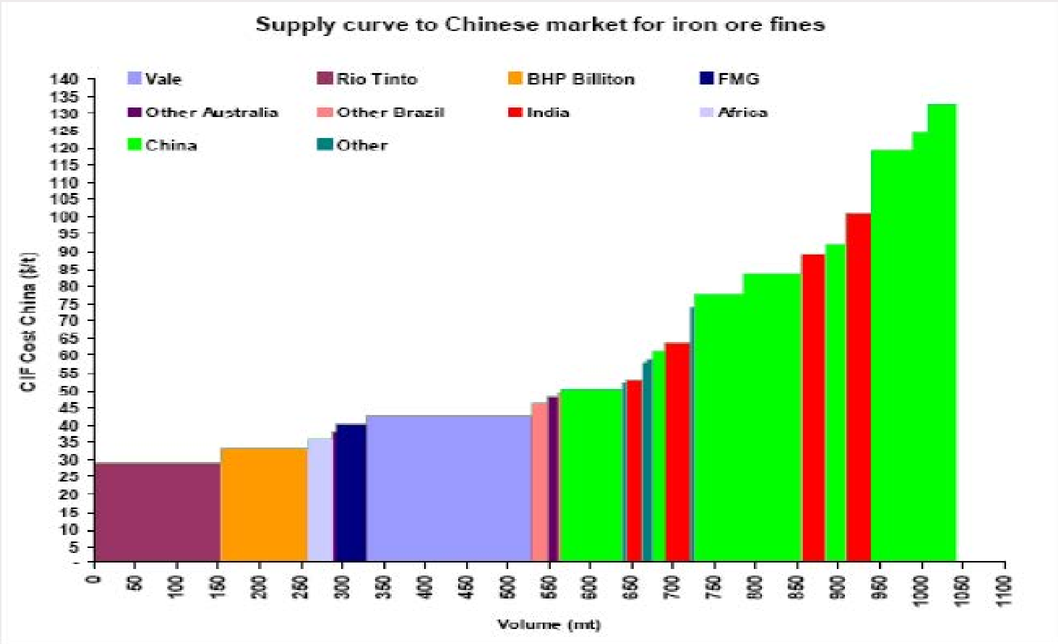
Company	Project	Incremental capacity (Mtpa)	Cumulative capacity (Mtpa)	Start year	Completion year	Life of mine (years)
	magnetite (Phase I)					
	Ridley magnetite (Phase II)	4	32		feasibility	
Mt Gibson Iron	Tallering Peak	3	3			3
	Koolan Island	4	7			9
	Extension Hill DSO	3	10	2012		4
Hancock Prospecting	Hope Downs JV expansion	15				
	Roy Hill	55			2014	
Cape Lambert	Mayoko Project (Africa)	5	5		2013	10
Citic Pacific	Sino Iron Project	27.6			2011	
BC Iron	Nullagine JV (with FMG)	5	5		2011	

Source: Atlas Iron, http://www.atlasiron.com.au/IRM/Company/ShowPage.aspx?CPID=2717&EID=20658610&PageName=Investor Presentation February 2011;
Mt Gibson Iron, http://www.mtgibsoniron.com.au/uploads/13.8.10%20-%20Koolan%20Site%20Visit%20Presentation.pdf;
Hancock Prospecting, http://d301432.u111.fasthit.net/files/China_Mining_2010_English_version)_final.pdf;
Cape lambert, http://www.capelam.com.au/IRM/Company/ShowPage.aspx?CPID=2061&EID=82828566&PageName=Investor Presentation; http://www.bciron.com.au/images/stories/company_presentation/BCI-Company-Update-2010-12-13.pdf

Notes: Atlas Iron currently producing at $45/tonne FOB.
Atlas Iron merging with Giralia – may be Dalton & McPhee Creek DSO. Mt Gibson Iron producing at $54/tonne FOB.
Hancock Prospecting's Hope Downs JV 30 Mtpa already counted under Rio Tinto.
Completion year refers to completion of project construction and commencement of mining.

In order to usefully incorporate the information on iron ore expansions, it is necessary to develop a global iron ore supply curve. Figure 10 presents the baseline 2010 iron ore supply curve sourced from Macquarie Bank. The main suppliers to the Chinese market are represented and arranged in ascending order of supply cost (calculated on a CIF basis).

Figure 10 Supply curve to Chinese market for iron ore fines



Source: Macquarie Bank – Sept 10

Figure 11 Augmentation of global iron ore supply curve

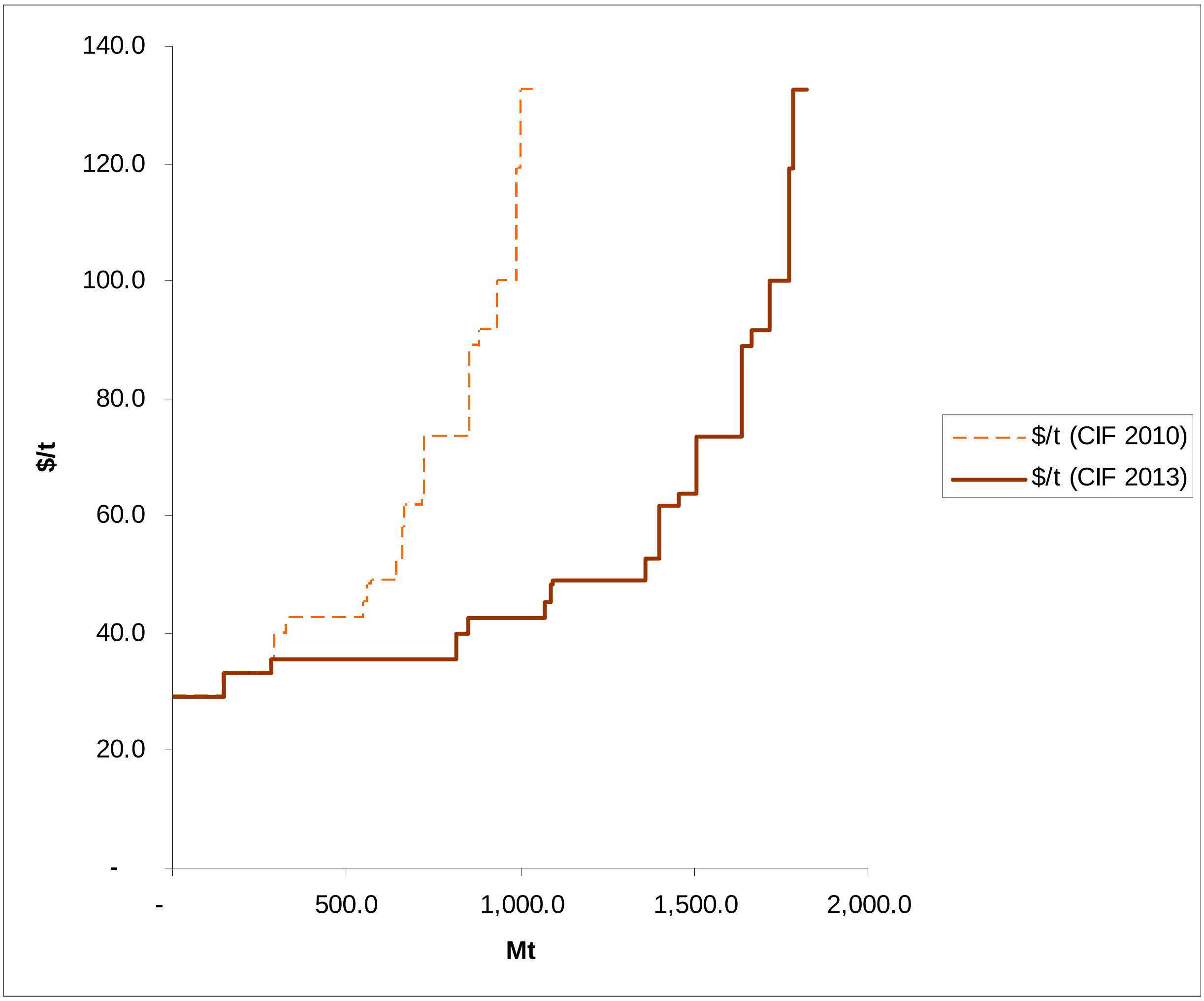
Year	Company	Cumulative additional capacity (Mtpa)	FOB Cost ($/tonne)	CIF cost
2013	BHPB	240	30	39.75
	Rio Tinto	283	30	39.75
	FMG	195	40	49.75
	Atlas Iron	12	45	54.75
	Mt Gibson Iron	10	54	63.75
	Citic Pacific	27.6	60	69.75
	Cape Lambert	10	60	69.75
	BC Iron	5	45	54.75
	Sub-total	*782.6*		
2015	Rio Tinto	50	30	39.75
	Hancock Prospecting	55	40	49.75
	Atlas Iron	60	45	54.75
	Sub-total	*165*		

Source: various as documented in previous tables

Note: Transport cost of USD9.75/tonne assumed based on http://www.ironoreholdings.com/documents/369.pdf, page 7.Assumed USD/AUD 1 exchange rate.

Figure 11 provides the details of how the global iron ore supply curve was augmented. Where there are gaps in source information, an average estimate was used. Note that the mines located in the NCR have deliberately been excluded since these are the subject of the analysis. Figure 12 presents the result of the augmentation.

Figure 12 Augmented global iron ore supply curve



The resulting iron ore supply curve forms part of the model detailed in later sections.

3.5 Progress toward iron ore mine development in the Mid West

Indicative information relating to the likelihood and timing of mining commencement is presented in Table 6. Gindalbie Metals Ltd's Karara project appears to be the most advanced in terms of project milestones achieved. Additional information provided by the Department of State Development indicates that all funding, infrastructure and off-take solutions are being developed. In addition, construction has commenced.

Asia Iron's magnetite project is the next most advanced in terms of planning. A memorandum of understanding between Extension Hill Pty Ltd and the Geraldton Port Authority was executed in March 2010. Conditional environmental approval has also been granted by the Environmental Protection Authority.

Figure 13 Development status of prospective Mid West iron ore mines considered likely to seek connection to the SWIS

Company	Project Name	Ore Type	Development Milestones/Approvals Status	Indicative commencement date
Asia Iron Holdings (Extension Hill Pty Ltd)	Extension Hill Magnetite	Magnetite	Environmental approval granted for 10 Mtpa production rate	2012
Gindalbie Metals Ltd	Karara	Magnetite	Financing secured State and Commonwealth environmental approval granted	2011
	Mungada/Blue Hills	Hematite	Environmental approval granted for the Terapod deposit	2011
Mt Gibson Iron	Tallering Peak	Hematite	Approvals granted	Commenced mining
	Extension Hill	Hematite	Approvals granted	2011
Sinosteel (Midwest Corporation)	Koolanooka/Blue Hills	Hematite	Environmental approval granted	2010-2014
	Magnetite Concentrate	Magnetite	None granted	Not available
	Weld range	Hematite	Bankable feasibility study underway	2014

Source: Department of State Development, 30 March 2010

Mt Gibson Iron is the most advanced hematite iron ore project with the Tallering Peak operation having already commenced mining. Finally, Sinosteel's hematite projects are advanced while its magnetite operation is in the early stages of planning.

3.6 Conclusion

Growth in demand for iron ore from China appears likely to sustain growth in global iron ore demand. This is despite the sharp downturn in global demand for iron ore during the Global Financial Crisis.

Although it would appear that the Pilbara iron ore industry is capable of providing all of the demand for WA's iron ore, adjustment of announced capacity expansion to allow for normal rates of capacity utilisation suggests a shortfall. Nevertheless, developiong iron ore mines located in the Mid West region will be subject to significant competition in the Pilbara.

Within the Mid West region, there are two significant prospective iron ore operations in advanced stages of planning that are seeking connection to the SWIS.

4 Method of evaluation

4.1 Introduction

This section provides a brief description of the methods used to calculate the likely range of incremental revenue. Broadly, the approach is to establish a relatively simple economic model based on the discounted cash flow (DCF) method. DCF is typically used for project/investment evaluation and captures all of the relevant cash flow implications of a specific project.

DCF analysis is supplemented with Monte Carlo simulation analysis in order to properly assess the risks to incremental revenue. The use of Monte Carlo simulation within a DCF model is briefly described in the next sub-section. The following sub-section then briefly outlines the economic factors underlying mine development and the risks that these factors pose. The sub-section concludes with a discussion of how the identified risks impact on the risk of variation in electricity demand.

Overall, this section provides a justification and brief description of the model structure. Note that a more detailed description of the model is provided in Appendix A.

4.2 Overview of Monte Carlo simulation analysis

The Monte Carlo approach to simulation analysis broadly describes any method that approximates solutions through statistical sampling.[4] This method recognises real-world uncertainty through the use of probability distributions. Uncertainty is represented in Monte Carlo simulation by repeatedly drawing random numbers from specified probability distributions. Each random draw is used as input to a model of a system (in this case an economic system) and the impact is gauged in terms of the distributions of specified output variables.

A key strength of Monte Carlo simulation analysis is the ability to gauge the likelihood of a future event occurring. An extension of this method is the ability to quantitatively define the circumstances in which a specified event is likely to occur. The modelling also provides insight into the critical level of important variables. The real-world values of these variables can then be monitored with an understanding of the implications in relation to specified outcomes.

Within a DCF modelling framework, Monte Carlo simulation requires the assignment of statistical distributions with defined parameters (such as mean and standard deviation) to key inputs. Model iterations generate random draws from these distributions, which are used as inputs to the model and, via model calculations, determine the outputs. Repeated draws define a distribution of each model output, thereby reflecting the risk of variability.

Once the risks are quantified, analysis is generally conducted to determine the effectiveness of alternative risk mitigation strategies.

4.3 Economic factors underlying mine development

The main output of the analysis contained in this report is the quantified risk-adjusted demand for electricity among major block loads in the Mid West region of Western Australia. The largest part of the expected new load consists of several prospective iron ore mines.

The development of new mines presents a challenge to infrastructure service providers for several reasons:

[4] http://www.goldsim.com/Content.asp?PageID=511 [accessed 9 March 2010]

- New mines tend to develop during periods of prosperity, which is reflected in relatively high commodity prices. Accommodating high demand often requires expansion of capacity. Capacity expansion, however, typically involves long lead times.
- Commodity prices tend to be volatile and difficult to predict. This means that there can be considerable uncertainty with respect to changes in demand for raw materials (mine output) and the associated demand for electricity and other inputs to mine production. A particular issue is whether changes in demand for raw materials and the associated demand for mining inputs is likely to persist.
- The investment associated with capacity expansion can be substantial with most of it required to be spent before any return can be realised. If the increased demand turns out to be transitory, investors are likely to suffer financial losses that may never be recovered.

The combination of these factors implies specific kinds of risk that need to be measured and assessed. These risks manifest as:

- Output variability from mining operations.
- Likely long-run return on capital invested.
- Financial strength or weakness of mine proponents and their financiers.
- Barriers to mine development such as an absence of adequate infrastructure and services.

This report is primarily focused on measuring the magnitude of output variability and its implications for the demand for electricity. Variation in mine output is likely to be caused by:

- Delays in mine commencement.
- Unexpected breakdowns, variation in extraction rates and processing, industrial action, mine accidents and other operational issues.
- Management decisions to temporarily suspend mine operation due to a deteriorating demand outlook.

Delays in mine commencement could be caused by either a deteriorating demand outlook, rapid escalation in construction costs relative to expected future revenue or delays in delivery of capital items such as plant and equipment. A deteriorating outlook for iron ore demand may result in a management decision to defer mine development in order to protect shareholder value.

Operational variation would be unlikely to have a material impact on the demand for electricity since demand is measured as CMD. CMD is a constant unless there is a discrete change in total mine capacity.

Temporary mine suspension would be in response to unexpected and possibly dramatic events such as the Global Financial Crisis. Management's decision to shutdown would not be taken lightly as this would incur additional cost. The key decision rule would be based on whether the expected revenue is less than the avoidable cost less shutdown (and reopening) costs.

The model results presented in this report recognise the limitations posed by barriers to mine development. If demand for Mid West iron ore turns out to be high, it is likely that the associated demand on existing infrastructure services (in terms of port and rail throughput and supplied energy) will outstrip supply. This will either stimulate an expansion of infrastructure (e.g. the construction of Oakajee Port) or place limits on the scale of iron ore production. Rather than trying to assess the likelihood of infrastructure capacity expansion, the modelling is confined to the assessing the likelihood of mine commencement independently of infrastructure constraints.

5 Assumptions

5.1 Introduction

The model strategy requires a range of assumptions to be made. These are divided into the following groups:

- Statistical model of the evolution (behaviour) of iron ore prices over time.
- Mine economic characteristics.
- Strategic behaviour of mine management, which is focused on maximising shareholder wealth.

5.2 Statistical properties of iron ore prices

With respect to how iron ore prices are likely to evolve, there are many choices outlined in the academic literature. This is distinct to a consensus of how prices actually evolve. The lack of consensus suggests that a reasonable starting point is to consider the empirical evidence. Cashin et al. (1999) provide a convenient summary of the stylised facts. Namely, commodity prices:

- are dominated by long periods of doldrums, punctuated by sharp upward spikes;
- tend to trend down in the long run;
- periodically experience shocks, which tend to persist for several years at a time; and
- that otherwise unrelated commodity prices tend to move together.

In specific reference to iron ore, Cashin et al. reported four price cycles over a period of 42 years between 1957 and 1999. Within this period, iron ore prices spent nearly 70 per cent of the time in a slump. The amplitude of the largest slump was 50 per cent from peak to trough. The largest trough to peak movement was 42.5 per cent (Cashin, McDermott, & Scott, 1999: 19).

The relationship between the amplitude of price spikes and their duration is also relevant. Cashin et al. calculated a high correlation (0.8) between the amplitude of the price slump and the duration of price slumps. This suggests that low prices tend to persist in direct proportion to the severity of the price slump. In contrast, there was little correlation (0.1) between the amplitude of price booms and their duration.[5] One other observation is that commodity prices exhibit substantial negative skewness and positive kurtosis.[6] Negative skewness indicates that the mass of the distribution is clustered to the right with a long left tail while high kurtosis indicates that the distribution (in comparison to the normal distribution) has a distinct peak near the mean, which declines rapidly as the distance from the mean increases, and has fatter tails. Together, the statistics indicate that that the risk of encountering below-trend iron ore prices is significantly higher than the normal distribution would indicate.

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[5] A test of statistical significance failed to reject the null hypothesis of no correlation.

[6] These results are based on the residuals of a deterministic trend regression.

These statistical observations have important economic implications. First, it suggests that price spikes are likely to be observed much more frequently than many would expect. However, it is unlikely that the price spike observed between January 2008 and February 2009 will be repeated for at least 10 years. Also, the persistence of low prices suggests that deviations from long-run equilibrium may be asymmetric. That is, the speed at which prices increase from a slump back toward the long-run marginal cost of production may be substantially slower than the speed of price decreases following a surge in prices during a boom. On balance, we should expect to observe longer periods of below-trend prices than above-trend prices.

