ANALYSIS OF OPPORTUNITY TO INCORORATE RAW COAL INTO CLEAN COAL PRODUCTS AT GREENHILLS OPERATIONS

by

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B.Sc. in Mining Engineering, University of Alberta, 2000

PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION

In the Executive Master of Business Administration Program
of the
Faculty
of
Business Administration

SIMON FRASER UNIVERSITY

Spring 2011

Approval

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Abstract

This project looks at an opportunity to increase the metallurgical coal production at Greenhills Operation.

Analysis of the seaborne metallurgical coal industry indicates that it has experienced a dramatic shift in supply and demand balance over the past five years due to increased urbanization in developing China. Increased demand has put continued upward pressure on metallurgical coal prices.

Teck has stated that its strategy in the metallurgical coal industry is to grow its productive capacity by leveraging its existing resource base. This project looks at the potential to do that through bypassing raw coal with sufficiently low ash content, thus increasing capacity without changes to the mine plan or processing plant.

An economic analysis of the project indicates extremely favourable results. Potential concerns from a quality perspective are explored, and recommendations are made to test the product to determine the feasibility from a quality perspective.

Keywords: metallurgical coal; coking coal;

Executive Summary

Greenhills Operation is coal mine located in the East Kootenays of British Columbia. The mine is operated as a joint venture between Teck Resources Ltd. and POSCAN, the Canadian subsidiary of Korean steelmaker POSCO. The mine primarily produces metallurgical coal with an annual capacity between 4.0 and 5.0 million metric tonnes. The coal is sold into the seaborne coking coal market.

Market dynamics have experienced a significant shift in the balance of supply and demand in the metallurgical coal industry, and the demand for coal is quickly outpacing supply. The move towards urbanization in China, coupled with the government-mandated economic growth, has increased the steel production in that country to the point where it can no longer depend on the domestic production of raw materials to satisfy requirements. Over the past few years, China has changed from being a net exporter of metallurgical coal to a net importer to the point where China is now the second largest importer of metallurgical coal from the seaborne market.

With the market in a state of under-supply, existing coal producers have been enjoying extremely large margins on their products. New producers are virtually non-existent due to the barriers to entry that exist for new entrants into the metallurgical coal marketplace. Scarcity of the resource, and the geographic and political challenges facing the owners of developing deposits, translate into delays in getting new production to market, so incumbent producers can expect to continue to receive significant value for every tonne of product they can get into the market.

At Greenhills Operation, the largest coal seam with respect to proportion of overall reserves is 010-seam. This coal is a very good quality coking coal,

included in the metallurgical product blends at Greenhills, and possesses many desirable characteristics in terms of its performance in coking ovens. As it exists in the deposit, 010-seam coal can vary from 10 to 30 meters in thickness and exhibits a wide range of raw ash values throughout the mine. It is estimated that approximately one tenth of the entire reserves of 010-seam coal have a raw ash content of less than 10%. The significance of this is that the average raw ash content of this portion of the reserve is lower than the target clean ash of the finished product.

The economics of bypassing the plant with the lower ash portion of the 010-seam coal and adding it into the final products are very favourable. It allows the Greenhills mine to increase production capacity without having to make changes to the existing mine plan or coal release schedule, or add any additional mining equipment. Additional benefits include reduced emissions from the plant dryer associated with burning of coal in the dryer.

The problem surrounding the 010-seam coal is that it is extremely fine, and therefore creates many handling issues for the final product, if the moisture content is too low or the overall content of fines is too high. Additionally, the effects of including raw 010-seam coal, on the coking parameters of the coal blends, are currently not understood. Research on the effect of raw ash on coking coals has indicated that the potential problems that could arise are reduced size of the coke produced, and lower coke strength after reaction. However, the ash in 010-seam coal is also very fine, and therefore not typical of the ash that exists in other raw coals. Therefore, testing of coke blends that include raw 010-seam coal should be conducted to assess the extent of these effects, and to determine whether the inclusion of raw 010-seam coal is a viable option for increasing clean coal production at Greenhills.

For my wife Erin,
whose selfless
support and understanding
allowed me to pursue my goal.
I hope you know the
true depth of my
gratitude.

And for my children,
whose patience
belies their
years.

Acknowledgements

I would like to take this occasion to thank Teck for providing me the opportunity to take this extraordinary journey. Special thanks go to Ross Pritchard for believing in me enough to endorse my original application into the program.

I would also like to thank the exceptional faculty at Simon Fraser University for reminding me how much I enjoy learning.

And of course, heartfelt thanks go out to my fellow members of Team Revolution – Michael Harrington, Colin Petryk, and Tammy Salway. We were truly more than the sum of our parts.

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Glossary

Coking Coal	Coal that is used to produce coke for steel making, consisting of hard coking coal (HCC) and soft coking coal.
Metallurgical Coal	Coal that is used to make steel. Includes both coking coal and PCI coal.
Steam Coal	Coal that is burned to create heat used to produce steam that is used in a variety of processes.
PCI Coal	Pulverize coal injection, coal that is pulverized and injected into blast furnaces as a source of heat.
CSR	Clean strip ratio, BCMW/MTCC
Yield	Ratio of the mass of clean produced to the mass of raw coal input for a coal seam, blend, etc.
MTCC	Unit of measure, metric tonne of clean coal
BCMRC	Unit of measure, bank cubic metre of raw coal
BCMW	Unit of measure, bank cubic metre of waste
MTRC	Unit of measure, metric tonne of raw coal
BCMTM	Unit of measure, bank cubic metre of total material, includes BCMW and BCMRC

1: INTRODUCTION

1.1 Problem Statement

Teck Resources Limited is a diversified mining company with major business units focused on coal, copper, zinc, and energy. Within its coal business, Teck's strategy is to grow their participation in the global steelmaking coal market by utilizing Teck's existing resource base. The focus of this project will be to determine the potential for Teck to increase the production capacity and reduce overall unit costs at its Greenhills Operation by including raw coal of sufficiently low raw ash content as part of the product blend.

The focus of this project is going to be on the proportion of 010-seam coal that has a raw ash of 10% or lower. The raw ash content of this coal is equal to or lower than the clean ash of the final blended clean coal products. This has prompted the question of whether or not the raw coal could be added to a clean coal blend without the need for processing, since the primary purpose of processing is to remove mineral matter (ash) from the raw coal so that it meets contractual ash specifications. This project will determine the feasibility of adding raw coal to the blend and under what situations this would be economic to do so. The project will examine the impact from the start of the mining process right through to the effect on final product specifications, as well as end-use final product specifications to determine the potential effect on customers.

The economic analysis of the project will assess the current coking coal market and will determine under what conditions the project is most economic for Teck. The ultimate aim is to make a recommendation on whether or not to proceed with the project, and to consider any potential risks to Teck, with plans on how to mitigate them.

1.2 Teck Overview

Teck is a diversified Canadian mining company with roots dating back to 1906 with the creation of Cominco through the amalgamation of several units controlled by the Canadian Pacific Railway (CPR). Teck-Hughes Gold Mines Limited opened in 1913 to develop a gold discovery at Kirkland Lake, Ontario. Teck grew as a mining company, diversifying into copper in 1956, zinc in 1963, silver in 1965, and niobium in 1975. It was in 1983 that Teck originally diversified into coal with the acquisition/start up of the Bullmoose mine in Tumbler Ridge, British Columbia.

Today, Teck owns mining assets producing coal, copper, and zinc. It also has ownership in energy resources in Alberta's oil sands. In total, Teck has six operating coal mines, five active copper operations, and three operating zinc mines along with a zinc smelter. It also has an additional coal mine, two additional copper mines, and two oil sands operations in development.

Teck primarily produces good quality hard coking coal used to make steel from its six operating coal mines with some thermal and PCI coal production as well. Five of the six mines are located in the East Kootenays of south-western British Columbia near the Alberta border, and the sixth operation is located in west-central Alberta near the town of Hinton. Based on stated company strategy, Teck intends to grow its coal production, increasing annual production to 30 million metric tonnes by 2013. This project examines an option for growing that production.

1.2.1 Greenhills Operation

Greenhills Operation is located in the Elk Valley, and is the third largest of Teck's coal operations by annual clean coal capacity. The Greenhills mine is 8 km northeast of the town of Elkford and covers over 11,800 ha of area, approximately 2,265 ha of which has or eventually will be part of the mining footprint.

Mining started at Greenhills in 1983 as a joint venture between Westar Mining Ltd and POSCAN, a subsidiary of Korean steel giant POSCO. Westar held ownership of 80% of the operation, with the remaining 20% owned by POSCAN. In 1992, Westar Mining filed for bankruptcy, and the bankruptcy trustee sold the 80% ownership held by Westar to Fording Coal, which was owned by Canadian Pacific at the time.

Shortly after the turn of the last century, the Canadian metallurgical coal industry went through an amalgamation. Up to that point, the three major companies, Fording, Teck and Luscar, were competing for sales on the world stage against foreign as well as domestic competitors. This drove prices down in an extremely competitive and low margin market. Teck, Fording, and Luscar combined coal assets as the Elk Valley Coal Corporation in 2003, owned by both Teck Cominco (40%) and the Fording Canadian Coal Trust (60%). Teck was the managing partner within the partnership. In 2008, Teck purchased the remaining 60% ownership held by the Fording Canadian Coal Trust. Greenhills Operation has maintained its joint venture status with POSCAN through all of the ownership changes.

Greenhills mine has an annual production capacity of 4.0 to 5.0 million metric tonnes of clean coal (MTCC). Historical production can be found in Figure 1-1. The mine employs approximately 560 people in a non-unionized environment. Mining operations run 24 hours per day split into two 12-hour shifts, 7 days per week, 365 days per year.