For modelling purposes, there are several important pieces of information to consider. The first is that the trend price (in real terms) may meander sideways for a significant period of time. This suggests that if the iron ore price falls below its long-term trend, it may persist in this state for years. The second is that prices could experience several spikes over the next 40 years.

Figure 14 Iron ore price statistics

Parameter	1996-2006	2006-2009
Average price (AUD/DMTU)	0.69	1.23
Average annual volatility	29.06%	43.24%
Max. trough to peak amplitude		128%
Max. peak to trough amplitude		46%
Number of cycles	1-2	
Number of spikes	1	
Proportion of observations below trend	60%	
Kurtosis	4.75	
Skewness	1.75	

Source: Department of Mines and Petroleum, *Minerals and Petroleum Statistics Digest*, Government of Western Australia

Figure 14 presents summary statistics for benchmark iron ore prices since 1996. These statistics indicate some similarities and some differences between data sampled by Cashin et al. and the post-1995 sample. There is one, possibly two price cycles observed and one price spike over a period of ten years. Another similarity is that prices spent more time below-trend than above-trend. In contrast, the trough to peak amplitude is substantially larger than the subsequent peak to trough amplitude. In real terms, prices began substantially below-trend and appear to have returned, after the price spike, to the long-run level rather than over-shooting it to the downside.

The post-2005 price distribution exhibits high kurtosis, although substantially less than Cashin et al. observed. Skewness is positive in the post-1995 sample in contrast to the 1957-1999 sample analysed by Cashin et al. These statistics indicate that extremely high prices have been observed more often than would be predicted by the normal distribution. Most of these extreme observations are contained in the spike in prices observed during 2008.

In summary, the body of the post-1995 de-trended price distribution clusters around the long-run trend. Given that a price spike (that pushed prices substantially higher than the long-run trend followed a sharp return to the long-run trend) has occurred recently, it would be reasonable to expect that prices would tend to cluster around the long-run trend for the foreseeable future. Weighing the probabilities of below-trend versus above-trend prices it would appear that there is a larger probability of below-trend than above-trend prices.

With respect to model structure, the statistics indicate that it would be reasonable to describe future prices as a mean-reverting process with volatility averaging 30% to 40% per year. It may also be reasonable to entertain two or three price spikes occurring over a 40 year projection period. However, if price spikes are included, mean-reversion behaviour would need to reflect a substantially faster return to trend from above than from below.

Given that prices are currently in the vicinity of the long-term trend, a random walk may also be a reasonable representation.

5.3 Assumptions about the economic characteristics of prospective iron ore mines in the Mid West

Economic characteristics of Mid West iron ore mines determine the supply-side responses to market prices. Low cost operations are likely to operate for longer periods of time and exhibit more stable production profiles than high cost operations. For the current exercise, it is not necessary to evaluate whether Mid West iron ore mines are low- or high-cost. Rather, all that is required are summary statistics about the prospective iron ore operations.

Figure 15 presents the underlying assumptions that vary across prospective mines. The statistics are confined to Stage 1. Some of the prospective mines have announced long-term plans to expand production in subsequent stages. There are seven prospective mines that are considered potentially relevant to justifying the proposed 330 kV transmission line. These are classified as either hematite or magnetite. Hematite in-situ ore grades typically average 60-66% iron content compared with a typical in-situ average magnetite grade range of 30–35% iron content.[7] Unlike hematite, the low grade nature of magnetite does not allow it to be directly used in smelters. Magnetite ore is processed to produce a magnetite concentrate which is then transformed into iron ore pellets. Industry advice indicates that magnetite concentrate will be exported within a range of 65–68% iron content.

Figure 15 Mid West prospective iron ore mine summary statistics (Stage 1)

Variable	Unit	Prospective mine	Mine type	Value
Total resources	Millions of tonnes	Asia Iron, Mount Gibson	Magnetite	240
		Gindalbie, Karara	Hematite	16.2
			Magnetite	1,853
		Mount Gibson, Extension Hill	Hematite	19.5
		Sinosteel, Weld Range	Hematite	155
		Sinosteel, Blue Hills/ Koolanooka	Hematite	7.5
		Sinosteel, Koolanooka	Magnetite	430
Initial capital expenditure (Stage 1)	Millions of dollars	Asia Iron, Mount Gibson	Magnetite	1,000
		Gindalbie, Karara	Hematite	40
			Magnetite	1,975*
		Mount Gibson, Extension Hill	Hematite	100
		Sinosteel, Weld Range	Hematite	450
		Sinosteel, Blue Hills/ Koolanooka	Hematite	26

7 http://www.baseiron.com.au/files/announcements/BaseIronProspectus_internals_v7_mods6_web.pdf?chkProspectus=on&getFile=Download [accessed 1 April 2010].

Variable	Unit	Prospective mine	Mine type	Value
		Sinosteel, Koolanooka	Magnetite	800
Operating expenditure	Dollars per tonne	Asia Iron, Mount Gibson	Magnetite	30***
		Gindalbie, Karara	Hematite	30
			Magnetite	46.7**
		Mount Gibson, Extension Hill	Hematite	30
		Sinosteel, Weld Range	Hematite	40
		Sinosteel, Blue Hills/ Koolanooka	Hematite	30
		Sinosteel, Koolanooka	Magnetite	33
Production rate	Millions of tonnes per year	Asia Iron, Mount Gibson	Magnetite	10
		Gindalbie, Karara	Hematite	2
			Magnetite	8
		Mount Gibson, Extension Hill	Hematite	3
		Sinosteel, Weld Range	Hematite	10
		Sinosteel, Blue Hills/ Koolanooka	Hematite	1.5
		Sinosteel, Koolanooka	Magnetite	10
Customer maximum demand (Stage 1)	Megawatts	Asia Iron, Mount Gibson	Magnetite	110
		Gindalbie, Karara	Hematite	0.3
			Magnetite	130
		Mount Gibson, Extension Hill	Hematite	0.3
		Sinosteel, Weld Range	Hematite	10
		Sinosteel, Blue Hills/ Koolanooka	Hematite	0.15
		Sinosteel, Koolanooka	Magnetite	150

Source: Economics Consulting Services, North Country Electricity Demand Mining and Industrial Demand

* January 2010; Gindalbie Metals Ltd (5 May 2010) *Gindalbie Announces Updated Karara Construction Cost Estimate*, Securities Exchange Announcement & Media Release - $905 million is required for mine development and magnetite concentrator, $1,070 million is required to fund rail, power and port infrastructure;

** Gindalbie Mining Limited (March 2010), Gindalbie: Karara and Beyond, p. 13, http://www.gindalbie.com.au/Investor+Relations/Latest+Presentation/default.aspx [accessed 1 April 2010].

*** This is considered to under-estimate the true cost when compared to Gindalbie's estimate. Western Power modelling adopted Gindalbie's estimate for Extension Hill.

The additional processing required to increase the iron content of magnetite iron ore to export specifications implies a substantial increase in capital expenditure. In turn, the additional plant and machinery represents a substantial increase in electricity demand.

- In considering differences in capital and operating expenditure, it is prudent to be cautious. Taken at face value, Gindalbie's costs appear higher than Asia Iron's. However, it may be the case that Gindalbie's costs are both more accurate and more certain.

In order to be internationally competitive (in which magnetite iron ore operations compete with hematite iron ore operations in a single, global market) the unit cost (measured in $ per tonne) of magnetite concentrate production ideally needs be within the vicinity of the unit cost of the typical hematite operation. Given the disadvantage imposed by substantially higher capital expenditure (which is an order of magnitude of 5-6 times the typical Mid West hematite operation) magnetite mines need to achieve significant economies of scale. This implies the need for a large resource.

Other assumptions relating to the economics of iron ore mining are presented in Figure 16. The iron content in output is likely to vary across mines. However, this level of detail is typically lacking. For modelling purposes, a distinction has been made between the average iron content for hematite and magnetite operations. There is also a general lack of precision with respect to the composition of capital expenditure. A portion is likely to be allocated to relatively passive and long-lasting assets such as infrastructure (e.g. buildings, rail sidings, rail trucks, electrical poles and lines etc). The remainder will be allocated to purchasing active assets (e.g. crusher, diggers, on-site electrical generators, heavy vehicles etc). Active assets tend to wear out relatively quickly compared to passive assets. A key economic issue is the required replacement rate of assets and the amount of expenditure that would be incurred over time.

The approach taken in this report is to assign an average asset life and a portion of capital expenditure to account for significant capital replenishment milestones. If these milestones are significant enough, they could determine the operational status of mines under alternative price scenarios. For example, if iron ore prices happen to be low at a time in which significant capital expenditure is required to maintain operations, management may consider shutting down the mine if the expected revenue is less than the required capital expenditure.

Figure 16 Underlying assumptions common across prospective iron ore mines

Parameter	Unit	Value
Iron content in output (hematite Direct Shipping Ore)	%	62
Iron content in output (magnetite concentrate)	%	68
Productive life of active assets	Years	20
Portion of initial capex replaced	%	25
Real (pre-tax Officer WACC) discount rate	%	10

Notes: Iron content in output based on Gindalbie Mining Limited (March 2010), Gindalbie: Karara and Beyond, p. 12, http://www.gindalbie.com.au/Investor+Relations/Latest+Presentation/default.aspx [accessed 1 April 2010]. Specifically, hematite Direct Shipping Ore iron content is assumed to match Hamersley Pilbara blend; magnetite concentrate is as reported by Gindalbie Mining Limited.

Finally, a real discount rate of 10% per annum is considered to be a reasonable hurdle rate for iron ore mines.[8] This reflects the relatively high risk of incurring variation in annual cash flows. Therefore, a high rate of return is required to encourage risk-averse investors to provide funds to mining companies. Empirical support is provided in the literature for this position.[9]

5.4 Strategic behaviour of mine management

5.4.1 Introduction

Given the risks to shareholder value, it is reasonable to assume that mine management would develop risk mitigation strategies to protect shareholders. In developing a risk mitigation strategy, it is important to consider the impact of uncertainty.

[8] Based on an equity beta of 2.0, a real risk-free rate of 2.97%, debt to equity ratio of 60%, market risk premium of 6.5% and a gamma of 0.65.

[9] Bowman, R.G. (2005). Queensland Rail – Determination of Regulated WACC, http://www.qca.org.au/www/rail/Sub_QRattach7_2005%20DAU%20Draft.pdf [accessed 1 April 2010]

The main issue associated with uncertainty is the possibility of incurring a loss of wealth. Statistically, this can be represented by a distribution of possible return on capital. Management's mission is to minimise the potential downside while maximising exposure to the upside. This can be achieved by a wide variety of measures such as striking fixed-price contracts, hedging with financial derivatives, changing the production level or the operating status of the mine.

Management's discretion over the operational status of a mine (i.e. whether the mine is operating or not) is a primary concern in analysing the likely incremental revenue risk to Western Power. There are two facets to this risk:

- Timing risk in anticipating the likely commencement of mining and, therefore, the step change in demand for electricity.
- Variability in demand once operating. Mine management will likely retain the flexibility to shutdown if market conditions deteriorate. Fixed demand contracts will hedge against temporary shutdowns. However, it is unlikely to provide sufficient protection against permanent abandonment.

The traditional approach to the DCF method of investment appraisal is likely to be a poor predictor of investment timing since it implicitly only considers the value of committing to the investment now compared to never investing. The obvious alternative is to compare the value of investing now against the value of investing later. The greater the degree of market uncertainty, the greater the potential value of investing later. Recognising this opportunity cost implies that investors will seek a premium before choosing to commit to the investment now as compensation for irrevocably sacrificing the option to defer.

Similarly, once committed and operating, investors will value strategies that minimise exposure to wealth losses. This implies that there is value in closing mines during periods of low demand. If the deterioration in market conditions is severe enough, investors will choose to abandon the investment. This would lead to a permanent step change reduction in the demand for electricity.

In assessing these risks, the approach taken in Western Power's analysis is to incorporate real options analysis in the risk assessment. In both theoretical and empirical terms, this approach is likely to provide improved predictability and insight into the quantification of these risks.[10]

In order to incorporate real options analysis in risk modelling, it is important to identify the factors that are most likely to change operating status of a mine. These factors are:

- The size and quality of the in-situ resource.
- Capital and operating expenditure.
- Iron ore prices.

[10] For a summary of the empirical support of real options analysis in terms of predicting investment behaviour see Bulan, L., Mayer, C. and Somerville, C.T. (2009). "Irreversible investment, real options and competition: Evidence from real estate development", *Journal of Urban Economics* 65, pp.237-251. This reference also cites studies relating to other industries, including mining.

The size and quality of the in-situ resource has a direct bearing on the cost of operation. High mineral content is likely to be less expensive to extract than a resource with low mineral content. Similarly, a resource that is close to the surface is likely to be less expensive to exploit than a resource located deep underground. Other factors affecting the quality of the resource include the level of impurities and the number of discrete deposits.

The size of the resource will be a significant factor determining the life of the mine. In turn, this will impact on the total revenue that can be earned.

Resource size and quality is likely to be an important factor determining the capital and operating costs of each mine, along with proximity to existing infrastructure such as electricity, gas, port and rail. Other important factors are the cost of plant and machinery, labour hours and productivity.

Iron ore prices will have an obvious impact on revenue. Price influence can be analysed in terms of its initial conditions as reflected in its price level and its volatility as well as its behaviour over time. Significant price changes are likely to induce changes in the level of competition between miners. However, such changes will eventually be reflected in iron ore prices. For example, an increase in competition following a period of relatively high prices would place downward pressure on prices over the long-term. Hence, given knowledge of how prices are likely to evolve over time, there is no need to evaluate the likely patterns of competition that occur in response to price changes.

These factors will help determine when mining is likely to commence. Once operating, significant changes in these factors are likely to cause management to change production level. For example, a substantial price spike may prompt management to consider investment in capacity expansion. However, the decision to expand is also likely to be affected by capital and labour costs. High capital and labour costs would reduce the incentive to increase production. Alternatively, an unexpected plunge in prices may induce management to temporarily shutdown operations until demand returns to a higher level.

In order to adequately reflect the strategic behaviour of mine management, two sub-models have been added to mimic mine evaluation. The first sub-model relates to the initial decision to commence mining. The sub-model calculates the probability of incurring a loss of shareholder wealth over the life of the mine. If the probability exceeds a specified threshold, then the decision is taken to defer commencement until prices increase.

The second sub-model mimics management's annual decision about whether to continue operating the mine. This is based on a similar evaluation of shareholder wealth outcomes to the first sub-model over a specified period. If the probability of incurring a loss is greater than a specified threshold, the mine is temporarily shutdown.[11]

In both the commencement and shutdown cases, the specified threshold is calculated according to the concept of opportunity cost.[12] This is applied in the model by calculating the real option values of waiting and abandonment. These option values determine the threshold at which mine management would commit to changing mine operating status.

[11] This decision rule is a second-best approach. A better approach would be to compare the present value of expected loss with the present value cost of shutdown, mine maintenance and reopening costs. If the expected avoidable loss is greater than shutdown, mine maintenance and reopening costs, the mine would be shutdown. However, the data required is not publicly available to implement this decision rule.

[12] Opportunity cost is defined as the cost of foregoing alternative investments.

5.4.2 Calculating the option value of waiting

The option value of waiting[13] recognises that significant investment in capital (e.g. plant, machinery, equipment, buildings etc) is largely irreversible once committed. Hence, there is a risk that a large part of the investment is actually a sunk cost once incurred. From an investment point of view the main issue is that if market conditions deteriorate, investors will not be able to recover most of their investment by selling assets.

A good example of this issue is the development and subsequent sale of BHP Billiton's Ravensthorpe Nickel Project. BHP Billiton spent an estimated $2.32 billion developing the nickel mine, only to discover that nickel prices collapsed during the Global Financial Crisis. Poor market conditions combined with technological problems associated with exploiting a nickel laterite deposit prompted BHP Billiton decided to sell the project for $376 million.[14] As a result, BHP Billiton's shareholders sustained an 84% loss of wealth.[15]

In recognising this kind of risk, it is necessary to develop a method of determining the optimal time to commit to a project. The option value of waiting provides one explicit way of achieving this aim.

The option value of waiting[16] is calculated by taking the difference in net present value between two scenarios:

1. Committing to the project now;
2. Delay project commitment until customers are willing to pay higher prices for mine output.

Scenario 1 exposes mine owners to the full distribution of all possible investment outcomes. This means maximum exposure to the downside. Scenario 2 reflects a risk mitigation strategy in which the project would only proceed when prices are high compared to historical benchmarks.

The net present value of committing now requires estimation of the expected present value of future annual net cash flow over the life of the mine (call it EPV(NC)). The upfront investment cost (capital expenditure) is deducted from the expected present value of the net cash flow to derive the required net present value. The EPV(NC) is calculated as the average across a distribution of PV(NC) generated by simulating the operation of the mine 100 times.

The source of the distribution of future annual cash flow is generated by simulating iron ore prices. The other variables, namely the annual production rate and operating expenditure are maintained as constants.

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[13] This is sometimes referred to as the option value of deferral.

[14] La Canna, X. (9 December 2009). "BHP offloads Ravensthorpe nickel mine", *The Age*, http://news.theage.com.au/breaking-news-business/bhp-offloads-ravensthorpe-nickel-mine-20091209-kiff.html [accessed 28 May 2010].

[15] One rationale for realising this loss of wealth is that the decision minimises losses. That is, fixing the problems and waiting for the market to improve would be likely to result in an even larger loss of wealth.

[16] See Pindyck, R.S. (2008), "Sunk Costs and Real Options in Antitrust Analysis", in *Issues in Competition Law and Policy*, pp. 619-640 (ABA Section of Antitrust Law 2008).

Given a distribution of PV(NC), the high price scenario can be determined by calculating the upper value portion of the PV(NC). The 75th percentile is the threshold chosen for determining whether a specific realisation is included in the upper portion. That is, the top 25% PV(NC) estimates are included in the calculation of an upper EPV(NC) (call it EPV(NC) – High). The net present value of Scenario 2 is calculated by deducting the present value of the upfront investment deferred for one year from the EPV(NC).

The option value of waiting is the difference between the net present values (i.e. Scenario 2 NPV less Scenario 1 NPV).

Commitment timing is determined at the point in which the expected present value at least equals the investment cost plus the option value of waiting.

5.4.3 The option value of mine abandonment

Given that there is uncertainty associated with the future demand for iron ore, mine management would be expected to anticipate a scenario in which demand collapses. In this situation, there are two choices:

1. Continue operating the mine, possibly including a period in which the mine temporarily shuts down; or

2. Abandon the mine and sell it for its substantially reduced market value.

Novaes and Souza (2005)[17] demonstrate how the option value of abandonment can be calculated using Margrabe's adaptation of the Black-Scholes options pricing model. The most important step is to calculate the likely salvage value of the mine during a period of low demand. This requires calculation of the expected present value of future net cash flow (i.e. ENPV(NC) - Low) derived from operating the mine in which the initial price corresponds to a low price scenario.

Other required parameters are the: expected present value of value-in-use (call it ENPV(VIU); the coefficient of variation for both ENPV(NC) – Low and ENPV(VIU); and the correlation coefficient between ENPV(NC) – Low and ENPV(VIU). The coefficient of variation for both is equal to the estimated historical volatility of iron ore prices. Given the inputs, the correlation between the two assets is likely to be high.

Applying Margrabe's formula with these parameter estimates yields the option value of mine abandonment. This value will vary according to differences across mines in terms of their underlying economic characteristics.

The value of abandonment is included as part of the threshold to commit to mine development by deducting it from the result calculated in accordance with Section 5.4.1. The threshold in which a mine is abandoned is the point in which the expected value-in-use is at most equal to the option value of abandonment.

5.4.4 Conclusion

The traditional approach to investment decisions is to invest when the present value of direct revenue less cost is greater than zero. However, this rule does not account for uncertainty. When uncertainty is explicitly considered in investment plans, it is clear that

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[17] Novaes, A.G.N. and Souza, J.C. (2005). "A Real Options Approach to a Classical Capacity Expansion Problem", *Pesquisa Operacional*, vol. 25(2), pp. 159-181.

there is a risk of wealth loss. Strategies that minimise the risk of wealth loss while maximising the risk of wealth gain will add value for investors.

Given mine owners' exposure to the risk of wealth loss, it is reasonable to expect that managers would develop risk mitigation strategies. Strategies such as price hedging via contracts or financial derivatives may be effective, but are likely to come at the cost of capping the upside potential of wealth creation as well as capping the downside of wealth loss.

An alternative risk mitigation approach is to develop strategies that provide full exposure to the upside while minimizing exposure to the downside. Such strategies tend to focus on contingency plans that are activated under defined market conditions.

This approach to mine management poses a risk to the derived demand for electricity and therefore needs to be accounted for in risk-based estimation of anticipated incremental revenue. In the absence of information relating directly to management's contingency plans, real options analysis helps to explain and reflect these rules in economic models.

Several real options are recognized in the risk model:

- The option of waiting (or deferral) with respect to initial mine commencement;
- The option of changing the operating status from closed to open or open to closed; and
- The option to abandon an investment after commitment.

These options have differing implications for the derived demand for electricity. The option to defer an irreversible decision to incur a substantial sunk cost reflects real world behaviour in which major investments do not occur until it is clear that the risk of loss is minimal.

In terms of predicting the timing of significant investments, the traditional approach to investment decision making is likely to perform poorly as a predictor of when investments are likely to occur. Actual decisions tend to occur significantly after the timing trigger point indicated by the standard DCF analysis. Indeed empirical studies indicate support for the predictions offered by real options analysis in terms of investment timing.[18]

Therefore, including the option to defer in economic and financial modeling offers improved predictability in investment timing. This is particularly due to the use of explicit measures of uncertainty to explain changes in the likelihood of real option valuations.

The option to change the operating status of mines has clear implications for the risk to the derived demand for electricity. There may be periods of several years in which network assets are under-utilised due to mining downturns. This form of managerial flexibility predicts that substantial changes in market conditions are required to change mine operating status. However, once incurred, mining inactivity is likely to persist.

The option of abandonment has the opposite effect to the option to defer. Increasing the value of an abandonment option prior to investment would reduce the level of uncertainty

[18] See Bulan, L., Mayer, C. and Somerville, C.T., op. cit.

with respect to investment outcomes. Hence, this option tends to bring forward investment timing.

The use of these options implies the following investment rules:

- Invest if the expected present value of future returns plus the option value of abandonment is greater than the sum of the present value of capital expenditure and the value of the option to defer. This rule will be a reasonable predictor of the timing of initial investment.

- Once operating, close the mine if the expected present value of future returns is less than cost of shutdown (including care and maintenance) plus the cost of recommencement.

6 Results

6.1 Introduction

The tables and charts contained in this section present the main results obtained from the Monte Carlo simulation modelling. The results are based on 100 simulations (or trials) spanning a projection period of 40 years. In each trial, an iron ore price series is simulated. The iron ore price level influences mine investment, production, revenues, costs and resulting electricity demand. These variables are modelled and collectively describe the extent of commercial risks associated with these mines.

This section is organised as follows. Sub-section 6.2 discusses the likely price range (confidence interval) associated with iron ore prices and presents estimates of total Mid West iron ore production. This is followed by discussion of the resulting range of incremental revenue estimate in sub-section 0. The results section concludes by presenting results of sensitivity analysis in sub-section 6.4.

6.2 Iron ore price range and aggregate Mid West iron ore production

Given the lack of consensus with respect to how iron ore prices actually evolve, this sub-section presents the results based on two alternative choices:

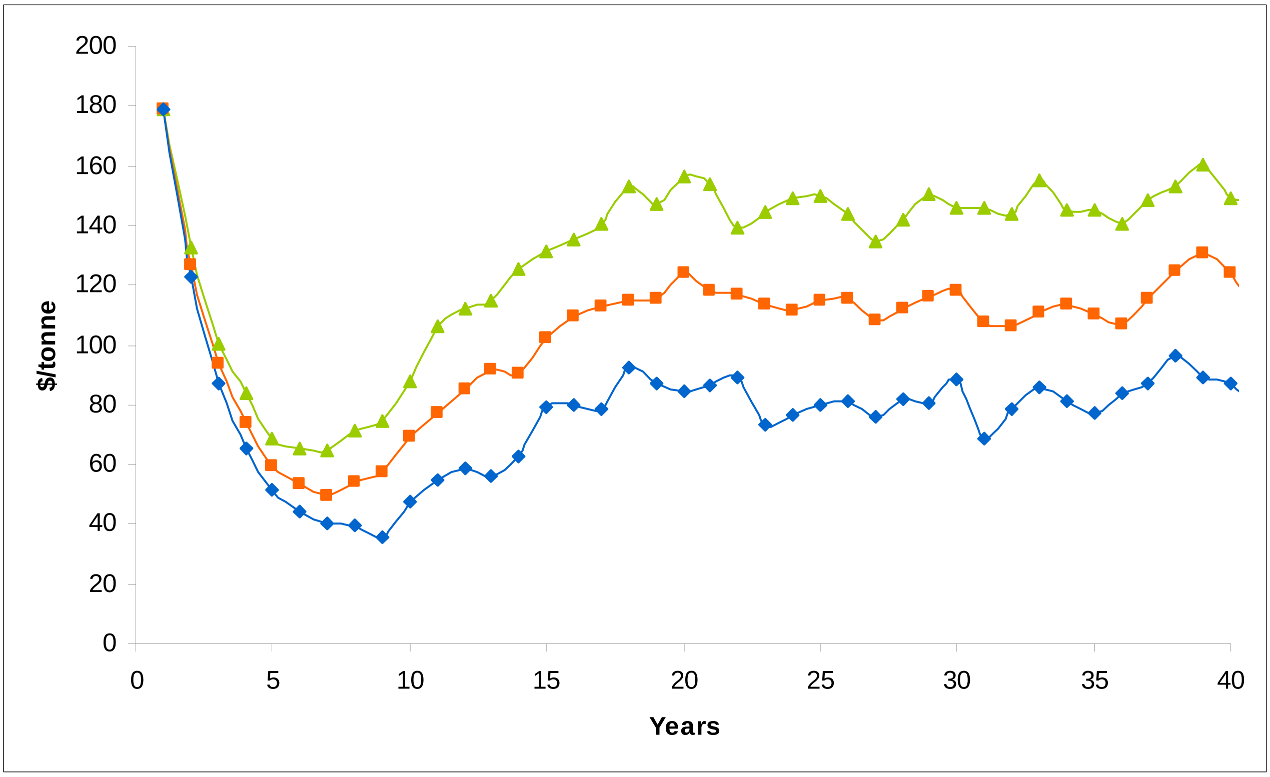
1. Mean reverting process

2. Random walk process

These processes can lead to significantly different results. However, in applying the statistical properties reported in sub-section 5.2, it turns out that in this case there is no significant difference in results.

Figure 17 and Figure 18 presents summary results of the simulated iron ore price series for the mean reverting process and random walk process. In both cases, the shape of this distribution is dominated by the starting price level for iron ore. Subsequent movements in price are random, although the magnitude of these random movements is influenced by the assumed level of annual volatility and degree of reversion back to a long-run equilibrium level.

Figure 17 Simulated iron ore prices (mean reversion case)



Note: DM# 8094186; see Appendix E Mean reversion process reviewed for details of how this was developed; the annual reversion rate is assumed to be 30 per cent.

Prices begin at the latest available benchmark price as published in the International Monetary Fund's Annual Market Prices for Non-Fuel and Fuel Commodities, 2006-2010.[19] Subsequent price movement is based on random variation.

The assumptions underlying the mean-reverting process reflect a belief that iron ore prices are likely to converge toward the long-run marginal cost of production. If relatively high prices persist, it is reasonable to expect that new mine development would be accelerated, particularly in the iron ore rich provinces of Western Australia, Africa and South America. Over time, these new mines with higher quality, lower cost resources should crowd out inefficient Chinese mines. Consequently, the price should fall over time. In contrast, a relatively low price would tend to delay new mine development and may lead to closure of inefficient mines. In this case, prices should rise over time.[20]

Figure 18 provides an alternative outcome for iron ore prices. This reflects a tendency for prices to meander over time without any reversion back to a long-run equilibrium price level. For risk assessment purposes, each simulated price series is generated from what is considered to be the long-run price of iron-ore. The resulting chart shows prices beginning from a common starting point and fanning out over time based purely on random chance.

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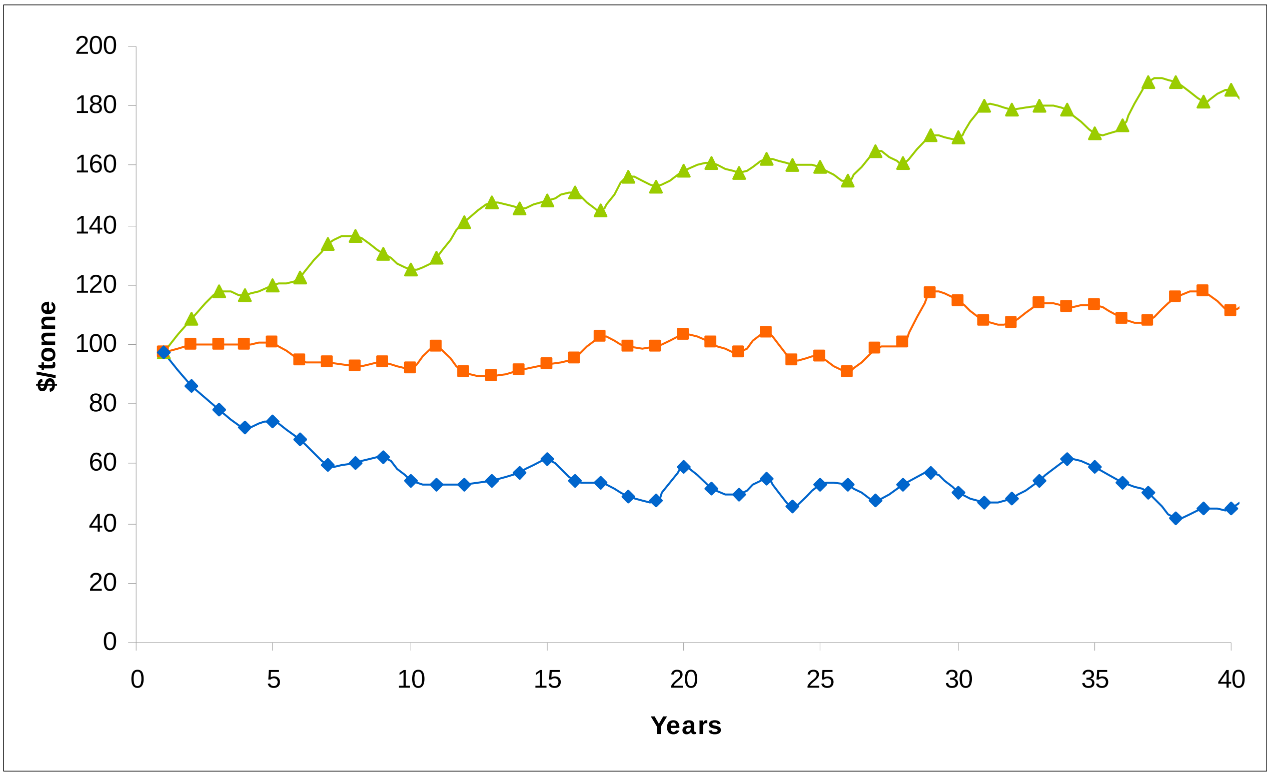
[19] International Monetary Fund (5 May 2011), *Actual Market Prices for Non-Fuel and Fuel Commodities, 2006-2010*, http://www.imf.org/external/np/res/commod/table3.pdf [accessed 8 June 2010]. Note that prices are quoted in US cents/DMTU. Assumed exchange rate of AUD/USD 1.00.

[20] An update of the mean-reversion process is provided in Appendix E

The inclusion of random variation has the effect of generating a distribution of prices over time. This provides a measure of price risk, which is measured by distance between high and low prices at each subsequent point in time.

Figure 18 Simulated iron ore prices (random walk case)

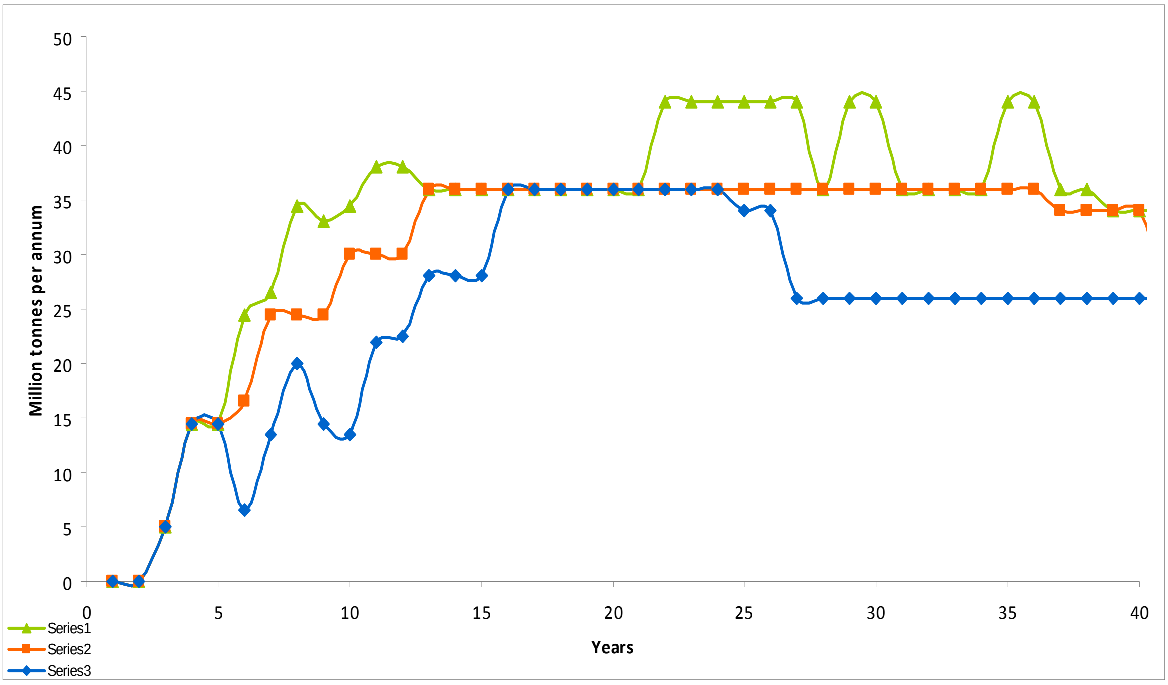


Note: based on results in DM# 8094186

As illustrated above, the assumed behaviour of prices can significantly influence the measurement of risk of variability in the derived demand for electricity.

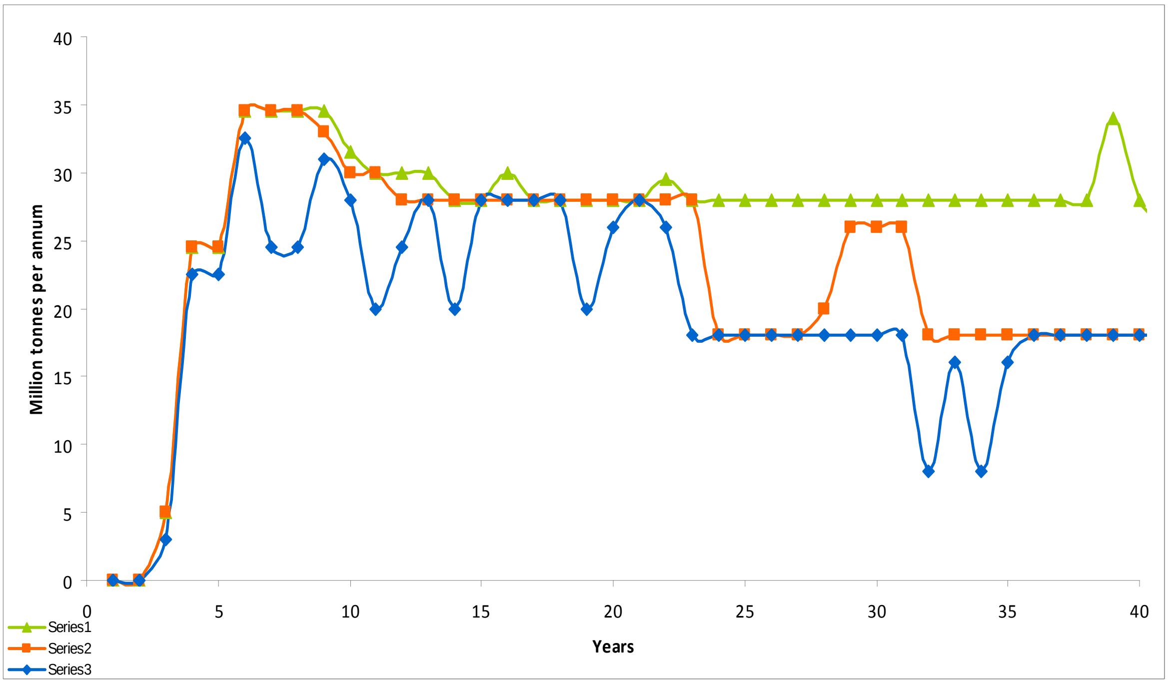
Results relating to aggregate production of Mid West iron ore are presented in Figure 19 and Figure 20. The two sets of results indicate different production profiles, with the mean reversion process showing a more gradual build up than the random walk. However, the random walk indicates a more rapid drop-off, which reflects the wider range of uncertainty with respect to future iron ore prices.