1.3 Coal

Coal is a rock formed from the remains of vegetation that has accumulated over time, millions of years ago. Accumulated vegetation is covered with many types of sediment that over millions of years provide incredible pressure and extreme temperature, altering the vegetation, concentrating the carbon and transforming the vegetation into coal. It takes approximately eight metres of compacted vegetation to produce one metre of coal (The Coal Association of Canada [CAC], 2003, p. 2). The properties of coal vary greatly and it is important to understand how the properties of coking coal are different from other coal, and how they contribute to the downstream products that the coke will be used for – coke and steel. It is very important that possible changes to these properties be understood in the context of this project to ensure that product quality is kept consistent.

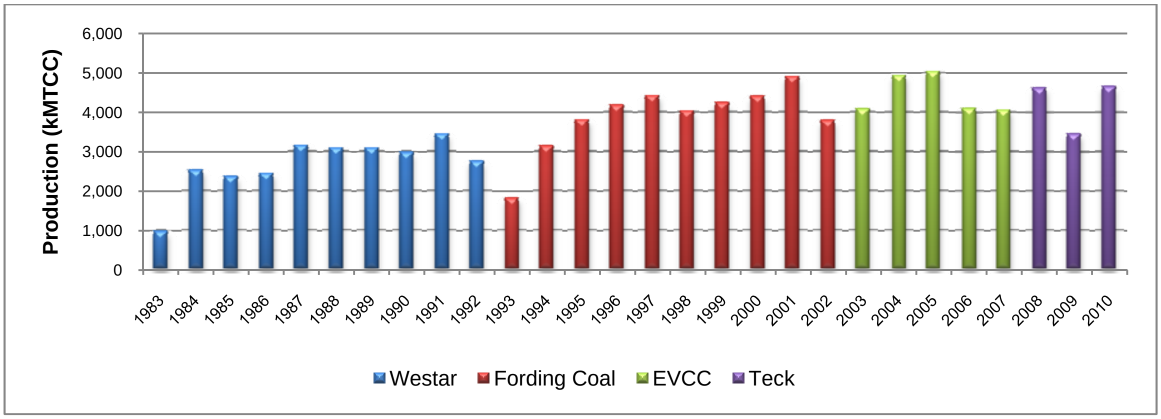

Figure 1-1: Historical Greenhills Production (figure by author)

1.3.1 Coal Rank

Coal is classified by rank based on physical parameters and chemical composition, most notably fixed carbon and volatile matter content. Generally, coal rank changes based on the overall age of the coal, with younger coal having the lower rank. The youngest and lowest-ranked coal is lignite, followed by sub-bituminous, bituminous, and finally anthracite. The fixed carbon content varies from a low of around 25% for lignite, up to above 92% for anthracite.

The most abundant type of coals are the lower rank coals of lignite and sub-bituminous. These coals are primarily burned for heat, which is most often used to make steam to drive turbines and generate electricity. Bituminous coal is a relatively scarce commodity compared to the thermal coals, and is used to produce steel. Bituminous coal has a carbon content greater than 60%. It has many additional properties other than carbon content that allows it to be coked and used to make steel. Anthracite, the least abundant rank of coal, is primarily used as a clean-burning source of heat. Lignite is considered brown coal, or soft coal, while the remaining ranks are considered hard, or black coal. Hard coal used for the production of heat or steam is called steam coal.

Within the rank of bituminous coal are coals used to make steel. This coal is called metallurgical coal and is divided into pulverized coal injection (PCI) coal and coking coal. Coking coal is used to produce coke that is a necessary ingredient in the production of steel. Not all bituminous coal can be used to produce coke. Only bituminous coals that fit into a narrow band of volatile matter content, fluidity, and plasticity can be classified as coking coal, the only type of coal that can be coked. Coking coal can further be classified into semi-soft coking coal and hard coking coal (HCC). Semi-soft coal produces a weaker coke and must be blended with hard coking coal in order to produce coke suitable for making steel. PCI coals are lower-rank coals, which are pulverized and added to a blast furnace as an economic source of heat in the furnace, displacing some of the coke required.

1.3.2 Coking Coal

As mentioned above, coking coal is bituminous coal that fits into a narrow range of specifications. The important specifications are the content of fixed carbon, ash, volatile matter, moisture, fluidity, free swell index, and average reflectance. These specifications are important to the project because they change when raw coal is processed. These specifications will be explained, and a description of how they relate to the project will be provided.

1.3.2.1 Ash (Raw and Clean)

Simply stated, ash is the mineral constituents within coal that will not burn and remains behind after combustion. Raw ash is the amount of ash in raw coal; clean ash represents the ash that remains in coal that has been processed in the wash plant.

Raw ash is a function of the amount of mineral content deposited with the coal. Clay bands and partings within the coal are contributors to raw ash content and are related to the depositional environment of the coal. Geological deformation of the coal through faulting and folding also increase the amount of raw ash within the coal. The nature of the ash within raw coal can have a great effect on how much of it can be removed through washing. If a coal blend includes a high proportion of coal with a high raw ash content, it will be difficult to run the plant efficiently and still achieve target specifications for clean ash. Dilution in the pit can also increase the amount of raw ash delivered to the plant. While larger rocks that dilute the coal are separated at the breaker, smaller particle dilution from host rock composed of shales and clays that reach the plant and must be removed through the processing (washing) of the coal.

Clean ash is the ash content of the coal after it has been washed in the processing plant. Desired clean ash parameters are usually set out in the commercial terms of a contract with customers, and so can vary from customer to customer. It also varies with the rank of the coal. It is important for coal producers to achieve results as close to the desired clean ash content as possible to ensure the maximum value for their coal. If the ash is lower than specified for the customer, value is lost as the carbon that goes out in place of the ash does not receive appropriate value. If the ash is higher than what has been specified, the producer will receive a price penalty because the customer is receiving less carbon than was stipulated in the contract. Opportunity losses for shipping out coal with too high an ash content occur on the shipping side, as the transportation charges are the same for less actual product – that is, the producer is paying for the shipping of additional ash, rather than carbon.

Not only is the amount of ash in the clean coal product important, the chemistry of the ash is critical to the coke makers because the chemistry (specifically the alkalinity) can affect the quality of the coke that gets produced from it. As this project was conceived primarily on the level of ash in the raw coal, it is important to understand how the raw ash will affect the final product.

1.3.2.2 Moisture

Excessive moisture content in the clean coal provides opportunity losses similar to ash on the customer and shipping side as moisture content above contractual specifications results in pricing penalties for the producers, and excessive shipping costs for shipping the extra moisture (that could be coal). This opportunity cost does have an inverse as water can be added to coal with moisture content below that specified in a contract, which can add significant value to the coal (the input costs for adding a tonne of water are a lot less than those for a tonne of coal).

Raw coal has a lot less moisture than coal that is processed in the plant, and in this project, the inclusion of raw coal is used to control the moisture in the final product.

1.3.2.3 Sulphur and Phosphorus

The content of sulphur and phosphorus in coal is important because these chemicals have an impact on the final quality of the steel ultimately produced with the coke that has been made from the coal – higher concentrations of both create weaker steel, and it is not always easy for the steel makers to remove these chemicals during their production process. It is much easier to handle these chemicals if they are in low quantities within the feedstock. Additionally, these elements – particularly sulphur – can have negative environmental impacts if they are included in too high of quantities within coal.

Fortunately, the coal in question has low values for sulphur and phosphorus and the content of these substances should not pose a problem.

1.3.2.4 Yield

The yield for any particular coal seam is a measure of how much clean coal is produced based on the amount of raw coal input. It is calculated as a ratio of raw tonnes to clean tonnes and is presented as a percentage. Yield is extremely important because it determines the amount of raw coal feed that is required in order to achieve a specific clean coal production target. Each seam mined has its own associated plant yield, and knowing the yield of each seam in the blend helps determine the required amount of raw input from each seam required to produce the clean blend. If raw coal can be included in the final product, the overall yield of the coal will increase; more clean coal is produced from the same raw coal input.

1.3.2.5 Rank and Volatile Matter

The definition of coal rank has been described above based on carbon content. However, for the purposes of determining the rank for coking purposes, it important to determine the precise rank for each coal being included in a coal blend. There are two tests for determining the rank of coal; one determines the amount of volatile matter within a sample, and the second uses reflected-light microscopy to determine a parameter called reflectance ($\bar{R}o_{max}$). The relationship between volatile content, $\bar{R}o_{max}$, and rank is shown in the following table, adapted from Pearson (1980, p. 4).

Table 1-1: Rank categories based on volatile matter and reflectance

Ro_{max}	Volatile Content*	Rank
<0.50%		Sub-bituminous
0.50-1.12%	>31%	High-volatile Bituminous
1.12-1.51%	22% - 31%	Medium-volatile Bituminous
1.51-1.92%	<22%	Low-volatile bituminous
1.92-2.50%		Semi-anthracite
>2.50%		Anthracite

*dry, mineral matter free (dmmf) basis

While volatile content is the easier of the two parameters to determine, it is important to know both, as variations in the actual composition of the coal can cause some deviations from the prescribed ranges. Reflectance is an independent variable that is superior to volatile matter yield as a rank parameter (Pearson, 1980, p. 4).

The volatile matter content and reflectance of the coal determines into which final clean coal products the raw coal can be included.