Figure 19 Simulated aggregate iron ore production across Mid West mines (mean reverting case)



Note: based on results in DM# 8094186

Figure 20 Simulated aggregate iron ore production across Mid West mines (random walk case)

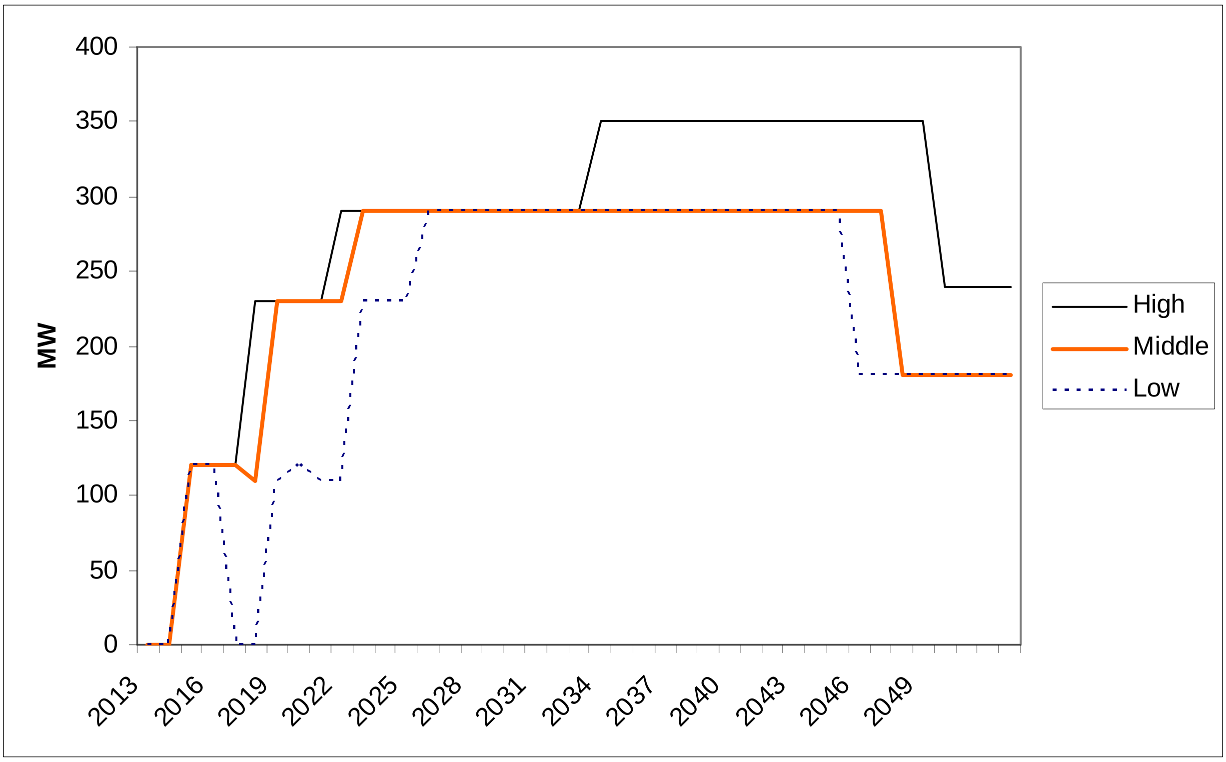


Note: based on results in DM# 8094186

Aggregate CMD results are presented in Figure 21 and Note: based on results in DM# 8094186

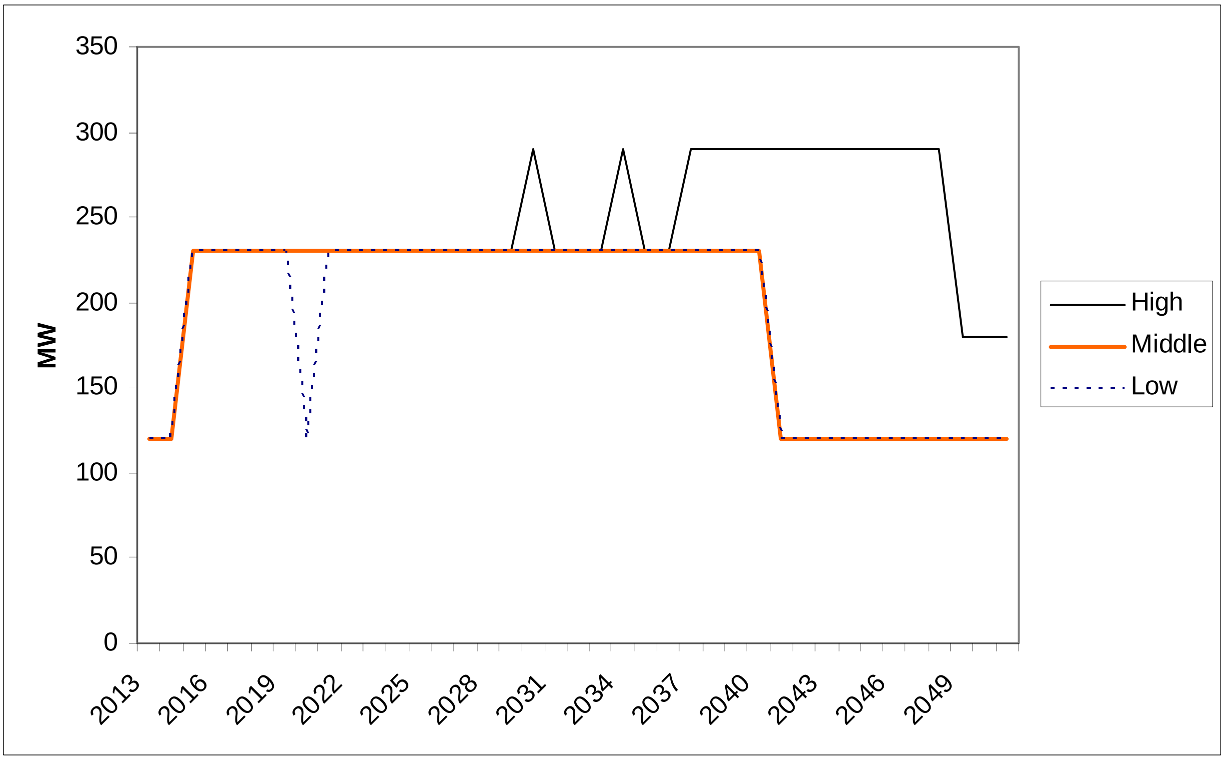
Figure 22. In each case, there are only two iron ore mines included in the low case. Only two iron ore mines (both magnetite) are included in the medium and high case.

Figure 21 Simulated aggregate customer maximum demand profiles (mean reversion case)



Note: based on results in DM# 8094186

Figure 22 Simulated aggregate customer maximum demand profiles (random walk case)

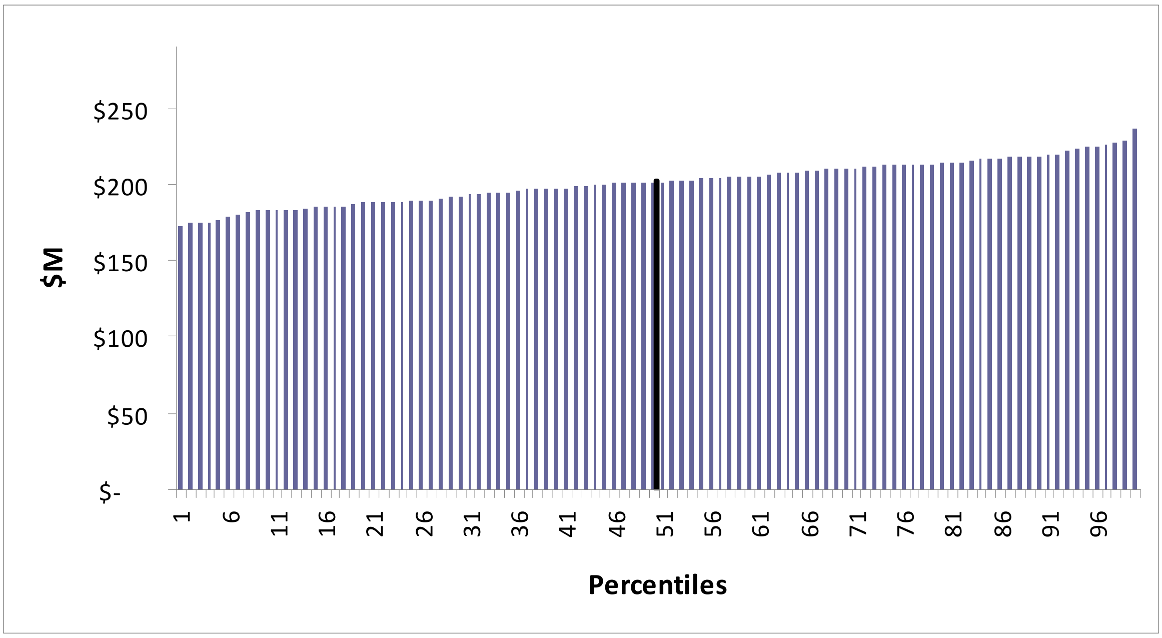


Note: based on results in DM# 8094186

6.3 Incremental revenue estimates

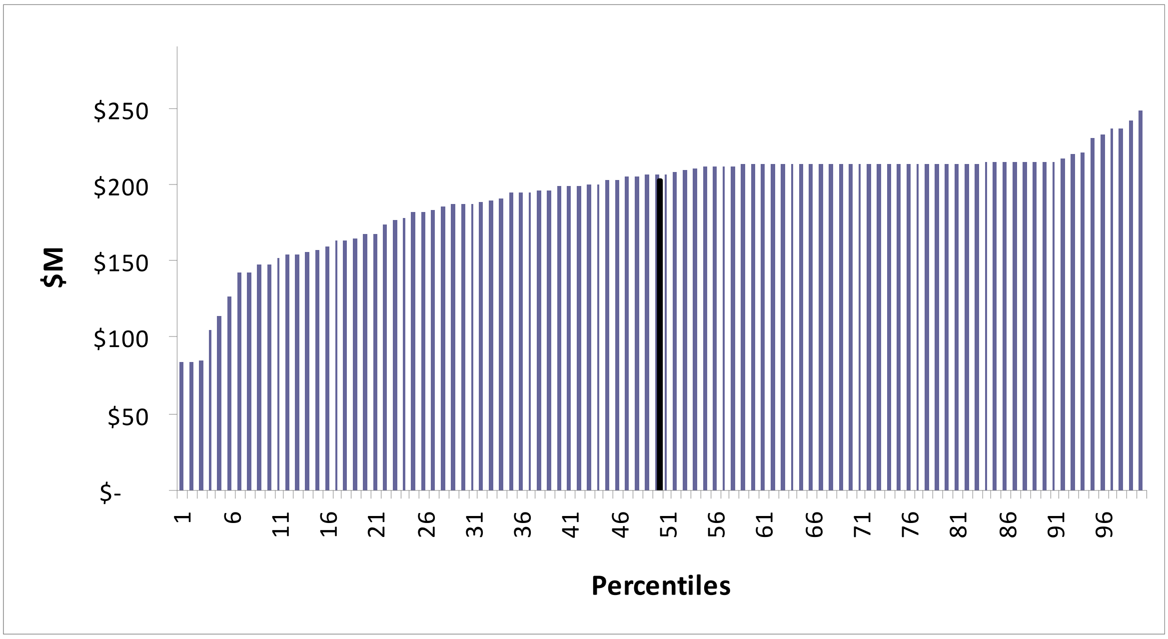
Figure 23 and Figure 24 present the simulated incremental revenue for the mean reverting and random walk cases. The medium and high cases are similar given that iron ore prices in both cases are high enough to trigger mine production.

Figure 23 Simulated incremental revenue (mean reverting case)



Note: based on results in DM# 8094186. Assumed tariff begins at $118/kW and declines to $100/kW as step changes in CMD occur.

Figure 24 Simulated incremental revenue (random walk case)



Note: based on results in DM# 8094186. Assumed tariff begins at $118/kW and declines to $100/kW as step changes in CMD occur.

Present value estimates of incremental revenue are provided in Figure 25. Combined, the mean reversion case and the random walk case exhibit a range from $162 million to $194 million.

Figure 25 Estimated incremental revenue (2010 $M)

	Low	Medium	High
Mean reversion	173 (75%)	184 (50%)	195 (25%)
Random walk	162 (75%)	187 (50%)	194 (31%)

Note: based on results in DM# 8094186; Assumed tariff begins at $127/kW and declines to $89/kW as step changes in CMD occur.; discount rate is 7.98% pre-tax real; operating expense allowance deducted from estimates. Estimates are indicative only. Actual incremental revenue will be capped to match capital expenditure. Numbers in parentheses are probability estimates of receiving at least the amount of revenue indicated in the cell.

Figure 26 provides estimates of incremental revenue for a range of possible initial tariff outcomes. The higher initial tariff reflects regulatory approval for tariff increases over the second Access Arrangement period. As indicated in the figure, incremental revenue could be as high as $170 million, depending on the number of mines connecting to the SWIS and the cost of network reinforcement.

Figure 26 Estimated incremental revenue by scenario and initial tariff (2010 $M)

Tariff ($/kW)	Low	Medium	High
106.2	140	147	153
118.0	156	163	170
129.8	172	179	187

Note: based on results contained in Stage 2 Results 100611v1.xls; discount rate is 7.98% pre-tax real; operating expense allowance deducted from estimates. Estimates are indicative only. Actual incremental revenue will be capped to match capital expenditure.

6.4 Impact of changes in assumptions

The preceding model results indicate that differences in how iron ore prices might evolve over time makes no material difference in the estimated incremental revenue. Rather, the most important risk factor is the price level, followed by its volatility.

Other factors are also important in determining the level of incremental revenue. Incremental revenue is mainly a function of whether the mines will actually commence operations. The degree of importance of each variable in determining this is indicated in Figure 27. The three most important factors are: the initial price level; operating expenditure; and capital expenditure. The correlation coefficients indicate that increasing price, production rate, size of resource and price volatility will increase the likelihood of mining commencement. Increases in capital expenditure, operating expenditure and the rate at which prices return to the long-run level tend to decrease the likelihood of mine commencement.

Figure 27 Results of sensitivity analysis: factors determining whether prospective iron ore mines will commence mining

Variable	Correlation Coefficient	Standardised Regression Coefficient	Partial Coefficient	Importance
Resource size	0.06	0.06	0.08	0.01
Capital expenditure	-0.15	-0.16	-0.21	0.05
Operating expenditure	-0.20	-0.19	-0.22	0.15
Production rate	0.06	0.06	0.09	0.03
Initial price	0.31	0.32	0.37	0.17
Long-run price	0.02	0.01	0.02	0.01
Reversion rate	-0.04	-0.04	-0.05	0.02
Volatility	0.01	0.00	0.00	0.01

Note: results averaged across prospective magnetite mines. Standardized regression coefficients range between -1 and 1 and provide a normalized measure of the linear relationship between variables and the result. They are the regression coefficients found when all of the variables (and the result) are transformed and expressed in terms of the number of standard deviations away from their mean (See Iman and Helton (1985)[21]). The Importance measure varies between 0 and 1, and represents the fraction of the result's variance that is explained by the variable. This measure is useful in identifying nonlinear, non-monotonic relationships between an input variable and the result (which conventional correlation coefficients may not reveal). The importance measure is a normalised version of a measure discussed in Saltelli and Tarantola (2002)[22].

Note that several assumptions have been omitted: the portion of capital that is replaced during the mine's operating life; and the average asset life. These variables help determine capital expenditure and are reflected in the impact estimates of capital expenditure in the table above.

Price has been decomposed into its constituent parts: the initial price; long-run price; speed of reversion back to the long-run level following a deviation from the long-run price; and volatility. The results indicate that the initial price is by far (up to 17 times) the most important factor when compared to other price assumptions. This simplifies the analysis substantially and suggests that the consequences of imposing incorrect assumptions about future price dynamics are likely to be small.

Given that conditions identified as being important are likely to change over time, it is convenient to develop a metric that can assist in quickly assessing the impact of any changes in key variables. Figure 28 presents the coefficient estimates of a probit model based on the data generated by the mine model.

Figure 28 Probit model coefficient estimates

Variable	Coefficient estimate	Standard Error	T-Statistic	Significance
Resource size	0.0002	0.0001	3.4171	0.0006
Operating expenditure	-0.0601	0.0036	-16.6520	0.0000
Capital expenditure	-0.0009	0.0001	-8.4000	0.0000
Production rate	0.2241	0.0197	11.3744	0.0000

[21] Iman, R. L. and Helton, J.C. (1985). *A comparison of uncertainty and sensitivity analysis techniques for computer models*. Albuquerque, NM: Sandia National Laboratory; Report No. NUREG/CR-3904.

[22] Saltelli, A. Tarantola S. (2002). "On the relative importance of input factors in mathematical models: safety assessment for nuclear waste disposal", *Journal of American Statistical Association*, 97 (459), 702-709

Variable	Coefficient estimate	Standard Error	T-Statistic	Significance
Initial price level	2.8563	0.2404	11.8820	0.0000
Volatility	-34.5139	10.1045	-3.4157	0.0006
Reversion rate	-0.3218	0.1082	-2.9742	0.0029
Long-run price	0.0007	0.0474	0.0147	0.9883

Note: the results indicate that all variables are statistically significant except for the long-run price level.

The probit model is a convenient way of calculating the probability of a discrete event occurring based on the variable values. In this case, the discrete event is the commencement of mining operations. The coefficient estimates are used to combine the variable values into a single, standardised index. This is then mapped into the cumulative inverse distribution associated with the normal distribution. The result is a probability score. The convenience of using a probit model is that the combined impact of simultaneous changes in variable values can be quickly assessed.

Figure 29 Probability of commencement of prospective magnetite mines based on current variable values

Variable	Units	Value
Resource size	Mt	1,800.00
Operating expenditure	$/tonne	45.00
Capital expenditure	$M	1,000.00
Production rate	Mtpa	8.00
Initial iron ore price	$/DMTU	1.20
Volatility	%	3%
Reversion rate	%	3.0%
Long run iron ore price	$/DMTU	1.00
Probability of commencement	%	84%

DMTU: Dry Metric Tonne Unit; Mtpa: million tonnes per annum

Figure 29 presents the calculated probability of prospective magnetite iron ore mine proceeding given contemporary variable estimates. As indicated, there is a high probability of commencement as announced of at least one magnetite mine in the Mid West.

Should any of these values change, it is useful to know in advance what the impact on commencement is likely to be. Figure 30 provides estimates of the probability of commencement given changes in key variables. For example, capital expenditure of $1,000 million holding all other variables identified in Figure 29 constant, produces a probability of commencement of 84%.

Figure 30 Estimates of probability of iron ore mine commencement given changes in key variable values

Capital Expenditure	Probability Estimate	Operating expenditure	Probability Estimate	Production rate	Probability Estimate	Initial iron ore price	Probability Estimate
$M	%	$/tonne	%	Mtpa	%	$/DMTU	%
1,000	84	25	99	4	53	0.50	15
1,250	77	30	97	5	62	0.75	38
1,500	70	35	94	6	70	1.00	66
1,750	61	40	90	7	78	1.25	87
2,000	52	45	84	8	84	1.50	97
2,250	43	50	75	9	89	1.75	99
2,500	34	55	65	10	92	2.00	100
2,750	26	60	53	11	95	2.25	100

Mtpa: million tonnes per annum. Note: each column headed 'Probability Estimate' shows the impact of changes in the variable in the column immediately to the left. This assumes that all other variable values remain unchanged.