1.3.2.6 Fluidity

Fluidity, or plasticity, is a measure of how fluid the coal becomes when it is heated, as it would be in a coke oven. Fluidity is an important parameter for determining how a coal is going to behave within a coke oven, and therefore the customer needs to know what the fluidity of the coal blend being sold to them is so that they can appropriately blend it to achieve the optimum fluidity required for their coke ovens.

1.3.2.7 Free Swell Index and Dilatation

Free-swell index (FSI) and dilatation are both measures of how the coal shape changes when it is heated. FSI is determined under rapid increases in heat while dilatation is tested for under slow, constant heating.

Each coal receives an FSI value corresponding to the profile of the sample button after it is rapidly heated. The final profile of the sample is compared to a scale of profiles to determine an FSI value between zero and nine, with higher numbers corresponding to better coking coals. FSI is a measure of the extent that coal will agglomerate when heated, and coal that does not agglomerate cannot be used for coke production.

Dilatation is determined when the coal is heated slowly, more closely mimicking the heating profile found in coke ovens. Dilatation is important when making coke because it determines the behaviour of the coal in a coke oven through the entire temperature range experienced in the oven. It determines at what temperature the coal will contract when heated, how much it will expand, and the temperature of maximum expansion.

Coke makers need to know these two properties so that they can predict the behaviour of the coal in the coke oven, and blend for optimum specifications for the proper operation of their coke ovens to yield the best coke product.

1.3.2.8 Coke Strength after Reaction and Stability

Coke Strength After Reaction (CSR) is one of the most important coal specifications to potential customers as it is a measure of how well coke made from the coal will stand up to the high temperature conditions found inside of blast furnaces. CSR is a measure of how resistant to breakage the coke is after it has been reacted in a carbon monoxide environment at a temperature of 1,100 °C (Ryan & Price, 1992). This is a much better reflection of the strength of the coal than other tests that determine the resilience and resistance to breakage under cold conditions. CSR tests approximate the actual conditions within a blast furnace because it is impossible to determine how the coke is actually performing during blast furnace operation.

Coals with high CSR values are very attractive to steelmakers because if coal with a higher CSR is used to produce the coke, more lower-cost PCI coal can be substituted for coke in the blast furnace, reducing overall raw material costs for steel producers. Consequently, coals with lower CSR are not as attractive and the market price is devalued accordingly.

Both stability and CSR are a measure of the percentage of coke that stays above a threshold size fraction after the testing is complete. It will be important to understand whether the inclusion of raw coal in a product blend will affect the strength or stability of the coke that is produced from it because this will ultimately determine the attractiveness of the product in the market place.

1.3.3 Coke Making

Coke is produced when coal is heated in an oxygen-free environment. The coal liquefies and the volatile matter is liberated. In more modern coke ovens, the volatile matter is captured and can be used as a source of fuel. The coal liquid solidifies as a hard, porous substance that is primarily carbon.

Coke ovens are typically banks of tall, narrow ovens that are separated by refractory bricks, and each oven shares a heating flu with the adjacent oven. Heat is transferred through the bricks, and the coal is heated from the outside of the oven through to the centre. Temperature brought up to approximately 1,200°C within the ovens and carbonization is considered complete once the coke reaches this internal temperature. The process takes between 18 and 24 hours. Hydraulic arms then push the coke from the ovens and the coke is cooled using either a wet- or dry-quench process. From the American Iron and Steel Institute (AISI) website, Valia (n.d.) provides an excellent description of the process that takes place inside of a coke oven:

> *"The coal-to-coke transformation takes place as follows: The heat is transferred from the heated brick walls into the coal charge. From about 375°C to 475°C, the coal decomposes to form plastic layers near each wall. At about 475°C to 600°C, there is a marked evolution of tar, and aromatic hydrocarbon compounds, followed by resolidification of the plastic mass into semi-coke. At 600°C to 1100°C, the coke stabilization phase begins. This is characterized by contraction of coke mass, structural development of coke and final hydrogen evolution. During the plastic stage, the plastic layers move from each wall towards the center of the oven trapping the liberated gas and creating in gas pressure build up which is transferred to the heating wall. Once, the plastic layers have met at the center of the oven, the entire mass has been carbonized."*

One of the other parameters that bear mentioning is the gas pressures that develop within the coke ovens during the coking process. The specifications of coal used to charge the coke oven have a direct bearing on these pressures, as some coals can develop excessive pressure that can cause damage to the brick between the ovens. The brick is only friction-fit together, and excessive pressure or swelling of the coal during the coking process can not only damage the walls, but also make it difficult to push the coke out of the oven when the process is complete.

In addition to having sufficient CSR, it is also desirable that coke be of a large size fraction with very few fines. This is to aid in the movement of gases through the coke inside the blast furnace. Not only does it allow the movement of gases up through the furnace, it also allows the liquid metal to permeate down through the mixture as it is produced from the reduction of iron. It is possible that the inclusion of raw ash in the coke blend may affect the size fraction of the coke produced, as raw ash particles may create points of weakness in the coke along which fracture lines can develop, reducing the average size of the coke lumps.

Typical physical and chemical parameters for coke in a large blast furnace appear in Table 1-2.

Table 1-2: Coke characteristics for a large blast furnace (Source: Valia [n.d])

Physical: (measured at the blast furnace)	**Mean**	**Range**
Average Coke Size (mm)	52	45-60
Plus 4" (% by weight)	1	4 max
Minus 1"(% by weight)	8	11 max
Stability	60	58 min
CSR	65	61 min
Chemical: (% by weight)		
Ash	8	9.0 max
Moisture	2.5	5.0 max
Sulfur	0.65	0.82 max
Volatile Matter	0.5	1.5 max
Alkali (K_2O+Na_2O)	0.25	0.40 max
Phosphorus	0.02	0.33 max

1.3.4 Steel Making

Coke is a necessary ingredient in the production of iron and steel. Combustion of the coke in the blast furnace provides two things to the process – heat, which is required to sustain the process, and a source of carbon to reduce iron ore (iron oxide) in order to produce molten iron.

Alternating layers of coke and iron ore enter the top of the blast furnace, which can vary from 25-50 metres in height. Limestone is mixed in with the iron ore to act as a flux for the reaction. Extremely hot air (>1,000°C) is blown in through the bottom of the furnace to facilitate the reaction. As the alternating layers of coke and ore fall through the furnace, the hot air facilitates the reduction reaction, liberating oxygen from the iron ore and combining with the carbon in the coke to produce carbon dioxide and molten iron metal. Since the reaction is endothermic, heat needs to be added to sustain it. The primary source of heat comes from the combustion of the carbon in the coke. A secondary heat source is the PCI coal that is blow into the bottom of the blast furnace specifically for the production of heat. Molten iron and slag are recovered at the bottom of the furnace, and the iron is cast as pig iron for further processing into steel. Figure 1-2 shows a cross section of the blast furnace, illustrating the processes that occur inside of it.

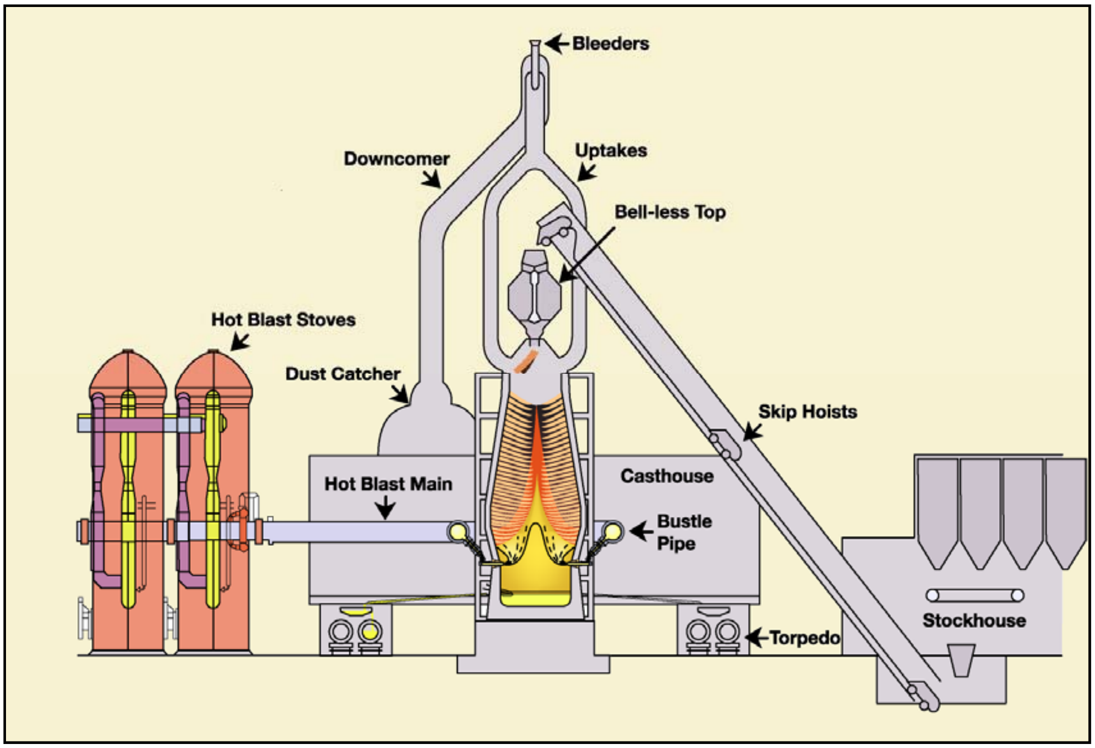

Figure 1-2: Blast furnace diagram (Source: Teck stock diagram; used with permission)

1.3.5 Oxide Coal

Coal within a deposit that reaches the ground surface, either by faulting for at a coal sub-crop, is subject to oxidation due to its proximity to the surface and exposure to air. The oxidation of coal negatively affects the coking abilities of metallurgical coal and therefore is undesirable in coal used to make coke. Extensive sampling is required where coal has the potential to be oxidized to ensure proper separation of the oxide coal from the metallurgical coal. Oxide coal retains the same basic physical properties of its metallurgical equivalent (ash, volatile matter, carbon content, etc.), but its ability to be coked is compromised. Oxide coal is still useful for its thermal properties, either in thermal coal or occasionally in PCI blends. It is extremely important that the oxide coal stays separate from the metallurgical coal because even small amounts of oxide coal can ruin a metallurgical coal blend, reducing the value of otherwise good coking coal.