The results in Figure 30 indicate that an escalation in capital expenditure above $1.5 billion would reduce the probability of commencement to 61%. Similarly, an escalation of operating expenditure above $55 per tonne would lead to a reduction to 65%. Should increases in capital and operating expenditure occur, the impact may be offset by increases in annual production and/or iron ore prices.

6.5 Results - conclusion

Overall, the results demonstrate a robust case for mine production and the subsequent demand for electricity across prospective iron ore mines located in the NCR. The range between the median and upper bound estimates for CMD are close in proximity.

The sensitivity analysis shows that the number of variables that are material to determining the level of incremental revenue is small. Specifically, the important variables are the initial price of iron ore, capital and operating expenditure. The sensitivity analysis also shows that increases in capital and operating expenditure can be offset by increases in production and prices.

Finally, it is important to note that commencement is likely to be positively correlated across mines. That is, if one mine commences, other mines are also likely to commence. Similarly, if conditions deteriorate sufficiently then it is possible that no mines would commence.

The binary outcomes, either more than one mine commencing operations or none, appear more likely than just one mine commencing. This is due to the similarity in the value of many of the important variables across mines.

Perhaps a more important consideration is the likelihood that the first iron ore mine to commence operations increases capacity beyond Stage 1 levels. This is a possibility that may lead to a "crowding out" effect in which there is insufficient capacity for the second and third mines to connect to the SWIS. This is the subject of the next section.

7 Alignment with Western Power forecasts

Up to this point, the risk-based modelling of incremental revenue has been conducted independently of Western Power's forecasts. This section provides a reconciliation of this modelling to official Western Power forecasts.

Western Power's North Country Region Central Load forecast includes Gindalbie Mining Limited's Stage 1 of the Karara Iron Ore Project and excludes Asia Iron's magnetite project and Sinosteel's magnetite project. The High Load forecast adds Stage 2 of the Karara Iron Ore Project and Asia Iron's magnetite project, but excludes the Sinosteel magnetite project.[23] Figure 31 presents estimates of incremental revenue based on the same mines included in Western Power's Central Load and High Load forecasts for the North Country Region. Incremental revenue ranges from $68 million to $174 million.

[23] See Western Power, System Forecast Branch, NCR Forecast Model, DM# 6429512v14

Based on the price outcomes estimated for the risk-based, the Central Load forecast delivers $147 million and the High Load forecast of $161 million.[24]

Figure 31 Aligned risk-based estimate of incremental revenue (NPV $M, 2010)

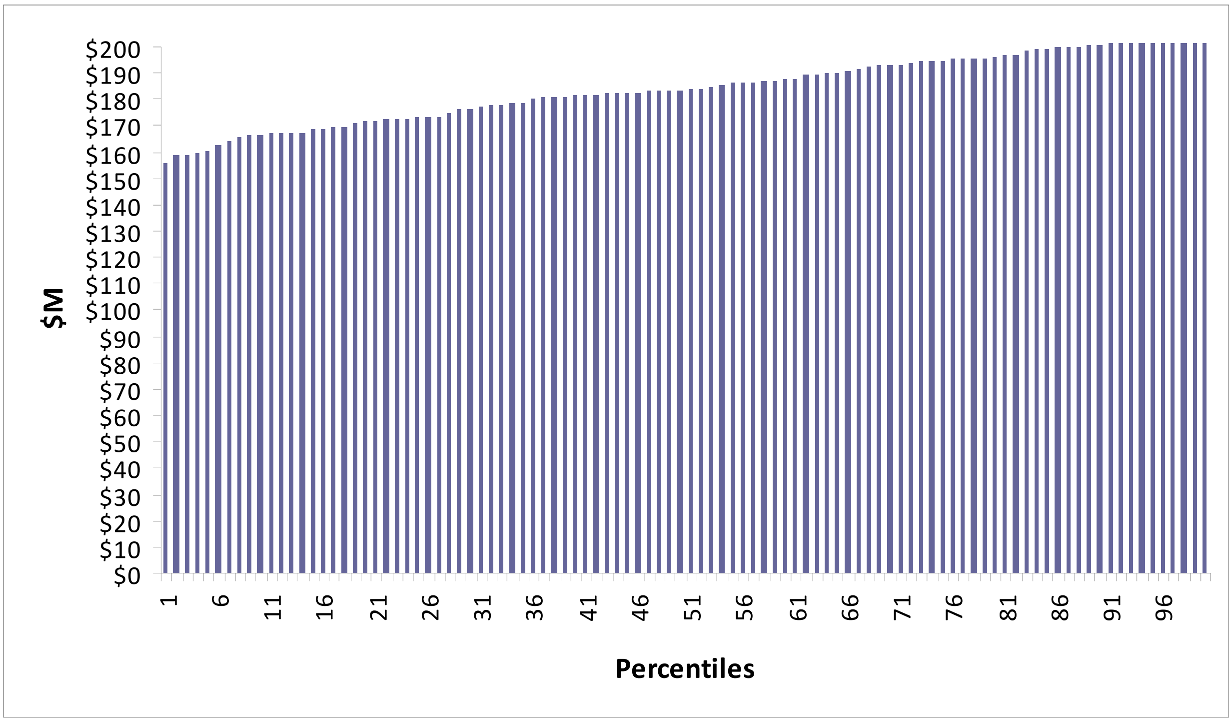
	Iron ore prices		
	Low	Medium	High
Central Load Case	68	68	68
High Load Case	131	165	174

Note: estimated over a 40 year projection period using a real pre-tax discount rate of 7.98%.

Source: Stage 2 Results 100611v1.xls

A more complete picture is presented in Figure 32. This shows that the High Load Case is more likely to occur, i.e revenue greater than $161 million. The probability of the Central Load Case and the High Load Case combined is approximately 95 per cent. In other words, the demand required to justify the Mid West Energy Project network reinforcement is likely to be realised.

Figure 32 Distribution of incremental revenue from connection of iron ore mines



Source: DM# 8094186

8 Conclusion

Anticipated incremental revenue derived from supplying several iron ore mines is estimated to range between from $162 million to $194 million. The likelihood of this new demand being realised is rated as highly likely given the current level of iron ore prices and estimated cost of mine development and operation.

[24] Results obtained from DM# 8094186, sheet: "Load revenue – Deterministic", cells S5 and T5

While this estimate spans a relatively wide range, it should be noted that a wide range of uncertainties have been taken into account. On balance, this estimate is considered to be robust and leaning toward the conservative.

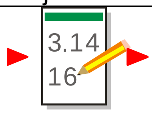
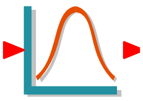
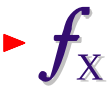
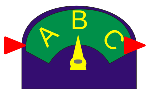
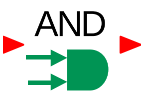
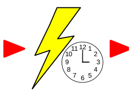
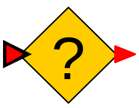
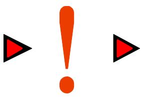
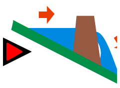
Note that the focus of this report has been on estimating the anticipated incremental revenue from just one source of new demand, namely iron ore mining. It is likely that demand for transmission services derived from wind turbine generation will add to this estimate.

Appendix A - Model description

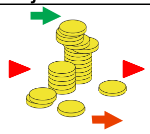
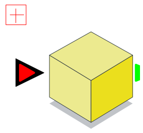
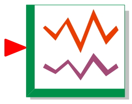
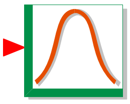
This appendix outlines the structure of the Monte Carlo model of key Mid West iron ore mines. The model platform employed is GoldSim. GoldSim simulation software is used to model dynamically complex systems in business, engineering and science. GoldSim supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems.[25]

A helpful feature of GoldSim is its graphical presentation, using objects and arrows to indicate the nature of model elements and the direction of causality between elements. The graphical, object-oriented presentation makes it easier to follow the structure of the model, revealing its inner logic to stakeholders. For convenience, Figure 33 presents a legend of the type of objects used in this model.

Figure 33 Object legend

Element typ	Object	Name	Description
Input		Data element	Scalar or array containing an exogenous parameter value
		Stochastic element	Contains a probability distribution function (e.g. normal distribution). This object will produce random draws according to the specified parameters (e.g. mean and standard deviation)
Function		History generator	The history generator simulates stochastic variables such as commodity prices. There are various types of stochastic variables. In this model, the iron ore price is generated as either a random walk process or a mean reverting process
		Expression	This element contains a mathematical function (e.g. a cost function)
		Selector	Defines expressions with nested if-then logic
		And	Combines multiple conditions using the logical "And" operator
Event		Timed event	Generates discrete event signals based on a specified rate of occurrence
		Decision event	Generates one of up to three signals based on specified conditions
		Discrete change	Generates a discrete change signal that discretely modifies values of other elements
Stock		Reservoir	Accumulates flows

[25] See www.goldsim.com

Element type	Object	Name	Description
Financial		Cash flow	Calculate the net cash flow, net present value and internal rate of return of a cash flow history
Container		Container	An element that acts like a box in which other elements can be placed. It is used to organise a model and create hierarchies.
Result		Time history result	Displays a model output as a time history
		Result distribution	Displays a model output as a probability distribution

Source: GoldSim (2008). *User's Guide*, GoldSim Technology Group

The following series of diagrams and tables present the components of the model used to assess the risk of electricity demand among Mid West iron ore mines.

Figure 34 Top layer

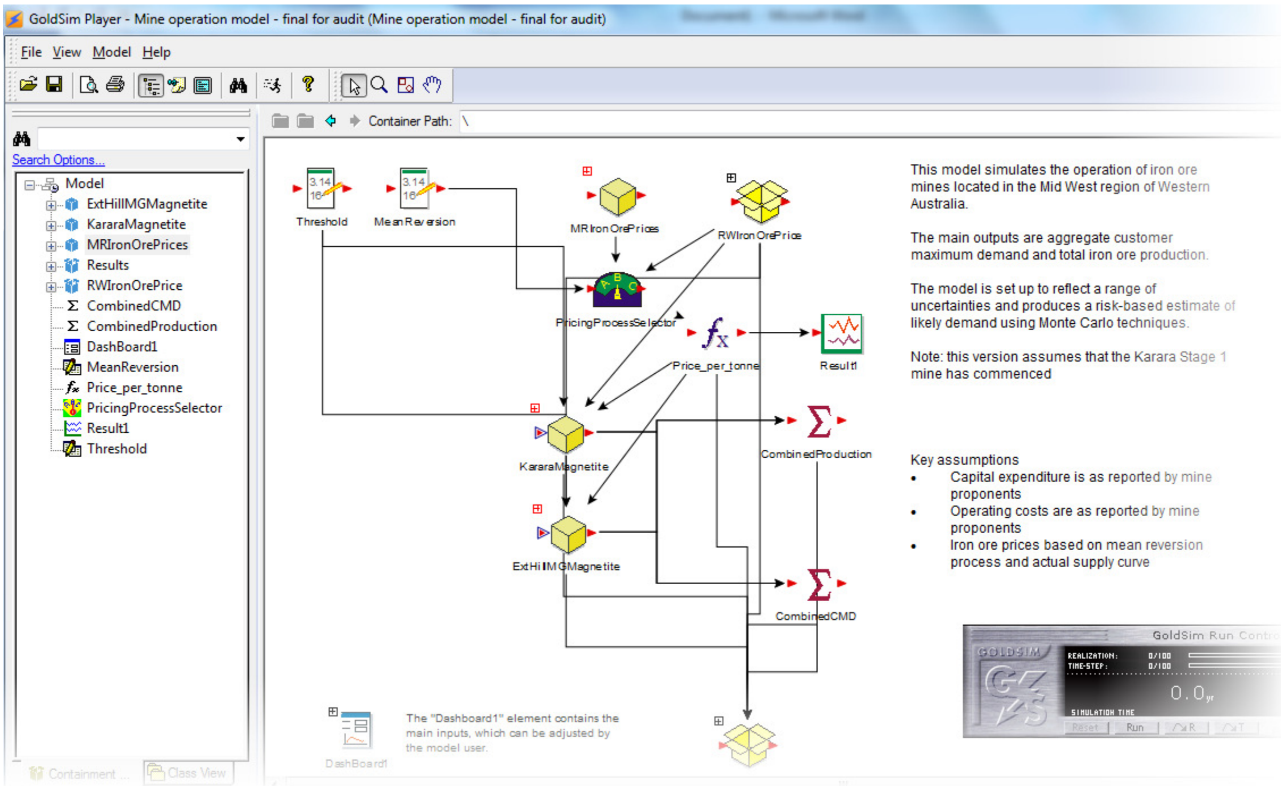


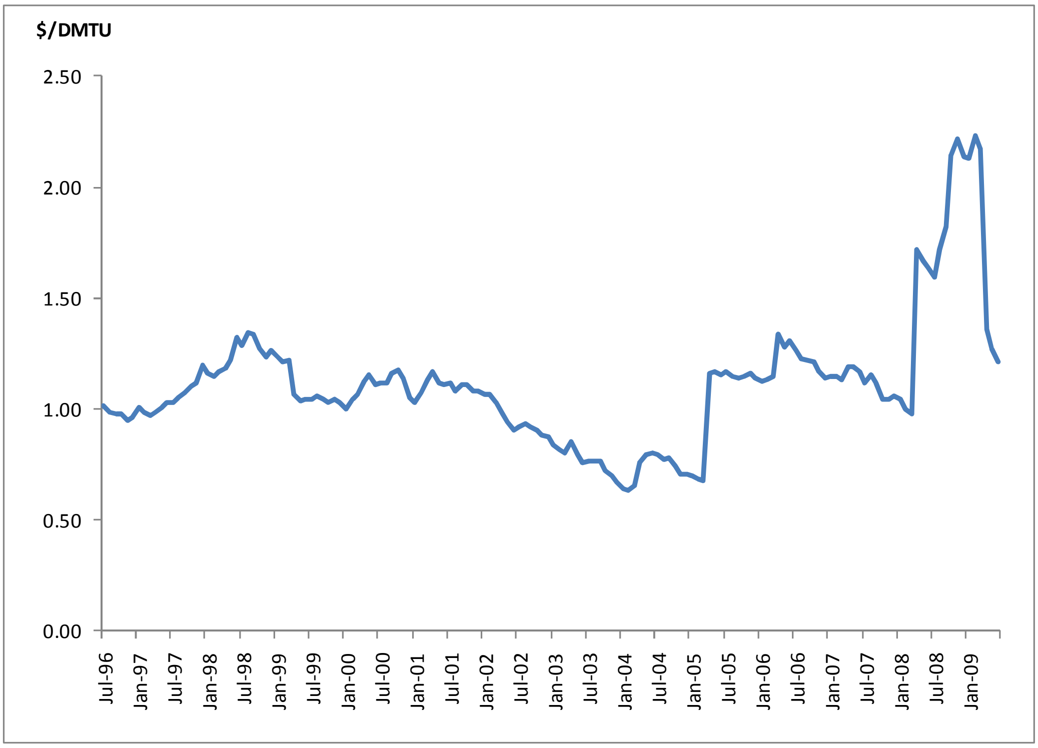
Figure 34 presents the top layer of the model, indicating that each mine represented in the model is responding to iron ore prices. Note that there are two iron price containers: MRIronOrePrices; and RWIronOrePrice. MRIronOrePrices models iron ore prices as a mean reverting process. RWIronOrePrice models iron ore prices as a random walk process.

Figure 35 presents the parameters used to simulate the iron ore price. These parameters are derived from a time series of iron ore prices provided by the Department of Mines and Petroleum. Figure 36 presents the time series adjusted for inflation.

Figure 35 Iron ore price parameters

Parameter	Units	Value
Mean annual growth	Per cent	0
Annual reversion rate	Per cent	10
Initial value	Dry metric tonne unit (DMTU)	0.98
Annual volatility	Per cent	30
DMTU multiplier	Dimensionless	64-68

Figure 36 Inflation adjusted iron ore price time series



DMTU: Dry Metric Tonne Unit

Source: Department of Mines and Petroleum, *Minerals and Petroleum Statistics Digest*, Government of Western Australia

One noteworthy feature is the apparent tendency for the iron ore price to return to values within the vicinity of $1/DMTU. Indeed, calculating quartiles for the series 1996 to 2009 reveals the first quartile of $0.98/DMTU, the second quartile of $1.09/DMTU and the third quartile of $1.23/DMTU. The time series has remained within the band defined by the first and third quartiles for half of the time.

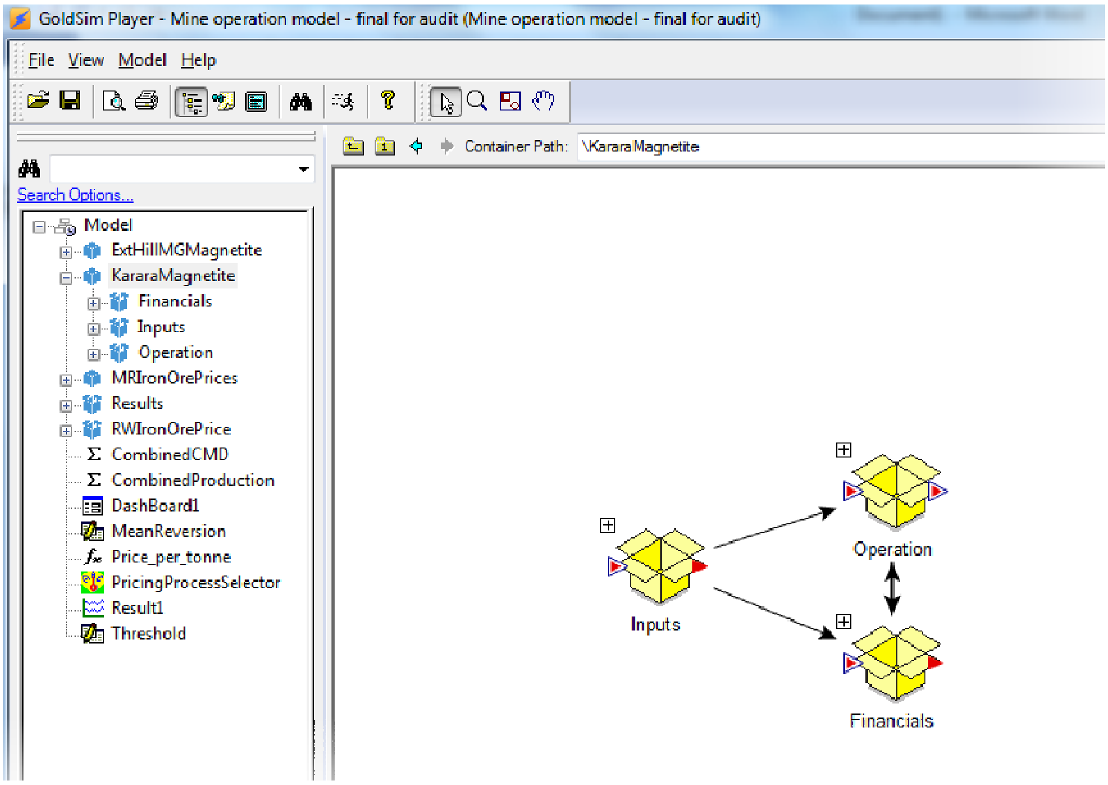
The time series has deviated significantly outside the band four times. The first time was April 1998 and lasted for 12 months. In May 2002, the time series decreased below the first quartile and lasted for 35 months. The remaining two occasions resulted in the time series increasing above the third quartile in May 2006 for 7 months and April 2008 for 15 months. Although this time series is relatively short, it exhibits an apparent mean reverting tendency.