Oxide coal is important, as the use of raw 010-seam oxide coal as fuel for the dryer is what first raised the question about whether or not the 010-seam coking coal could be added to the coal products as raw coal.

2: MARKET ANALYSIS

The coal market that Teck resides in is the seaborne metallurgical coal market. This market is concerned with supplying the steel industry and thus as the global steel industry goes, so does the coking coal industry. It is important to understand the market for coking coal for a variety of reasons as it is going to dictate the principle economic driver for this project – reducing cost to increase margins and gain a competitive advantage, or increasing production to sell more coal and increase revenue. Essentially, which market conditions are favourable for this project, and which market conditions are not.

In order to assess the potential, the history of the market will be reviewed to establish trends with supply and demand that will help assess the current market. These trends will then be examined in the context of Porter's five forces for the metallurgical coal industry to determine the basis for the strategy.

2.1 Supplier Landscape

There are only a few deposits worldwide currently producing bituminous coal with sufficient qualities for use in steel making. In addition to Western Canada, coking coal is produced out of the Appalachian region of the United States (USA), the Bowen Basin in Queensland, Australia, Indonesia, and the Shanxi province in China. Additional production comes from other countries including Russia, and Poland. China is by far the largest producer of coal and accounts for almost 49% of all worldwide hard coal production, including steam coal (World Coal Association [WCA], 2010, with data from International Energy Agency, 2010).

2.1.1 Current Coking Coal Supply

Coking coal is relatively scarce when compared to the total coal production in the world. The following Table 2-1 shows where Canada (14th) ranks with the top ten hard coal producers (does not include lignite) in the world, and further breaks down how much of each country's' production is exported, and what proportion of that export amount is coking coal. It should also be noted that although both India and China produce coking coal, it is all consumed domestically and both countries still import additional coking coal. Steam coal is included in Table 2-1 to illustrate the relative rarity of coking coal.

Table 2-1: Global Hard Coal Production and Exports

Country	**Hard Coal Production**	**Export**			**Rank (Coking)**
		Total	Steam	Coking	
China	2,971	**-**	-	-	-
USA	919	**53**	20	33	2
India	526	**-**	-	-	-
Australia	335	**259**	134	125	1
Indonesia	263	**230**	200	30	3
South Africa	247	**67**	66	1	7
Russia	229	**116**	105	11	5
Kazakhstan	96	**19**	19	-	-
Poland	78	**9**	7	2	6
Columbia	73	**69**	69	-	-
Canada*	52	**28**	7	21	4

*Canada ranks 14th in the world based on total coal production

All values in millions of metric tonnes (Mt)

2009 Data compiled from World Coal Association, Canadian Coal Association, Poland.pl, and Ignatov

The total metallurgical coal export market represents over 232 million MTCC per year (2009), with Teck Coal supplying 21 million MTCC, or approximately 9% of the total market. Greenhills contributed 4.1 million MTCC to the Teck total.

2.1.2 Future Supply

Despite coal reserves that are capable of providing the world energy needs for another 119 years (WCA, n.d.), coal with the necessary specifications for making coke are relatively scarce and most deposits are already producing. There are additional known deposits of coking coal in Russia, Indonesia, Mozambique and Mongolia. However, these new supply sources are still several years from producing their maximum potential as they present logistical challenges due to their geographic locations. There are also political sensitivities in Mongolia that could lead to delays in developing projects there.

The other option for increasing the supply of coking coal is the expansion of already existing operations. Teck Resources is planning expansions at five of its six coal operations, as well as reopening the Quintette mine in northeastern BC, which has been closed since 2000. Overall, total expansions at Teck are planned to push coal production over 30 million MTCC per year in 2013 (Teck Resources Ltd. [Teck], November 2010).

Current expansion plans at Greenhills are scheduled to increase coal production from the current 4.1 million per year up to 5.0 million MTCC (based on 100%). This expansion includes additional equipment and plant upgrades to handle the increased fines that are a result of the mining of 010-seam coal. The aim of this project is to determine whether the raw coal can be included in the final product to either increase production, or reduce costs while maintaining production levels.

2.2 Demand Considerations

The primary driver of demand for coking coal is the production and consumption of steel worldwide. Coking coal is used to make coke, a key ingredient in the production of pig iron, which in turn is required to make steel. According to the World Coal Association, it takes approximately 0.6 tonnes of coke to produce one tonne of steel, and that 66% of all global steel production is produced via processes that require coke as an input (WCA, n.d.).

Steel consumption is largely driven by economic growth and development, and there are no players that are as dominant as China on the world stage. China is currently experiencing rapid growth and development as the country urbanizes and more and more citizens move into urban centres. According to CLSA - Asia-Pacific Markets (CSLA, as cited by Teck Resources Ltd., 2010), in 1985 there were 22 cities in China with populations greater than one million people. By 2009, that number had grown to 154 cities. This represents an annual urbanization of over 15 million people per year, which equates to massive infrastructure improvements and construction in urban areas. Table 2-2, produced by the author with data from World Steel Association (World Steel Association [WSA], 2011, p. 2) shows the worldwide steel production by country, indicating China's immensity when compared to other steel producing nations. China is responsible for over 44% of the worlds steel production per year.

Table 2-2: 2010 Worldwide Steel Production

		2010 Production		YOY Growth					2006-2010 Growth
Rank	Country	Mt	% of World	2010	2009	2008	2007	2006	
1	China	626.7	44.3%	9%	15%	2%	17%	19%	50%
2	Japan	109.6	7.8%	25%	-26%	-1%	3%	3%	-6%
3	United States	80.6	5.7%	38%	-36%	-7%	-1%	4%	-18%
4	Russia	67.0	4.7%	12%	-12%	-5%	2%	7%	-5%
5	India	66.8	4.7%	6%	9%	8%	8%	8%	35%
6	South Korea	58.5	4.1%	20%	-9%	4%	6%	1%	21%
7	Germany	43.8	3.1%	34%	-29%	-6%	3%	6%	-7%
8	Ukraine	33.6	2.4%	12%	-20%	-13%	5%	6%	-18%
9	Brazil	32.8	2.3%	24%	-21%	0%	9%	-2%	6%
10	Turkey	29.0	2.1%	15%	-6%	4%	11%	11%	24%
11	Italy	25.8	1.8%	30%	-35%	-3%	0%	8%	-18%
12	Taiwan, China	19.6	1.4%	23%	-20%	-5%	4%	6%	-2%
13	Mexico	17.0	1.2%	21%	-19%	-2%	7%	1%	4%
14	Spain	16.3	1.2%	13%	-23%	-2%	3%	3%	-11%
15	France	15.4	1.1%	20%	-28%	-7%	-4%	2%	-23%
16	Canada	13.0	0.9%	40%	-37%	-5%	1%	1%	-16%
	Others	158.1	11.2%	15%	-21%	-7%	3%	6%	-12%
	World	**1,413.6**	**100%**	**15%**	**-7%**	**-1%**	**8%**	**9%**	**13%**

In order to ensure sufficient steel production to support this massive move to urbanization, China is consolidating its steel industry and moving capacity to the coastal regions. This allows them to build additional capacity and assures that it will have access to the seaborne coking coal market. China does have internal coking coal reserves, but they are not sufficient to sustain the current growth that China is experiencing. According to Table 2-2, China's steel industry is now 50% larger than it was 5 years ago (and 77% larger if you go back six years). Between 2003 and 2004, China changed from being a net exporter of metallurgical coal to being a net importer. In the past, China also produced enough coking coal domestically to sustain a substantial coke exporting market (see Figure 2-1). In 2009, China's demand for coal and coke increased so substantially that even the export of coke had ceased, and net imports of coking coal were 35 million MTCC from the seaborne market in 2009 (WCA, 2010).

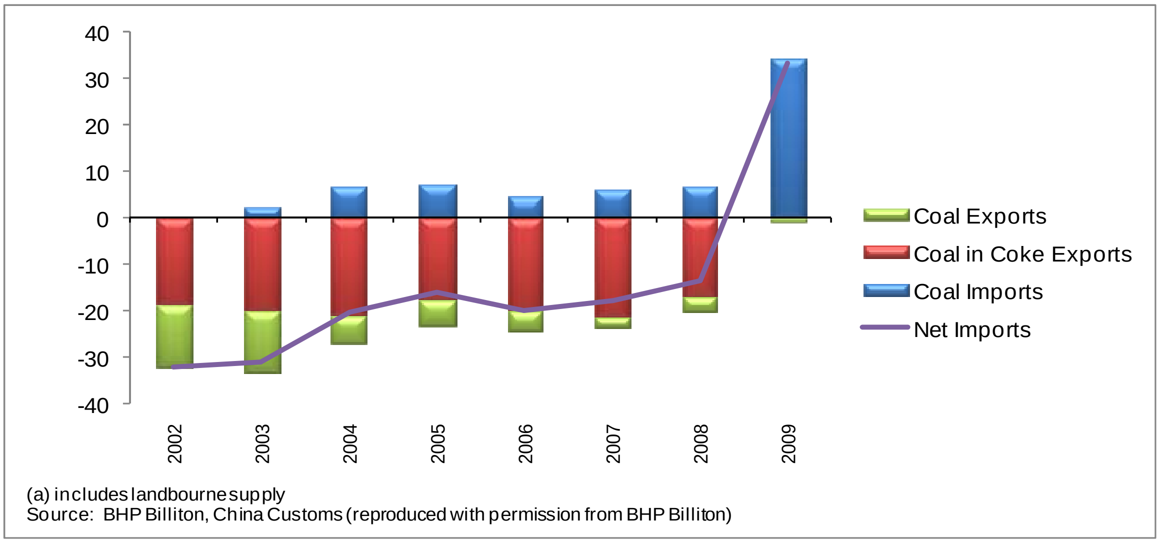

Figure 2-1: China's Coal Imports and Exports Balance

This change from net exporter to net importer has made China the number two player in the world import market. Major coking coal importers appear in Table 2-3 (WCA, 2010).

Table 2-3: Major Coking Coal Importers 2009

Country	Imports (Mt)
Japan	52
China	35
India	23
South Korea	21
Germany	6
UK	5
France	4
Taiwan	3

India, although lagging behind China in its position on the urbanization and growth curve, is also experiencing rapid urbanization and growth. Over the same period that China saw a 50% increase in steel production, India experienced a 35% growth and is currently the third largest importer of coking coal.

Based on the current information and forecasts, the demand for coal does not look to be diminishing any time in the near future and producers are going to struggle to keep up with capacity.

2.3 Coal Pricing

Overall, the world has experienced 13% growth in steel production over the past five years, without the equivalent growth in the export coal market. Over the same time, coal prices have seen a lot of volatility in, as shown in Figure 2-2 – especially when looking at coal prices since Greenhills started production in 1983.

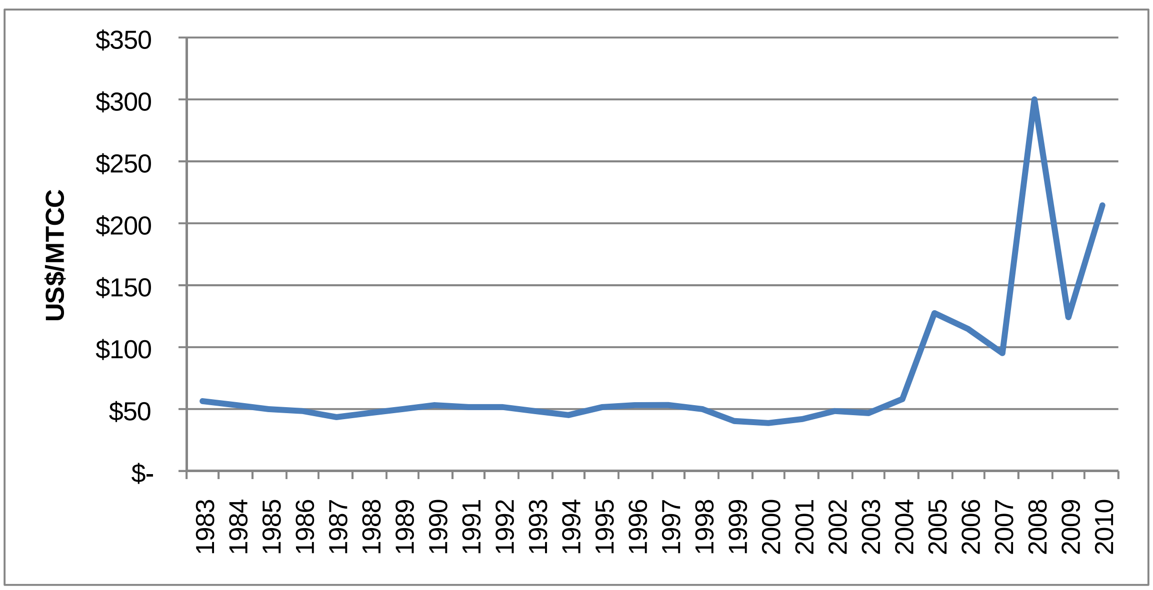

Figure 2-2: Annual Hard Coking Coal Price (figure by author)

When China changed from a net exporter to a net importer of coal, it created a massive swing in the supply and demand balance in the coking coal market. Prior to 2005, pricing had been relatively consistent, with only small changes in price from year to year. This is because the market had been in a state of oversupply for many years. When China started to grow and the market changed to one of undersupply, the value of coal started to rise accordingly, almost doubling in the first year of increased pricing.

The current pressures on the coking coal price are expected to keep the price elevated in the near future. Recent flooding in Australia has severely hampered coal mining in that country, reducing exports from the largest producer. In fact, coal producer Rio Tinto has set pricing for the second quarter of 2011 at a record US$330 per MTCC. Supply will continue to be tight going forward.

2.4 Porter's Competitive Forces

The volatile pricing that the metallurgical coal industry has experienced in the past years can be explained by examining the competitive forces within the industry. In some cases, the changes in the five forces postulated by Porter (2007) have been very dramatic. The discussion relating these forces to the metallurgical coal industry will provide framework for the strategic direction of this project that will be examined in the coming chapters. A diagram of Porter's five forces for the metallurgical coal industry appears in Figure 2-3.

2.4.1 Barriers to Entry

Teck is already a major player in the seaborne metallurgical coal market, and therefore has several advantages over new entrants into the market place. The most important of these advantages is Teck's substantial resource base. While almost every country on the globe has coal reserves of some kind, metallurgical coal is a scarce commodity in the world and there are few remaining undeveloped deposits.

Before the explosive growth experienced in China over the last several years, scarcity of the resource did not affect production potential because production capacity exceeded the demand. In fact, several developed deposits were not operating due to there being more supply than demand. Additional supply was brought on stream when economic conditions were favourable, and the higher cost producers were the first to shutter in when prices fell. Exploration for new deposits was essentially non-existent and the low margins and high capital start-up costs made the industry very unattractive for new entrants.

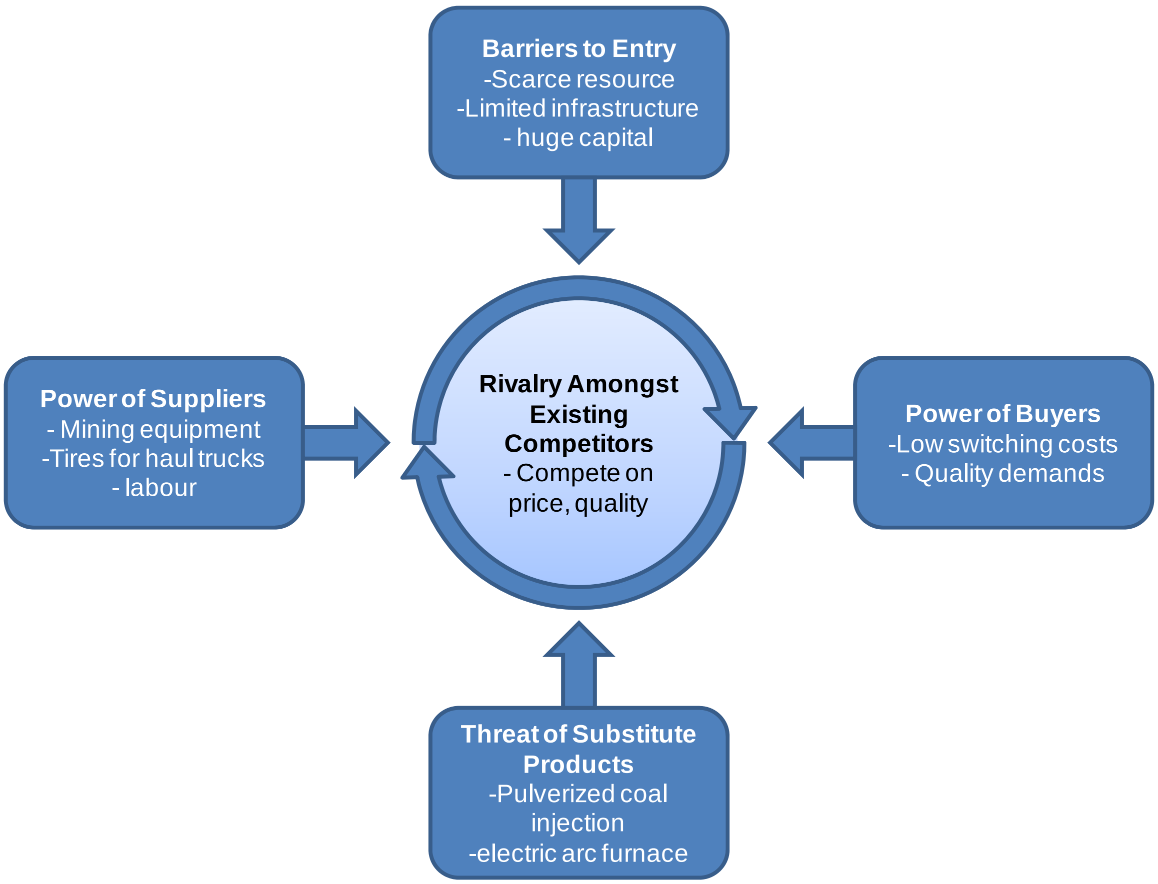

Figure 2-3: Porter's Five Forces Diagram (figure by author, reproduced from Porter (2007))

What this means for this project is that additional production is more likely going to come more from the existing resource base than from anything new, both worldwide and for Teck.