Volatility has changed substantially over the sample period with average annualized volatility of 30 per cent from 1996 to 2009 and 43 per cent from 2006 to 2009. An interesting characteristic of the 2006 to 2009 period is the occurrence of three significant spikes; two upward spikes and one downward spike. These spikes are significantly larger than any experienced in the period between 1996 and 2006. Indeed, spikes experienced prior to 2006 are of similar magnitude to the intermediate sized spikes occurring since 2006. Overall, it is apparent that volatility has increased, although it remains to be seen whether this increase proves to be a persistent feature of the time series. In summary, the parameter values presented in Figure 35 reflect the values exhibited in the time series since 2006.

The remainder of the model is concerned with the operating characteristics of each mine represented in the model. The model structure is similar for each mine. The two key differences are: Karara Mining Limited's Stage 1 mine is modelled as already operating; and Karara Mining Limited container reflects a total of four stages as opposed to just one for Extension Hill.

Figure 37 shows that this structure is divided into three distinct groups: Inputs; Operation; and Financials.

Figure 37 Second layer



Inputs

The content of the Inputs group is presented in Figure 38. These inputs define the parameters that determine the economic characteristics of each mine. Parameter values are based on research conducted by Economics Consulting Services.

Figure 38 Inputs

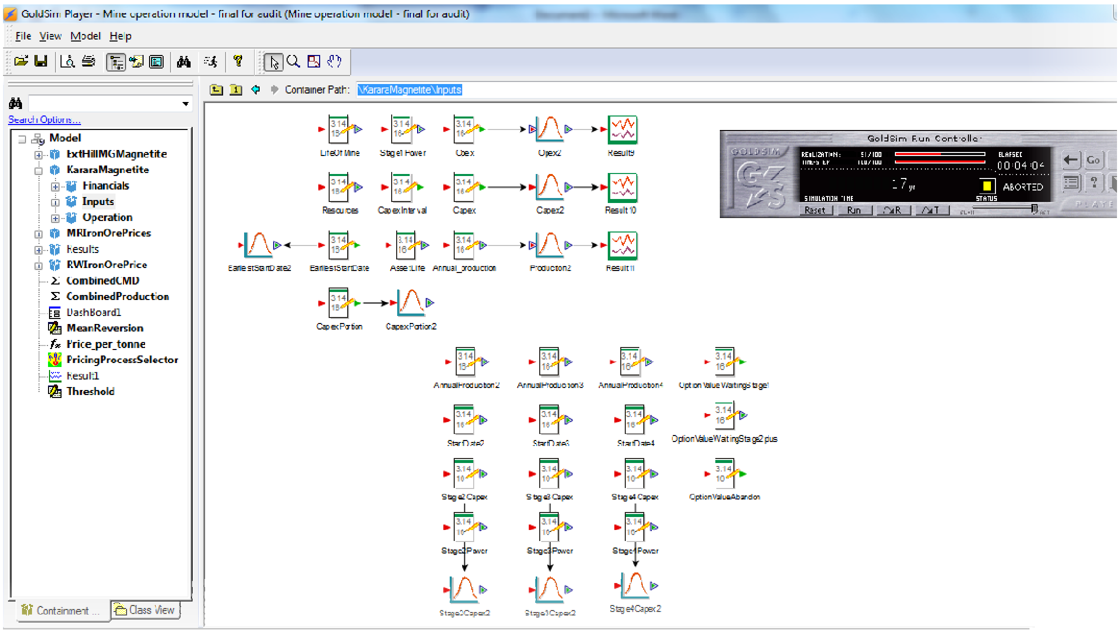


Figure 39 Input parameter description

Parameter	Description	Units
LifeOfMine	The number of years the mine is expected to last	Years
Resources	Total resources	Million tonnes
EarliestStartDate	The announced commencement date of the mine	Year
EarliestStartDate2	Creates random draws to reflect uncertainty in relation to government, finance approvals.	
CapexPortion	The proportion of capital likely to be replaced at the next capital replacement milestone	
CapexPortion2	Creates random draws to reflect uncertainty in relation to how much capital will be periodically replaced	
Stage1Power	The Customer Maximum Demand required by the mine	MW
CapexInterval	The expected average life of initial assets. It is expected that if there are sufficient resources that mine management will elect to replace capital as it wears out.	$
AssetLife	Average asset life of capital items	Years
Opex	Operating expenditure	$/tonne
Opex2	Creates random draws to reflect uncertainty in relation to operating expenditure	
Capex	Capital expenditure	$
Capex2	Creates random draws to reflect uncertainty in relation to capital expenditure	
Annual_production	The target level of production or nameplate annual capacity	Tonnes
Production2	Creates random draws to reflect uncertainty in relation to annual production	tonnes

Note that three parameters (Opex, Capex, and Annual production) feed into probability distributions. This allows these parameters to vary at the start of each simulation. The distribution associated with Opex is based on a truncated normal distribution with the left-hand side truncated 10 per cent below the stated operating expenditure ($/tonne). Opex can increase to any level, but cannot fall below 10% of the stated operating expenditure if the mine is operating.

Capex2 is defined by the truncated normal distribution. The minimum capital expenditure is as stated by mine proponents. The upper bound is unlimited. Annual production is a truncated normal distribution. The upper bound is capped at 10% higher than the target level of production. The mean of the distribution is 85% of target production. This reflects normal operating levels, which is assumed to be 85% of nameplate capacity. However, the actual operating level varies annually in the model.

Operations

The model structure of Operations is shown in Figure 40 and described in Figure 41.

Figure 40 Operations

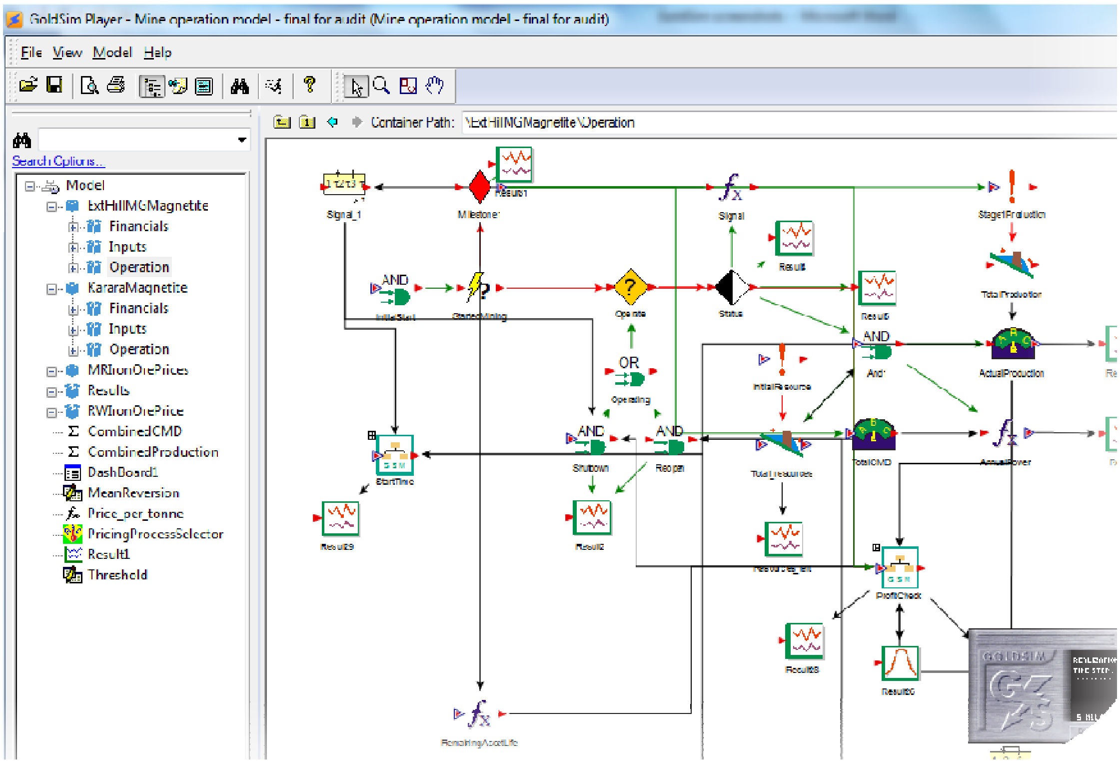


Figure 41 Variable description

Parameter	Description	Units
Signal_1	Indicates the operating status of the mine in the previous year	Dimensionless
InitialStart	Contains criteria that determines whether the mine will operate	Dimensionless
Milestone1	Records the elapsed time in which a mine has commenced	Time
StartedMining	Generates an event signal when mining has commenced	Dimensionless
Operate	Generates a discrete annual event depending on the decision criteria	Dimensionless
Operating	Is true if the mine has either not shutdown or has reopened, otherwise false	Dimensionless
Shutdown	Reflects a decision to shutdown the mine. This is true if the mine is currently operating and the probability of negative	Dimensionless

Parameter	Description	Units
	expected net present value (i.e. wealth loss) is greater than a prescribed threshold level, otherwise false	
Reopen	This reflects a decision to reopen the mine once shutdown. This is true if the mine is not currently open and the probability of expected net present value is less than a prescribed threshold level, otherwise false	Dimensionless
Status	Monitors the operating history of the mine	Dimensionless
Signal	Converts the signal into a digit (1 or 0) to record for Signal_1	Dimensionless
Initial resource	Is the initial resource estimate available to be exploited	Million tonnes
Total_resources	Measures the total resources remaining for the mine	Tonnes
And1	This makes sure that there is sufficient resource to support production).	Dimensionless
TotalCMD	Is the total Contracted Maximum Demand estimate (across stages of capacity expansion that have been implemented)	MW
Stage1Production	Is a discrete event signal that updates TotalProduction once Stage 1 production has begun	Mtpa
TotalProduction	Is the total production capacity (across stages of capacity expansion that have been implemented)	Mtpa
ActualProduction	Reports the production level (either annual production or zero)	Tonnes/year
Annual power	Calculates any variation in Contracted Maximum Demand for electricity. This will either be the specified Contracted Maximum Demand or zero.	MW
ProductionLevel_1	Records the production from the previous year	Tonnes/year

For the Extension Hill container, the Operations portion of the model begins with a decision to operate based on criteria contained in the InitialStart function. Karara Mining Limited's Stage 1 is assumed to be already operating. The InitialStart criterion is that the elapsed time must be greater than the announced (or scheduled) commencement date.

The effect of InitialStart is ensure that production does not proceed unless both conditions are satisfied. Operate emits one of two possible outcomes; either the mine is operating or not.

The And1 criteria are:

- Status (the mine must be operating)
- Total resources must be at least equal to a single year's target production

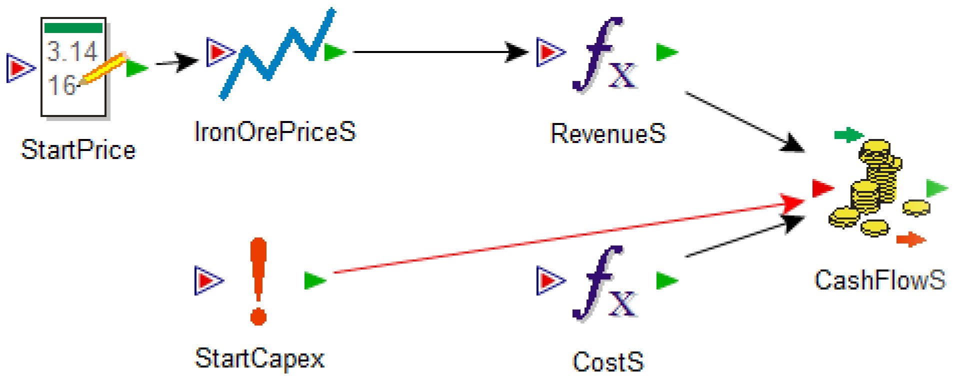
ActualProduction simply converts the production level from a discrete signal to a continuous signal for calculation purposes. Annual_power is a switch that emits output at either the total customer maximum demand if the mine is operating and zero, otherwise.

The structure of StartTime is shown in Figure 42. As indicated, iron ore prices are simulated 100 times. The expected production level and capital expenditure are inputs. The key output is a distribution of cash flow.

StartTime sub-model

The structure of StartTime is shown in Figure 42. IronOrePriceS[26] simulates iron ore prices given the same assumptions as the higher level model. StartPrice ensures the beginning price is the simulated price that corresponds to the simulated year. This implies that management understand the behaviour of iron ore prices. StartCapex adds the initial capital expenditure to the cash flow projection (CashflowS) at the beginning of the realisation. Revenues and costs are calculated based on the assumption that target production will be reached each year. StartTime only operates at the beginning of each realisation provided that the mine is not already operating.

Figure 42 Structure of StartTime



ProfitCheck sub-model

The structure of ProfitCheck is shown in Figure 43. And2 is set to true if:

1. the remaining life of existing assets is greater than zero; and
2. the elapsed time in this sub-model is at least equal to the remaining life of the assets to be replaced.

Rule 1 prevents the inclusion of replacement cost in forward-looking cash projections if it is not yet time to incur the replacement expenditure. Rule 2 determines the timing of the replacement capital expenditure.

If these conditions are not satisfied, then And2 is set to false. Once true, the replacement cost is calculated and included as a discrete expenditure in projected cash flows (CashflowS).

Iron ore prices are simulated 100 times over a projection period of at least 40 years.[27] The main output is the probability of incurring losses.

ProfitCheck is only activated if the status of the mine changes.

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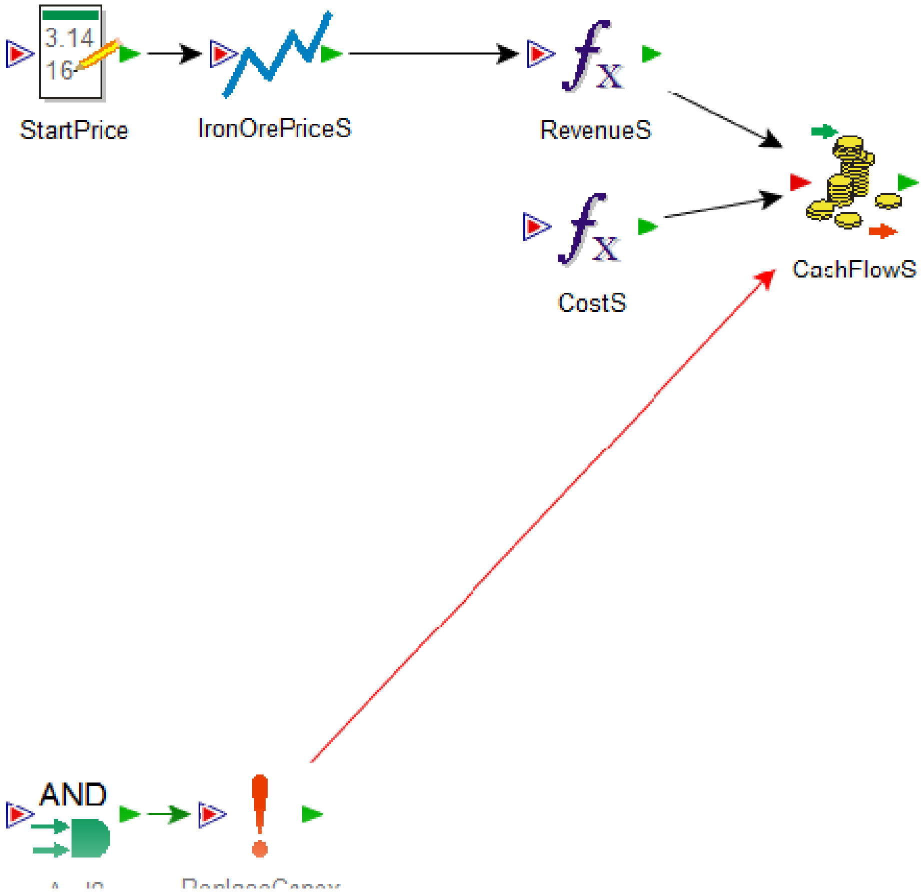
[26] The suffix ‘S’ in IronOrePriceS denotes that the price simulations are management’s simulations as they develop their expectations about future cashflows, as distinct to iron ore prices simulated in the main (upper level) model. In this sense, the simulated prices are shadow prices that may lead to real actions, hence the use of ‘S’ in the name.

[27] The actual number may vary. Recent model runs have set this period to 100 years to make sure that the shutdown rules actually operate.

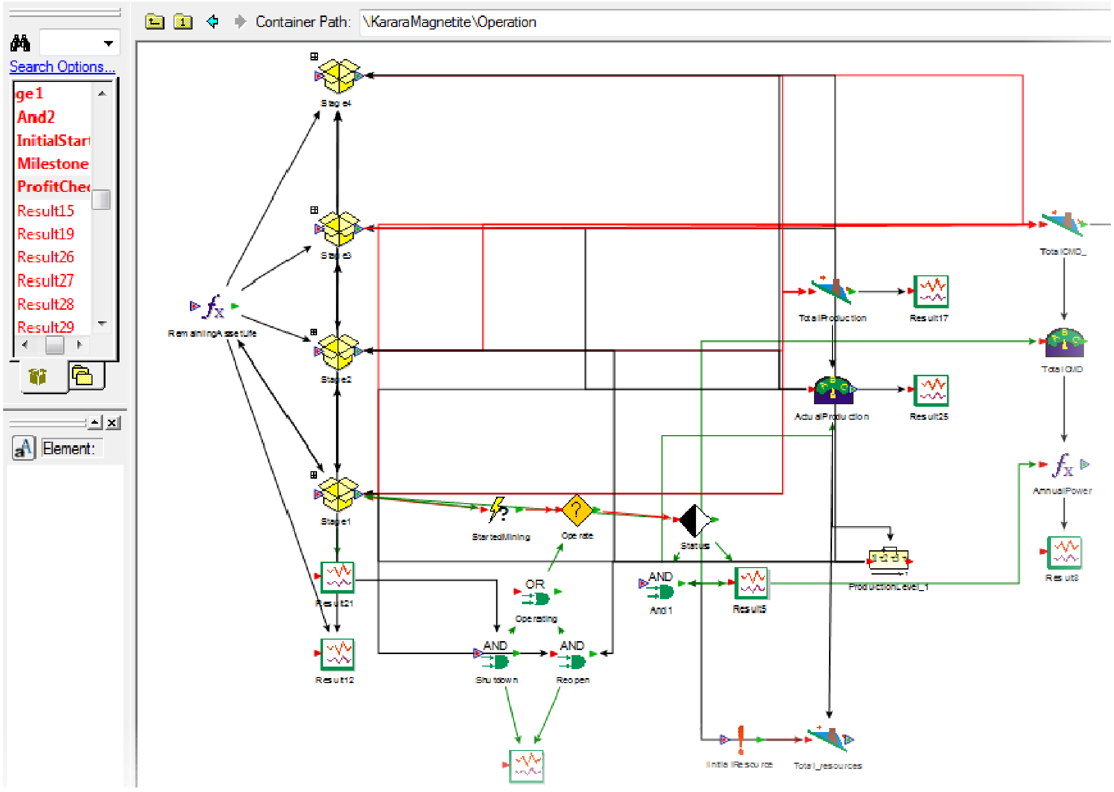
Figure 43 Structure of ProfitCheck



Modelling of additional stages for Karara Mining Limited's magnetite mine

Karara Mining Limited has indicated its intention to increase production beyond the initial Stage 1. As indicated in Figure 44, this model allows up to three additional stages (Stage 2 to Stage 4).