Another important barrier to entry for new producers is the unequal distribution channels described by Porter (2007). When the primary market is the seaborne coking coal market, access to large, deep-water ocean ports that can accommodate large bulk cargo ships is essential. Australian deposits have the biggest advantage, as they are located within a few hundred kilometres of adequate ports. In fact, this proximity to coastal areas, not to mention proximity to the east coast of Asia, has historically been a source of competitive advantage for the Australians. Teck's deposits, approximately 1,100 km from coastal ports, is quite far but the infrastructure is already in place.

New deposits in places such as Mongolia, Russia, Indonesia, and Mozambique are difficult to develop because they are either extremely far from the coast in the case of Mongolia and Russia, or pose other geographic challenges such as jungle and difficult terrain in the cases of Indonesia and Mozambique. There is currently no necessary infrastructure, most notably rail and power, servicing the regions, which presents significant barriers to entry. Again, it is advantageous for incumbent producers such as Teck to increase production utilizing existing infrastructure.

The next barrier to entry is capital. In the past, small margins made it difficult to justify both exploration effort and large capital expenditures in the metallurgical coal business. In the past, necessary capacity was usually brought on-stream by bringing shuttered deposits back into production. This required significantly less capital outlay because infrastructure was largely in place. Today, huge margins and lower interest rates, coupled with easier access to equity markets, ensure that capital would probably be available for new operators if there were deposits to develop. Time is also a consideration as it does take many years to bring a newly discovered deposit into full-scale production, and that presents a large risk in cyclical commodity markets, especially during times of increased volatility. There is no guarantee that demand will remain where it is right now.

Government policies and political stability play an important role for new entrants. Developing a new deposit in underdeveloped nations or in areas of political instability or uncertainty carries numerous risks. A prime example of this barrier is the Mongolian deposit. The size of the deposit and its proximity to China make it an extremely attractive project, but government inefficiency and lack of clear policies have delayed the project from moving forward in recent years. In addition to government fiscal policy, environmental issues are evolving and becoming more stringent for new and existing operators alike. New projects and project expansions face increasing environmental pressures when compared to even the recent past. Governments, the general public, and the investment community scrutinize companies over their environmental performance.

Not only have traditionally low margins kept new entrants out of the market, but it has also kept many existing operators from spending money on expansion. The only producers who could afford to expand were the larger, higher margin producers. These producers were taking advantage of supply-side economies of scale. Increasing the production from lower cost operations put lower cost supply into the market, and higher priced producers were squeezed out. Large producers could also take advantage of these scale economies not only in expanding, but also when the market is contracting – larger, low-cost operations could weather times of economic hardship better than smaller, high-cost producers could.

Of the seven barriers mentioned by Porter, the two that do not play as significant a role preventing new entrants are the demand-side benefits of scale, and customer switching costs. In the past, low customer switching costs was one of the key powers that buyers of metallurgical coal have held over the producers when negotiating price.

2.4.2 Rivalry Amongst Existing Competitors

The competitive framework of the seaborne metallurgical coal industry is an oligopoly, with the top three producers contributing over 57% of the overall market in 2009 (Oreninc, 2010). BHP Billiton has long been the dominant player in the industry, with most of its coal production coming from Australia. As mentioned, Australian producers hold a distinct advantage due to their proximity to adequate ports to serve the seaborne market, resulting in lower transportation costs that have allowed them to enjoy a competitive advantage over North

American producers. In the past, a reference price for coal was set as Free On Board (FOB) port, and the coal customer would pay for transportation. Generally, customers would consume Australian coal production first because of the lower transportation costs, and would then often offer reduced prices to North American customers to compensate for the increased transportation costs. This also made Australian coal more attractive to the Asian marketplace, forcing North American rivals to compete against each other on price. Although the transportation differential still exists, demand outpacing supply and inflating coal prices has rendered price competition moot.

In this type of environment, rivals in the metallurgical coal industry still compete on quality. If a company is able to demand even higher prices because of a quality advantage, they will do everything they can to differentiate the quality of their product versus their rivals. An Australian coal product called Peak Downs has become the quality reference for hard coking coal that will fetch the highest prices in the market place (Platts). Specifications for Peak Downs coal are found in Table 2-4. Other coals are compared to the reference coal and price is reduced accordingly. It is important within this project to understand that pricing competition is based on quality, especially if the quality of coal blends from Teck containing raw coal reduces the price that the coal receives in the market place. It becomes the marketing challenge for rivals to prove why their coal should be priced as close as possible to the Peak Downs pricing.

Table 2-4: Peak Downs Reference Specifications for Pricing (Platts, 2010)

Parameter	**Specification**
CSR	74
Maximum Fluidity	400 ddpm
VM (air dried)	20.7%
Ash (air dried)	9.7%
Sulfur (air dried)	0.70%
Phosphorus (air dried)	0.035%
Total Moisture (as received)	9.5%

2.4.3 Power of Buyers

Before China experienced the huge explosion of economic growth, steel producers, particularly from Japan, wielded substantial power over coal producers. In a market that was oversupplied, they could choose the customers to support. This drove several coal producing companies into bankruptcy because they could not meet the terms specified by the steel makers and therefore could not sell their coal for a profit.

In the current environment, buyers have very little power. Buyers want the good high quality coking coal that they have come to depend on. In the past, when the balance of power rested with them, they could get the coal they required at the prices they dictated. Now, the good quality coke required to operate a modern blast furnace efficiently requires good quality raw materials, so the producer has to pay for the high quality they have come to rely on. If they do not pay the high prices, another producer will, so the relative power has been completely reversed between the coking coal producers and the steel makers.

2.4.4 Threat of Substitutes

While there are no true direct substitutes for metallurgical coal in the production of steel, there are two technologies that help to reduce the amount of coking coal consumed when producing steel. PCI uses lower quality and lower cost coal as a source of heat within the blast furnace, displacing the amount of coke made from metallurgical coal required in the furnace. How much can be replaced depends on the quality of the coke, so high quality coke made from high quality coking coal is desirable as it allows more coke to be displaced within the furnace. In general, one tonne of PCI coal displaces approximately 1.4 tonnes of coking coal in the blast furnace (WCA, n.d.). Electric Arc Furnaces (EAF) are primarily involved with the recycling of existing steel but do present an alternative means of getting steel into the marketplace, but not yet to the extent that they are truly a threat to traditional steel making.

2.4.5 Power of Suppliers

The power that suppliers to the mining industry have vary depending on commodity cycles – not only are suppliers subject to the same cycles, there is intense competition among suppliers, especially for mining equipment. Any power that the suppliers may have relative to mining companies is kept in check through rivalries amongst the suppliers.

However, in commodity market upswings, mining companies usually go through expansions, and when all commodity markets are showing growth (as they have been, with economic growth in China also driving copper, iron ore, zinc, and other products of mining), mining supply companies are impacted because they cannot keep up to the demand for their products. Suppliers, who have ridden the ups and downs of the commodities markets along with the mining companies, know that cyclical growth is fragile and are hesitant to add capacity in the good times because by the time it is brought on stream, the commodity cycles are entering a down cycle. A good example of this is the off-road tire industry – during the economic boom that preceded the crash of 2008, there was a severe shortage of haul truck tires and a lot of productive equipment was unable to operate because of a lack of tires. It took a lot of effort to bring additional tire capacity on stream because new plants would have to be built as the existing plants were at capacity. Tire manufactures eventually consented to build plants and bring on capacity just in time for the world economic meltdown in the summer of 2008.

Another important supplier to producers of metallurgical coal is the labour market. In times of high margins and huge profits, labour groups do hold a lot of power over producing companies. In the past two years, Teck has experienced labour disruptions at two of its six coal mines that have impacted production and reduced the amount of coal produced and sold in the market place. Companies need to keep their employees happy or risk losing them to other mining companies that may be offering something extra to attract new talent.

2.5 Conclusions

Based on the current supply and demand environment, Teck should be able to sell every tonne of coal that it can produce and ship. This will increase the total revenue and increase profits within Teck. If the market were to change and the supply and demand imbalance were to reverse back to what existed in the industry prior to the emergence of China as a net exporter of metallurgical coal, than the reduction of costs associated with the production of coal will allow Teck to be more competitive on price. Both of these scenarios are considered for the project.

3: INTERNAL ANALYSIS

3.1 Coal in Teck

Coal has been one of the products produced by Teck since it first started mining coal at the Bullmoose Mine in Tumbler Ridge, BC. Over the years, it has grown its interest in coal, acquiring the Elkview mine in 1991 and Quitette in 1992. In terms of overall financial impact, the coal business unit has grown the most within Teck in the past several years, from 3.6 million MTCC per year to over 23 million MTCC.

Historically, coal has accounted for around 20% of total revenue for Teck, but now comprises almost 50% of total revenue and profits for Teck. Historical performance for the past fourteen years appears below.

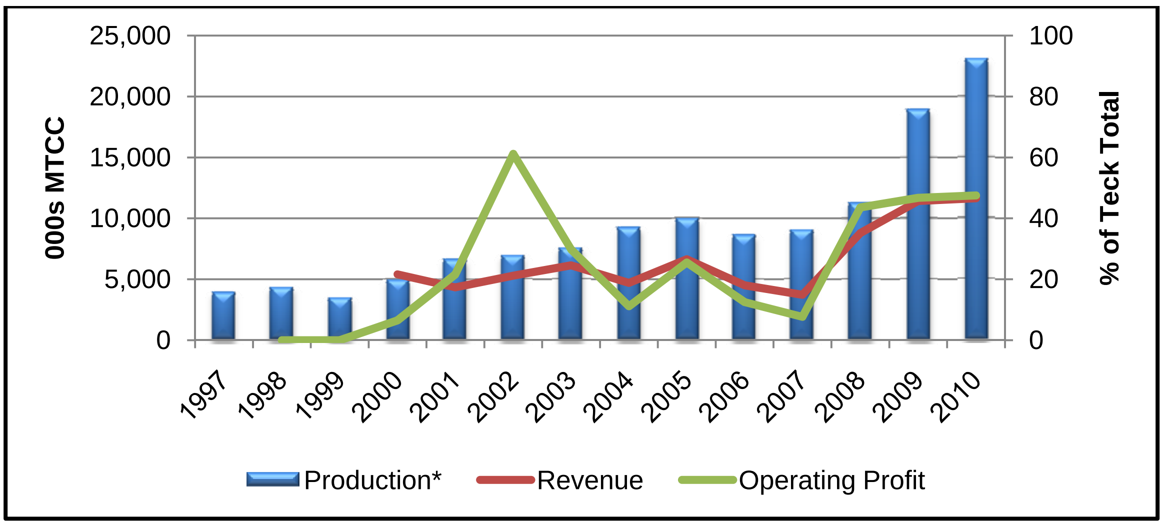

Figure 3-1: Performance of coal within Teck, from annual reports (figure by author)

Teck has stated that it plans to grow its coal production to over 30 million MTCC annual by 2013 (Teck, November 2010). This includes growth at existing operations through low-cost, low-risk incremental improvements, as well as opening an additional mine in BC. This project to include raw coal of a particular seam presents a potential low cost way of increasing the annual coal production capacity from the Greenhills mine.

3.1.1 Coal at Greenhills

The coal produced by Greenhills Operation is high quality hard coking coal. Small amounts of thermal and PCI coal are also produced, but this coal comprises a very small percentage of the overall reserve base. The reserves are contained in many seams, named based on where they occur in the stratigraphic column. A higher number of seam indicates a younger coal with higher volatile and lower carbon content.

3.1.1.1 Mining

Greenhills coal mine is a large open-pit truck and shovel coal mining operation. The mine plan divides the coal deposit into two major pit areas, Cougar North and Cougar South. Greenhills mines each pit in a number of phases in a scheduled sequence so that the different coal seams are available in an order that allows them to be blended to produce consistent products over the life of the mine.

The coal being mined at Greenhills is contained in the Mist formation of South Eastern British Columbia. Contained within this formation are over 30 different coal seams varying in thickness from 1-30 metres. The stratigraphic column can be found in Figure 3-2. The geological formation is a massive synclinal structure (see cross section in Figure 3-3), with most of the mining at Greenhills occurring on the west limb of the syncline. Current reserves at Greenhills will last another 18 years at 2010 production levels (2010 AIF), and exploration occurs on an annual basis in order to convert known resources into additional reserves.

Between the various seams within the formation are inter-bedded shale, sandstones, siltstones and mudstones of various thicknesses. The phases of each pit are mined in benches that are 15 metres high, the height chosen because it matches the physical capabilities of the equipment used to mine the waste and coal. The strata within the mine are dipping at around 32 degrees, allowing each bench to have several different seams available for mining. As mining progresses deeper into the pit, the pits get smaller and there is less variety of coal seams available for mining.

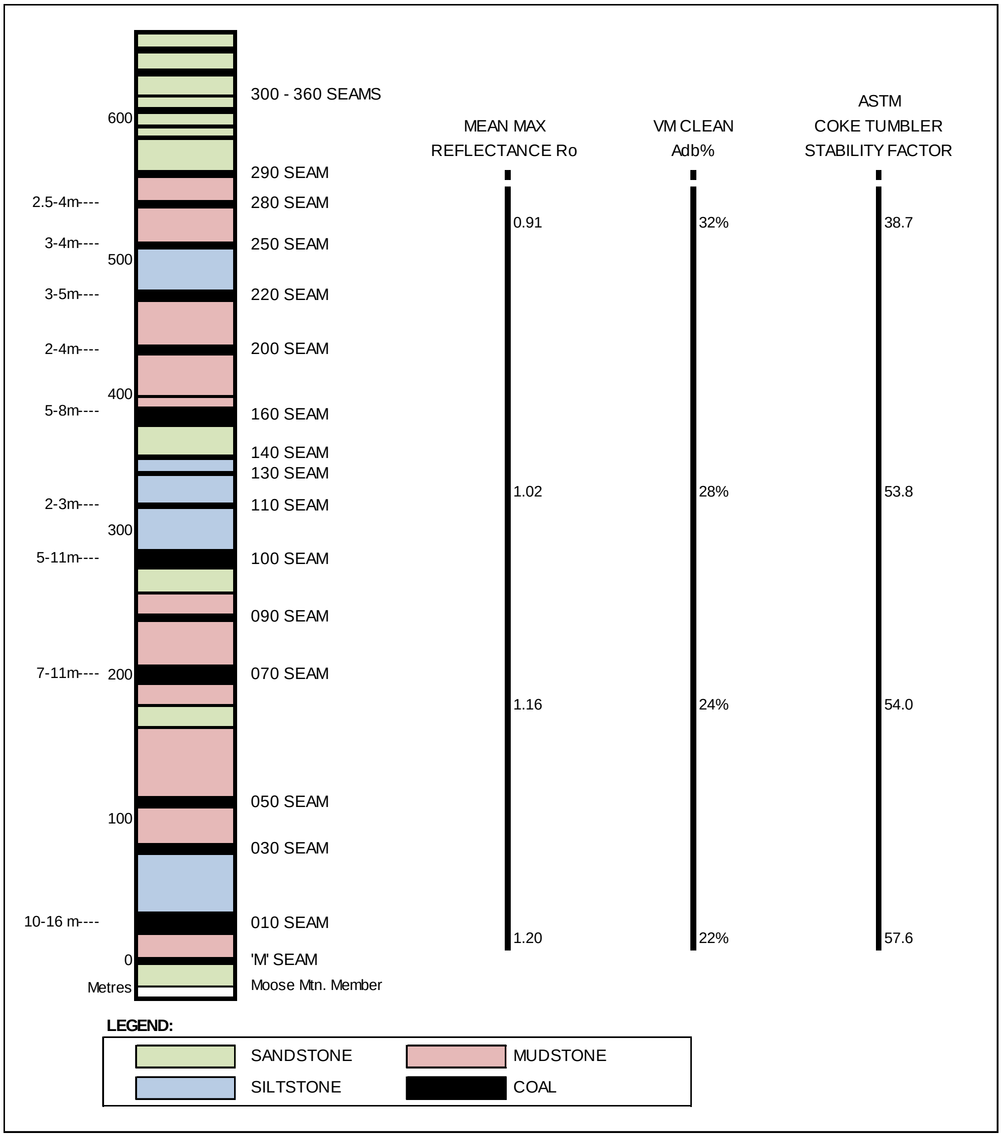

Figure 3-2: Coal Seam Stratigraphy at Greenhills (figure by author)

Mining starts with the drilling and blasting of the waste rock. Large electric cable shovels then dig the waste rock, loading it into haul trucks that move the waste to a spoil. The waste rock immediately above a coal seam is removed using a bulldozer, or in some cases, a track hoe is used. Once the waste rock is removed from on top of the coal, the coal itself is pushed to the floor of the bench. Care is required in removing the waste from on top of the coal, and then when removing the coal, to minimize the contamination and dilution that occurs when rock is mixed with the coal. This dilution increases the ash of the coal as well as reducing yield.

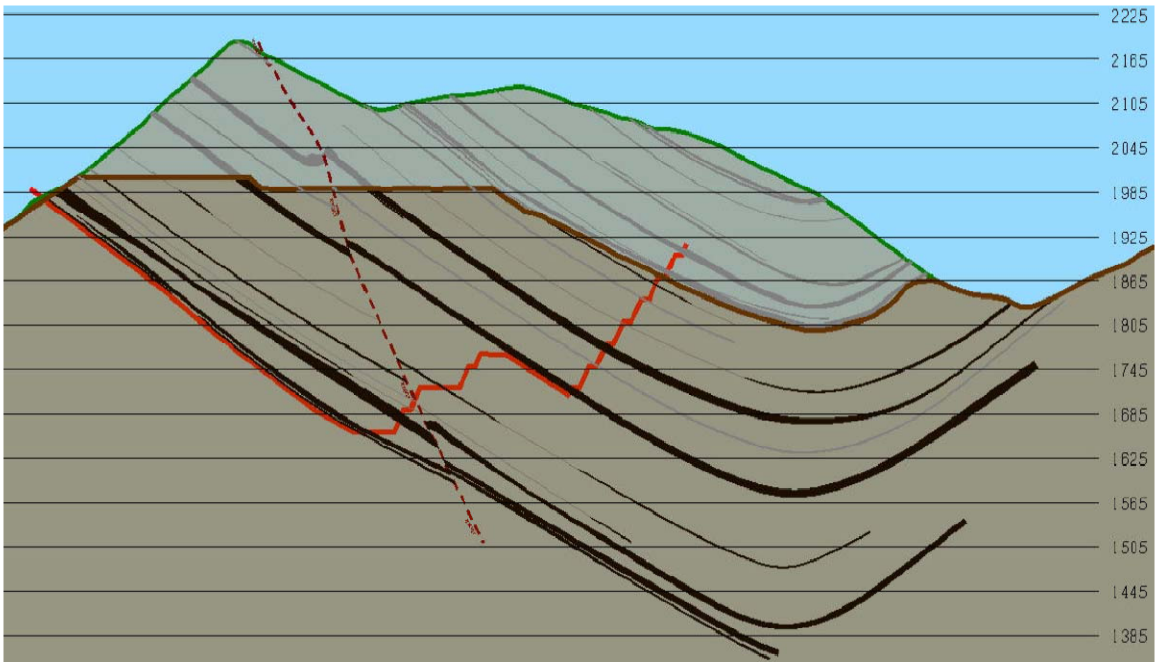

Figure 3-3: Typical Greenhills Cross-Section (Source: Teck; used with permission)

The coal is then loaded onto haul trucks and hauled to the breaker stockpile locations in the mine. Coal from the breaker stockpiles is trammed into the breaker to size the coal (see below). It is important that the appropriate amount of each coal seam be added to the breaker as the ratio of the different types of coals blended at the breaker determine the end product specifications. Once the coal has been trammed into the breaker, it is ready to be processed. Coal that has not been processed is considered raw coal.