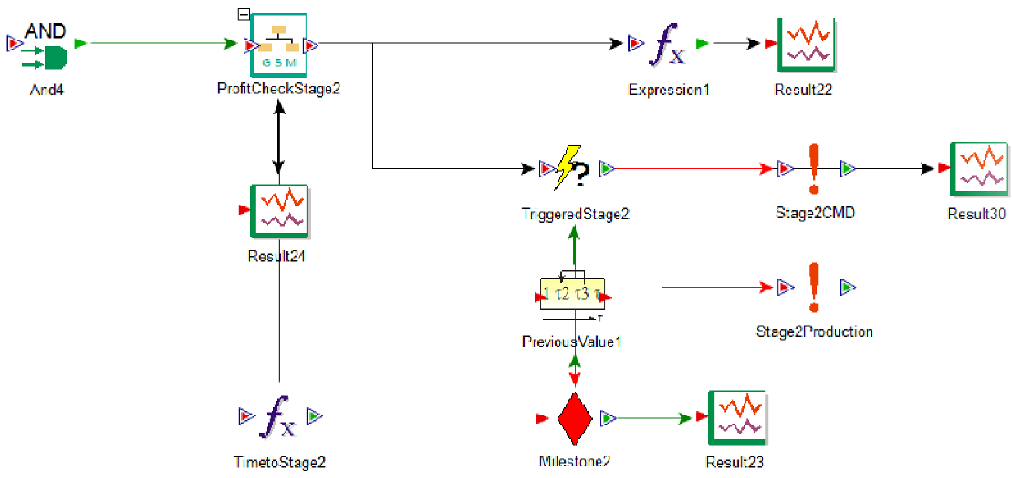
Figure 44 Operations container for Karara Mining Limited's magnetite mine



The only material difference between Stage 1 and Stage 2 is the model component called TriggeredStage2. This component contains the rule:

ProfitCheckStage2.ExpectedNPV+OptionValueAbandon*10^6>(Stage2Capex2)+OptionValueWaitingStage2plus*10^6

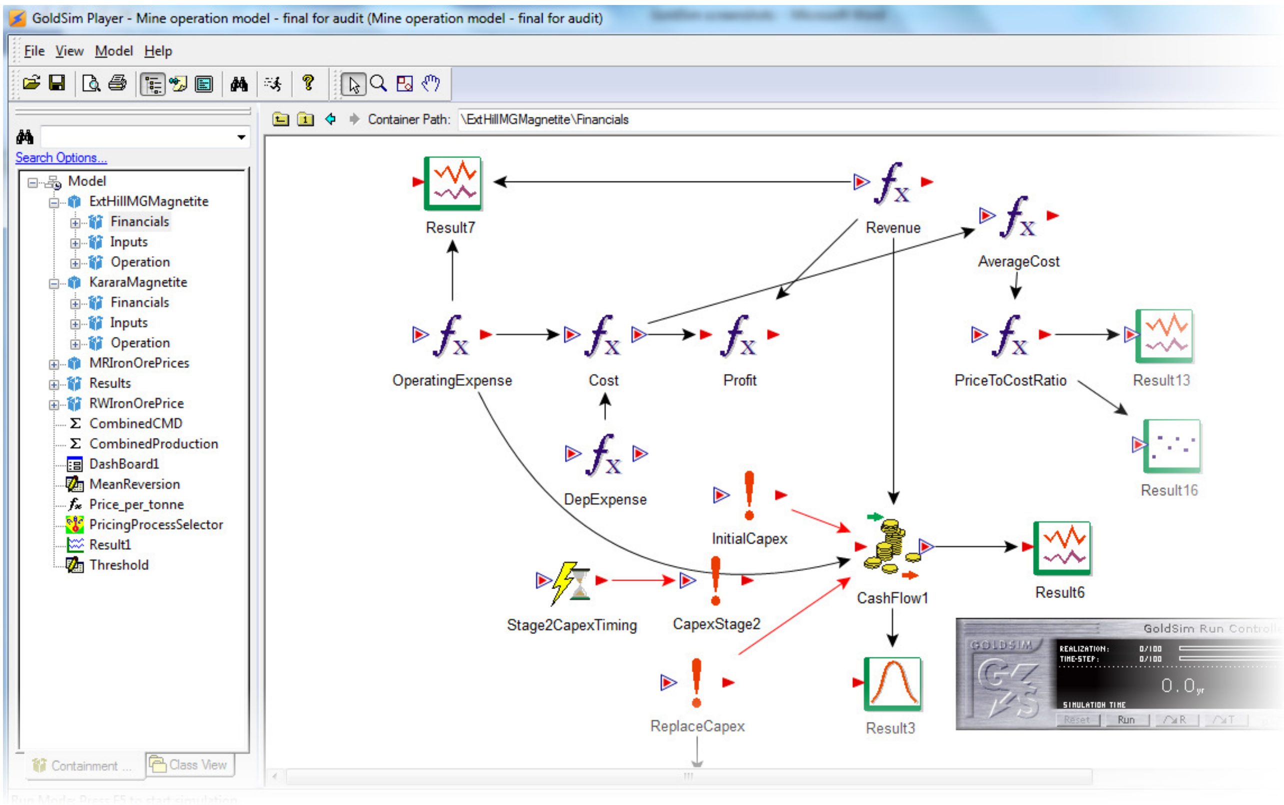
Figure 45 Stage 2 – Stage 4 container



Financials

The discounted cash flow modelling is contained in the Financials section of the model. Cashflow is calculated based on revenue, operating and capital expenses. Replacement capital expenditure is also included.

Figure 46 Financials



Cost calculates annual expenditure as follows:

Depreciation expense + Operating cost per tonne x Actual production

It is assumed that the reported operating cost (Opex2) is confined to variable costs and does not capture fixed charges associated with capital. The depreciation expense is calculated in one of two ways:

1. If the expected mine life is shorter than the economic life of the assets: the total capital expenditure (Capex2) divided by the life of the mine (LifeOfMine); or

2. If the expected mine life is longer than the economic life of the assets: the total capital expenditure (Capex2) divided by the average asset life (AssetLife).

Revenue is calculated as Price_per_tonne x ActualProduction. Profit is the difference between Revenue and Cost. The PriceToCostRatio is the ratio of the iron ore price per tonne and cost per tonne.

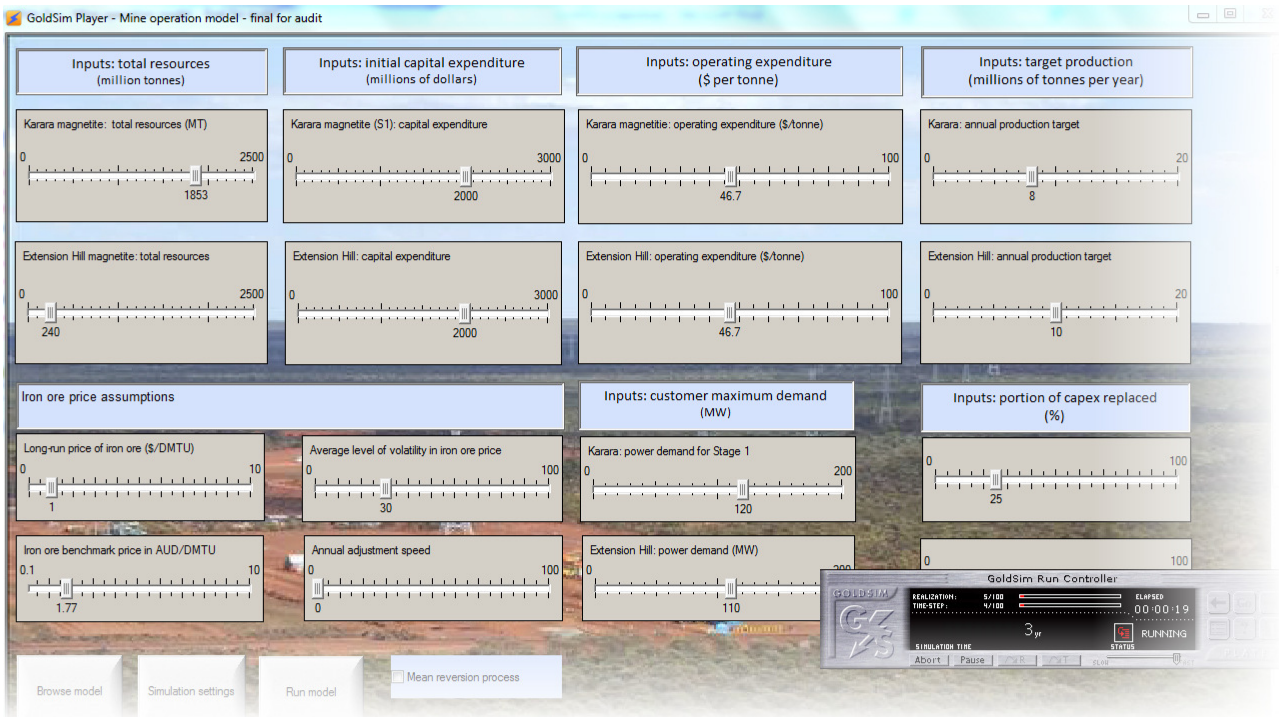
InitialCapex emits the upfront capital expenditure associated with mine development.

ReplaceCapex is the amount of capital expenditure required to replace the capital. This is added to projected cash flows as a discrete expenditure periodically. The period is determined by the average life of assets and the portion of capital that will be replaced.

Cashflow1 accumulates all cash flows and calculates the net present value of simulated mining operations.

Dashboard

The main assumptions are conveniently presented in the dashboard section of the model. This provides the ability to manually adjust all of assumptions crucial to the model outputs via the sliders. In many cases, the sliders determine the average values. Random sampling still occurs, so the dashboard will control the mean values.



Running the model

The name of the model is "Mine operation model – final for audit.gsp". This is available to the Economic Regulation Authority and delegated auditors for review. To browse and run the model, it is necessary to download the GoldSim Player. This is available free of charge from www.goldsim.com.

Appendix B - Calculation of volatility

A Volatility indicator provides an estimate of how much movement traded prices (in this case, iron ore prices) can be expected to make over a given timeframe. The most common method of calculating historical volatility is called the Standard Deviation. Standard Deviation measures the dispersion of a set of data points from its average. The more disperse (spread out) the data is, the higher the deviation.

There are two types of volatility defined in finance literature:

1. Historical volatility
2. Implied volatility

The calculations used in this model apply the standard approach to calculating historical volatility, namely:

$$= \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_t - \bar{x}\right)^2}$$

Where:

$x_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$; *N* corresponds to the total number of observations; $\bar{x}$ is the sample average; $\ln$ is the natural logarithm operator; P_t is the iron ore price this period and P_{t-1} is the iron ore price last period.

The iron ore price data obtained from the Department of Mines and Petroleum is monthly. Given the model simulates annual price changes, it is necessary to convert the monthly volatility to annual volatility. This is calculated according to:

$${}_A = {}_M\sqrt{12}$$

Appendix C - Calculating the option value of deferral

This appendix provides further detail about estimating the option value of deferring commencement of an iron ore mine. The value of deferment explicitly recognises uncertainty, which is in contrast to the traditional approach to the DCF method.

To see how the analysis changes, first consider the investment rule under the traditional approach to the DCF method:

$$\boldsymbol{PV} - \boldsymbol{I}_0 > 0$$

Where: $\boldsymbol{PV}$ denotes present value ($\sum_{t=1}^{N} \frac{(\boldsymbol{R}_t - \boldsymbol{C}_t)}{(1+\boldsymbol{r})^t}$); $\boldsymbol{R}$ denotes annual revenue; $\boldsymbol{C}$ annual costs; $\boldsymbol{r}$ is the discount rate; $\boldsymbol{t}$ denotes time; and $\boldsymbol{I}_0$ is the investment required now.

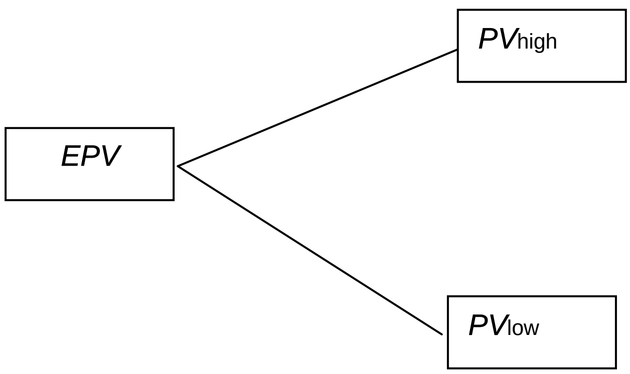
When applying this rule to real world investments with uncertain future outcomes, there is often a need to make an adjustment to this rule. The first step is to consider expected present value, which implies the following change to the investment rule:

$$\boldsymbol{EPV} - \boldsymbol{I}_0 > 0$$

Where $\boldsymbol{EPV}$ denotes *expected* present value.

With expected present value determined, a key question is whether investors can do better. Commitment to the investment now exposes investors to the possibility that the investment will impose a wealth loss. Analysis of this issue can be facilitated by partitioning the expected present value into a high state outcome and a low state outcome as depicted in Figure 47.

Figure 47 Expected net present value across future states (High versus Low)



If the low state (PV_{low}) could be removed, then the expected present value would increase. How much the expected present value increases by removing (or reducing) the influence of the low state depends on the probabilities of encountering the high and low states. Removing a low state that is highly likely (e.g. 90 per cent) will have a significantly larger impact than removing a low state that is highly unlikely (e.g. 10 per cent). Similarly, reducing the probability of the low state (e.g. from 90 per cent to 10 per cent) will lead to an increase in expected present value.

This leads the analysis to the concept of transitional probabilities. Taking specific action can alter the high and low state probabilities. For example, an investor can purchase a financial derivative, such as a put option, that can be exercised if the low state outcome is realised. This action has the effect of increasing investors' *expected* present value of an investment.

When investors (or their managerial representatives) have the choice of investing now versus investing later, then they implicitly have a deferral option. Unlike financial options, this kind of real option often does not necessarily have an expiry date. However, it is an option that can only be exercised once. The decision to commit to an investment now will forever extinguish the value of the deferral option. This may have a material impact on the market value of a company with plan to develop a mine. If a company tried to proceed with a mine development in the low state, it may well see its market value decrease rather than increase.

Hence, Pindyck[28] argues that the correct investment decision rule is one that explicitly recognises this value:

$$\boldsymbol{EPV} - \boldsymbol{I}_0 - \boldsymbol{DO} > 0$$

Where $\boldsymbol{DO}$ denotes deferral option.

As explained by Pindyck, the value of the deferral option is simply the difference in present value between the high state present value (PV_{high}) and the expected present value (EPV). If the current state is the high state, then the difference will be zero.[29] If the current state is the low state, then the difference between the current state and the high state is negative. In this case, the rule does not allow the investment to proceed and the effect is that investors will defer the investment to a later period.

How the value is calculated in this assessment

The GoldSim model used in this analysis generates a distribution of wealth outcomes measured in present value terms. The expected present value is the simple average of this distribution. The high state value is the 75th percentile value of this distribution discounted by one period. The deferral option is the difference between the high state value and the expected value, which turns out to be a positive value.

The principal driver of the distribution of wealth outcomes is the series of future iron ore prices. The series of future iron ore prices is modelled as a random walk with the initial value set at the sample (January 2006 - June 2009) average price of $1.2/DMTU.

Practical implications for this assessment

The practical outcome is that mine managers will tend to defer commencement of mining if circumstances justify the deferral. Clearly, this poses a risk to the derived demand for the electricity that the mine would require once it is operational.

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[28] See Pindyck, R.S. (2008), "Sunk Costs and Real Options in Antitrust Analysis", in *Issues in Competition Law and Policy*, pp. 619-640 (ABA Section of Antitrust Law 2008).

[29] The difference could also be positive if the actual conditions realised in the high state are higher than the *expected* high state value.

Estimating the value of deferral provides a simple, mechanical rule that reflects that judgement. By incorporating this rule, the risk model underlying this analysis can better reflect the likelihood of deferral. A side benefit is that it can help identify market conditions in which this deferral is likely.

Alternative approach to assessing timing risk

An alternative approach would be to assign a rule to the likelihood of incurring a wealth loss. This can be calculated by estimating the probability of incurring a negative net present value. However, this approach would require a threshold probability to be assigned to the decision to convert the probability estimate into an actionable outcome (i.e. commence or do not commence).

That is, it would require information about what risk level of wealth loss mine investors are willing to tolerate. For example, highly risk averse investors may set the threshold at 75 per cent (or higher). Risk neutral investors would set the threshold at 50 per cent.

Given that information about the actual risk tolerance of mine investors is not publicly available, it was considered that this approach to timing risk would be more subjective than estimating the value of the deferral option.

Appendix D - Calculating the option value of abandonment

The option to abandon an investment once committed recognises another form of managerial flexibility in planning irreversible investments. As with deferral options, the option to abandon an investment recognises that alternative contingent actions can lead to different expected present value measures of the return to investors.[30]

In general, investors (or their managerial representatives) may be able to identify opportunities to increase the expected return on a prospective investment by truncating the downside of a distribution of possible returns. Reducing or eliminating the negative portion of a distribution will increase its expected value.

An example of an abandonment option would be an agreement struck between the firm proposing an investment and another party to purchase the investment at a predefined price under predetermined circumstances. In effect, the other party would be selling an option. Novaes and Souza provide another example: a global automobile manufacturer planning to build a plant in Brazil.[31] In this example, the global manufacturer plans a contingency strategy to redeploy its plant and machinery in the event that the Brazilian plant encounters a country-specific, low payoff (loss making) state after it has committed to its investment.

Whatever contingency plan is developed, the effect is to increase the expected return to investors *prior* to committing to the investment. The practical impact would be to reduce the incentive to defer an investment. That is, the investment rule developed in Appendix C - would be modified as follows:

$$\boldsymbol{EPV} - \boldsymbol{I}_0 - \boldsymbol{DO} + \boldsymbol{AO} > 0$$

Where $\boldsymbol{AO}$ denotes the value of the abandonment option.

The method to valuing the abandonment option is a two-step process involving a variation of the standard Black-Scholes model of option pricing.[32] The first step is to establish the values of the investment under two possible outcomes at a predetermined date:

1. Abandoning the investment at a pre-determined price.

2. Continuing with the investment in the low state.

The present value calculation is straightforward:

$$\boldsymbol{NPV_i} = \frac{\boldsymbol{SV_i}}{(1+\boldsymbol{r})^{\boldsymbol{N}}}; \boldsymbol{i} = \{1,2\}$$

[30] For clarity, it should be clear that forward-looking market valuation of assets is based on expected net present value estimates. Hence, an increase in the expected net present value of an asset is identical to its increase in market value.

[31] Novaes, A.G.N. and Souza, J.C. (2005). “A Real Options Approach to a Classical Capacity Expansion Problem”, *Pesquisa Operacional*, vol. 25(2), pp. 159-181.

[32] Novaes and Souza, Op. cit., pp. 172-175.

Where: $\boldsymbol{R}$ denotes annual revenue; $\boldsymbol{C}$ annual costs; $\boldsymbol{r}$ is the discount rate; $\boldsymbol{t}$ denotes time; and $\boldsymbol{SV_i}$ is the salvage value, which varies across the two options.

Once the two net present values are calculated, the option value of abandonment is calculated according to Margrabe's equation:

$$\boldsymbol{f} = \boldsymbol{X}_0 \boldsymbol{N}(\boldsymbol{d}_1) - \boldsymbol{S}_0 \boldsymbol{N}(\boldsymbol{d}_2)$$

Where:

$$\boldsymbol{d}_1 = \left[\ln\left(\frac{\boldsymbol{X}_0}{\boldsymbol{S}_0}\right) + 0.5 \quad {}^2 \boldsymbol{N}\right]\left[\frac{1}{\quad \sqrt{\boldsymbol{N}}}\right];$$

$$\boldsymbol{d}_2 = \boldsymbol{d}_1 - \quad \sqrt{\boldsymbol{N}};$$

$\boldsymbol{X}_0 = \frac{\boldsymbol{SV}_1}{(1+\boldsymbol{r})^{\boldsymbol{N}}}$ (the abandonment value); $\boldsymbol{N}(\cdot)$ denotes the cumulative unit normal distribution; $\boldsymbol{S}_0 = \frac{\boldsymbol{SV}_2}{(1+\boldsymbol{r})^{\boldsymbol{N}}}$ (the continuation value); measures portfolio volatility; $\boldsymbol{N}$ is the expiry date. Portfolio volatility is calculated according to the following equation:

$${}^2 = {}_{\boldsymbol{X}}^2 - 2 \quad {}_{\boldsymbol{X}} \quad {}_{\boldsymbol{S}} + {}_{\boldsymbol{S}}^2$$

Where:

${}_{\boldsymbol{X}}$ is price volatility associated with the abandonment value

${}_{\boldsymbol{S}}$ corresponds to price volatility of continuing the investment

is the correlation coefficient between the two salvage values

The final step is to add the value of the abandonment option to the investment decision rule, which delivers the first equation presented in this appendix:

$$\boldsymbol{EPV} - \boldsymbol{I}_0 - \boldsymbol{DO} + \boldsymbol{AO} > 0$$

With respect to iron ore mining, ${}_{\boldsymbol{S}}$ is the volatility of iron ore prices, which is set at 30 per cent. Salvage value associated with continuing to operate is the low state expected net present value. The expiry date was set to five years.

In order to determine the other parameters, it was assumed that in the event that the low state is realised, mine owners would sell the investment to another mining company. This follows the BHP Billiton experience with its Ravensthorpe Nickel Project. Given this scenario, ${}_{\boldsymbol{X}}$ is identical to ${}_{\boldsymbol{S}}$; is likely to be high and is set at 0.9. A correlation coefficient less than one is justified on the grounds that the value of each project offers consolidated value to the new owners. This means that at very low valuations, there would be a small premium associated with fewer competitors. Hence valuations between continuing and selling the investment may diverge marginally. Notwithstanding this, the salvage value of the abandonment option is assumed to be identical to the continuing operation valuation.

Despite these assumptions, the option value of abandonment is positive, although small. In practice, it does not materially offset the value of the deferral option. In other words, it does not have any noticeable impact on the timing of mine commencement in the risk model.

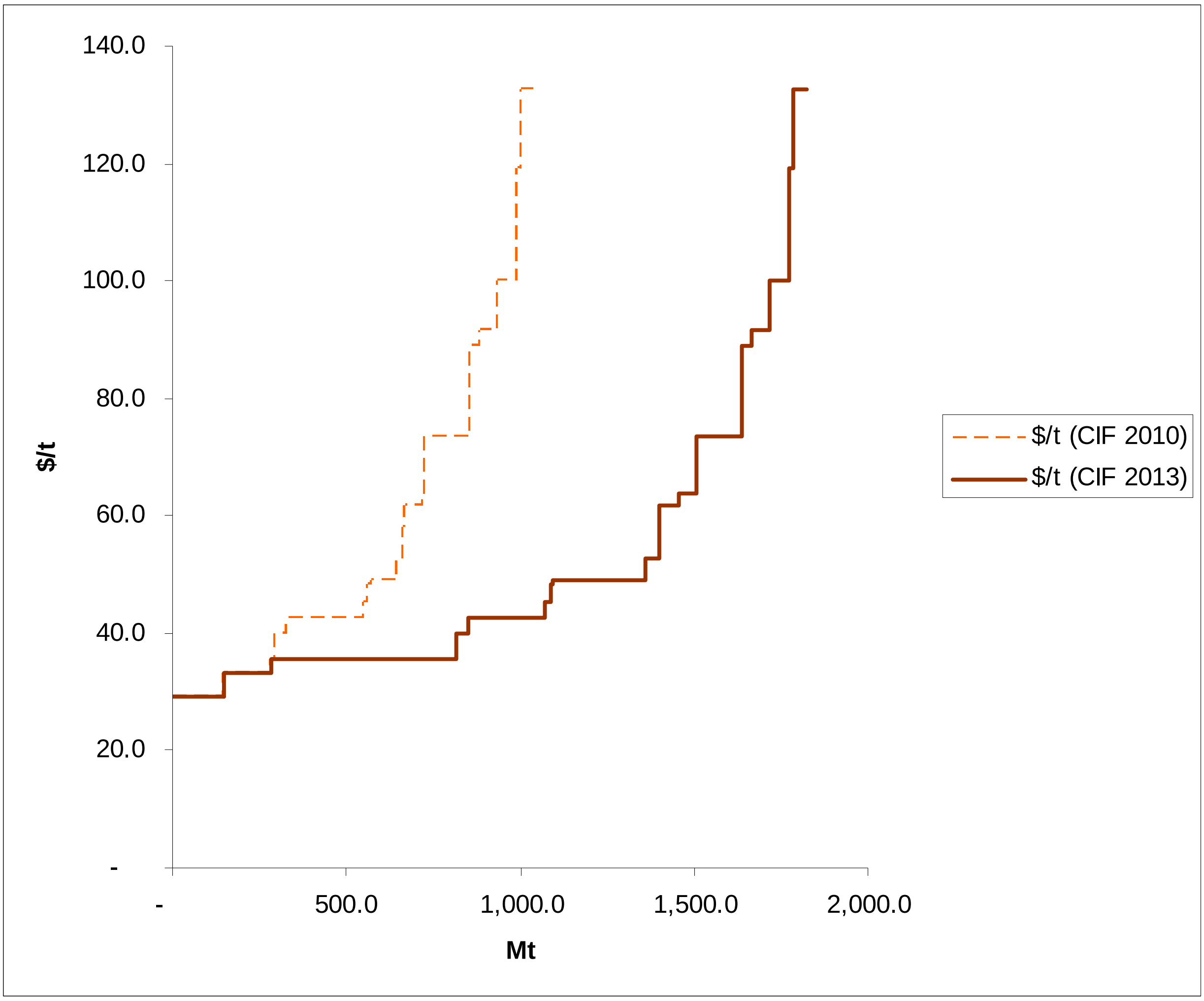
Specific information provided by mine proponents about contingent abandonment strategies, if made public, may make a material difference to this result.

Appendix E - Mean reversion process reviewed

This appendix provides an outline of the differences in assumptions made in the iron ore price is modelled.

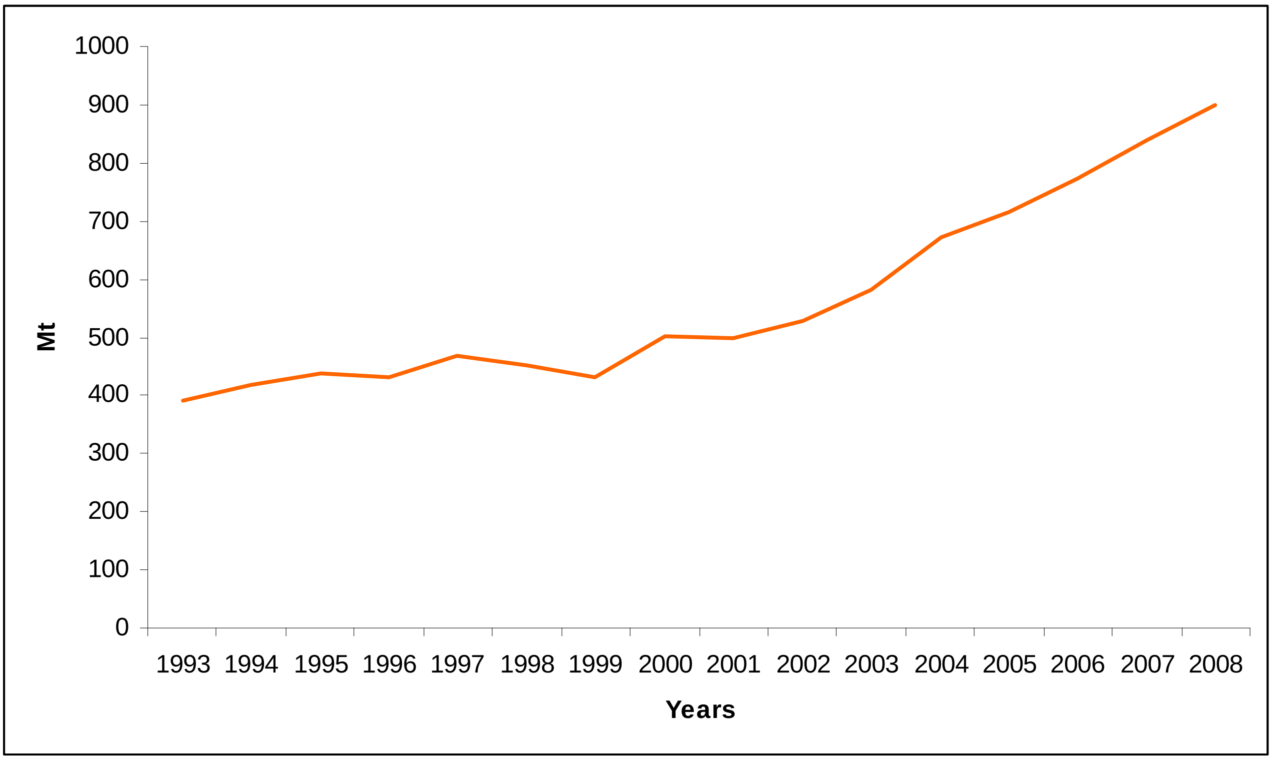
Figure E. 1 Presents the assumed iron ore supply curve as at 2013.

Figure E. 1 Calculated global iron ore long-run supply curve



To complement the long-run supply curve, a long-run demand curve was developed based on data obtained from ABARE. Figure E. 2 presents the data in chart form.

Figure E. 2 World iron ore imports

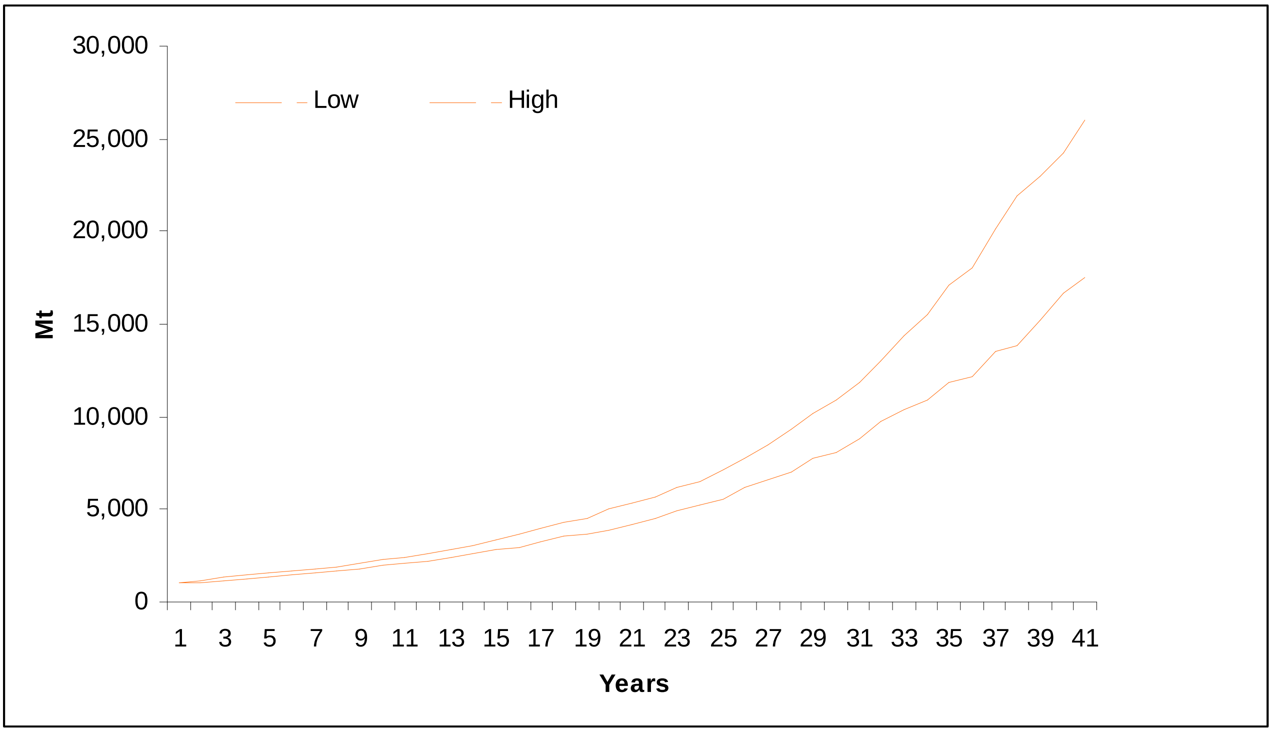


Source: ABARE, Australian Commodities

The key statistics obtained from these data was a compound average growth rate of 8.3 per cent per year and a standard deviation of 6.7 per cent. This provides the basis to simulate many possible future outcomes. The mean growth rate for the future was assumed to vary between 4 per cent per year and 8 per cent per year.

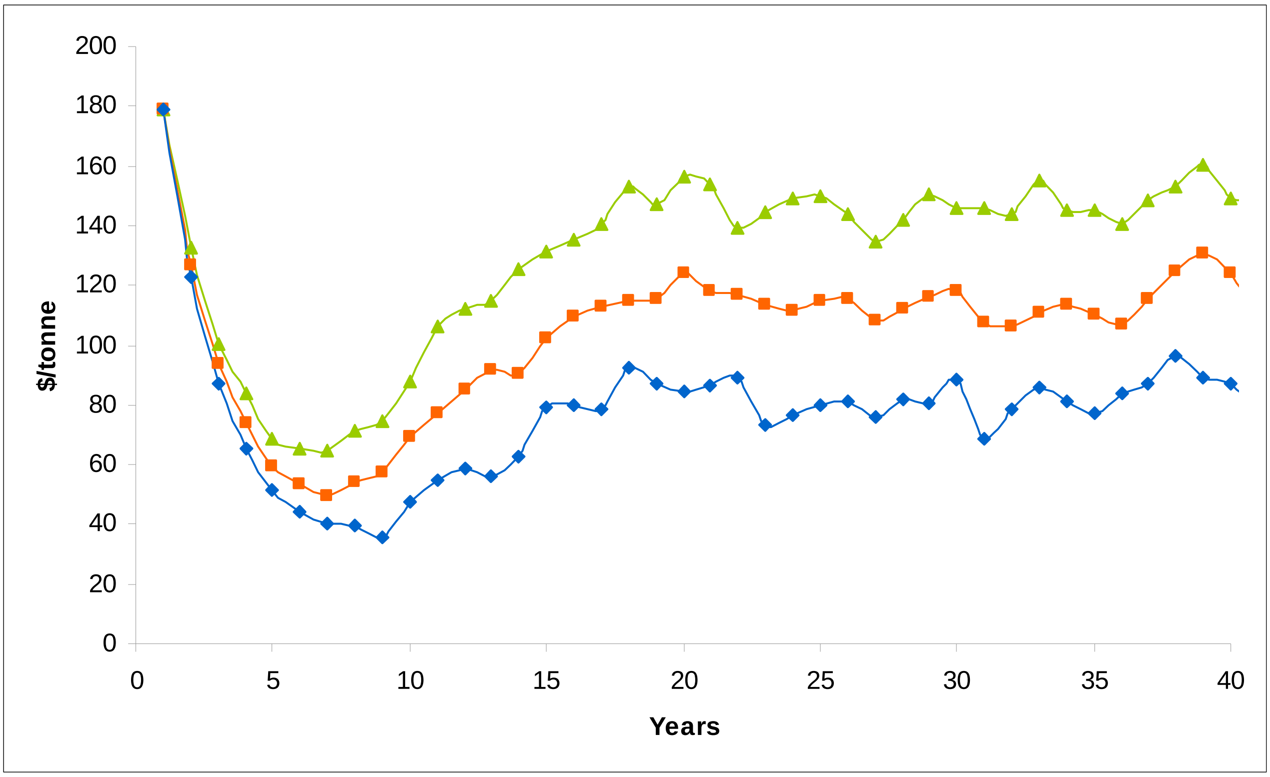
Figure E. 3 shows the resulting projection range over a period of 40 years. Note that it takes more than 18 years for the upper bound of the range to exceed 5,000 Mtpa.

Figure E. 3 Future world iron ore imports



The GoldSim model is programmed to use the demand curve as the reference and then return the corresponding long-run price of iron ore. Variation to the long-run price is then added, which can either increase or decrease the price according to annualised volatility of 40 per cent. This captures short-term pricing dynamics. Note that the initial price is obtained by the International Monetary Fund.

Figure E. 4 Simulated iron ore prices baed on the mean reversion process



The resulting price series exhibits a substantial and persistent fall in iron ore prices from its current high level to less than $60 per tonne in eight years. Beyond eight years prices are modelled as recovering substantially, levelling at an expected price range of $70 to $100 per tonne.

In terms of modelled variation in CMD, however, this results in little difference when compared to the random walk outcome.