3.1.1.2 Processing

The processing of coal is necessary to remove all foreign rock and debris contained within the raw coal. Rock in coal degrades the quality of the coal and seriously reduces the quality of the coke made with the coal.

The first step in the processing of raw coal is to size the coal appropriately by passing it through a large screen called a grizzly to remove large oversized rock that has contaminated the coal, and then a breaker to break up the larger lumps of coal. The breaker is a large drum, 12' in diameter and 27' long, with 2" diameter holes openings. Large coal pieces break up as the drum rotates and eventually pass through the openings while the rock pieces stay intact and exit the end of the drum as breaker reject. The coal is then carried 2.6 km via conveyor belt to the raw coal silos. The purpose of the raw coal silos is to buffer the feed to the plant so that the feed rate into the plant is constant when the feed into the breaker can vary due to delays such as lunch breaks, equipment problems, etc. A shorter conveyor then transfers the raw coal from the silos into the processing plant.

The raw coal enters the wash plant, is mixed with water, and passed through several sieve bends in order to separate the coarser particles (>1mm) from the fine particles (<1mm). The particles that do not pass through the sieve bend are then passed over deslime screens where water nozzles spray the particles, washing the fines through a screen. The fines from here join with the fines separated in the sieve bend, while the coarse stays above the screens and moves into the rest of the coarse coal circuit.

The coarse coal circuit is also referred to as the heavy media circuit because magnetite is added to the circuit in order to raise the density of the water above the density of the coal. This causes the coal to float in the heavy media while the higher-density rock particles sink to the bottom. The coarse raw coal passes through heavy media cyclones where the coal particles exit the top of the cyclone and the rock particles exit from the bottom of the cyclone as rejects. Any magnetite in the coarse rejects is recovered before the coarse rejects travel to the coarse reject bin to be hauled away. The coarse coal continues into another bank of sieve bends that help to remove magnetite from the coal. Additional magnetite is washed from the coarse coal as it passes over more screens. The last process in the coal circuit is the centrifuges before the coarse coal is added back to the fine coal and is mixed before entering the dryer. Coarse coal entering the dryer has a moisture content of around six percent.

The fine particles move from the deslime screens into several cyclones, where the lower-density coal particles exit at the top of the cyclones as the overflow and the higher density fines pass through the bottom as the underflow. The underflow passes through more sieve bends before entering the spiral separators. The speed of material passing through the spiral separators is varied to control the ash content of the material that is separated out. High ash material is dewatered on screens and passes to the reject bin. Overflow from the cyclones containing fine coal moves into the first of two fine coal flotation circuits.

Fine coal flotation is a froth flotation process that occurs in two stages, separating the fine coal particles from the finer ash particles. A flocculent is added to the fine coal slurry to make the coal particles hydrophobic so they will not attach to water. A frothing agent is added to the slurry to create bubbles. The hydrophobic coal is attracted to the air bubbles, and therefore attaches to the air bubbles and rises to the top of the floatation cell. Non-coal particles do not behave this way in the slurry and leave out of the bottom of the float cell. The fine coal flotation circuit currently limits the throughput of the Greenhills plant when feeding a blend containing 50% fine coal, but plant upgrades in 2011 should alleviate that bottleneck.

Overflow from this flotation is captured and sent to the clean coal thickener where the coal settles out so that much of the water can be removed. Thickened clean coal is then filtered, dewatering the coal through mechanical means. Clean coal from the filters is added to coal from the coarse coal circuit and then all clean coal enters the dryer. At this point, the fine coal has a moisture content over sixteen percent. Approximately 25% of the product entering the dryer comes from the coarse coal circuit, with the remainder coming from the fine circuit.

Another conveyor transports the clean, wet coal to the dryer. Heat in the dryer comes from the combustion of coal and natural gas, and the excess moisture evaporated from the coal, reducing the overall moisture of the coal to 8.5% or less to match the required specification. After it is dried, the coal is stored in the clean coal silo, where it is available for immediate loading onto train cars, or it is placed in the clean coal stockpiles near the rail line where it can be reclaimed and loaded on rail cars in the future.

3.1.1.3 Logistics

Once coal processing is complete, the clean coal is loaded on rail cars and taken over 1,100 km to one of three ports. At the port, the rail cars are dumped and the coal is moved around the port via a network of conveyors and reclaimers, and is loaded directly onto a vessel or is placed into stockpile. Rarely is the coal from one individual mine loaded onto a train exclusively, and coal from Greenhills gets blended with coals from other mines in order to meet the specifications required by the different customers. Most coal contracts are priced Free On Board (FOB) Vancouver, so coal vessels are arranged by the customers.

3.1.1.4 010-Seam

010-seam coal is a seam of hard coking coal that is mined at Greenhills. The seam is at the bottom of the stratigraphic column, indicating that it is the oldest seam mined at Greenhills in terms of geological age. It is subsequently one of the highest rank coals, with volatile matter and $\bar{R}\mathrm{o}_{\mathrm{max}}$ values placing it in the medium-volatile bituminous category, as per Table 1-1. Currently 010-seam coal represents a substantial portion of Greenhills overall reserves, at approximately 40% in 2010. Additional fine coals related to 010-seam coal bring the total reserves of fine coal to around 50%.

010-seam coal is an extremely good coking coal, producing coke with high CSR values. It is desirable for its low ash coal values and it achieves very high yields when it is processed. The low sulphur and phosphorus values contained within also make it attractive to steel makers. The seam is very thick when compared to the other seams at Greenhills, varying between 10 and 30 metres in thickness. The thickness of the seam allows the coal to be mined with little dilution and virtually no contamination, keeping the raw ash low and the yield high. It is important that all of Greenhills coal blends contain at least 50% fine coal to ensure reserves of coarser coal are not consumed ahead of the fine coal. This would leave only fine coal to process at the end of mine life.

Despite is excellent chemical properties and coking abilities, the concern with 010-seam coal at Greenhills is that it is also extremely fine. Through the mining process, as the coal is pushed down to the floor of the bench by dozer work, the coal becomes very fine and difficult to handle. In this fine state, it exhibits almost fluid-like behaviour and is easily wafted into the air to produce black clouds of dust that can affect visibility and air quality.

In the wash plant, the increased amount of fines added by the inclusion of 010-seam coal in the blend reduces the efficiency of the plant operation. The fine circuit quickly reaches its maximum capacity, and the plant needs to slow down in order to maintain recovery of the fine coal. If the plant does no slow down, good coal overflows the circuit and is sent to the tailings pond, reducing yield. When the plant is processing a blend with 50% fine coal feed, input to the plant is reduced by over 25% of maximum feed capacity. Offsetting this slightly is the high yield of 010-seam coal, and increasing the quantity of 010-seam coal also increases overall yield of the coal blend, so the total output of the plant is reduced by 16%.

Exploration and sampling data obtained on 010-seam coal, as well as the average of sampling efforts during production, provide an overall average raw ash quantity to be used in all blending calculations. In reality, the raw ash of 010-seam coal varies quite substantially in the different areas of the mine. In-situ (unmined) raw ash for 010-seam can vary from a very low 5% raw ash, up to around 25% raw ash. 010-seam with ash content above this level is classified as a different raw product for the purposes of blending. Overall, the average raw ash content for 010-seam coal is 18%.

3.1.1.5 010-Seam Oxide

The potential to use screened 010-seam coal was first piloted on 010-seam oxide coal at Greenhills. 010-seam oxide cannot be cleaned in the plant because oxide does not process the same way as metallurgical coal, and the fine oxide coal would all be removed and sent to the tailings pond. However, for the areas that have low enough ash, the coal is screened to remove the large rock particles and the raw oxide coal is transported down to the plant for use in the dryer.

The question that arose from this situation was whether the same thing could be accomplished with the 010-seam metallurgical coal in order to increase production at Greenhills.

3.2 Sustainability

Teck Resources Limited is committed to sustainability as a core value. Teck understands that their “success depends on the efficient use and stewardship of natural resources and protection of the environment” (Teck, 2011). This includes minimizing environmental impacts and reducing greenhouse gas emissions through energy efficiency improvements. A project such as this one provides an excellent opportunity to achieve that end, improving the efficiency of the drying process by reducing the amount of coal burned in the dryer per tonne of clean coal production.

Heat in the dryer at Greenhills is primarily provided by the combustion of coal, although natural gas can be used as well. Coal is the fuel of choice as it provides heat more economically than natural gas. The downside of using coal is that it is a lot less environmentally friendly – by-products of coal combustion include carbon dioxide, oxides of nitrogen, and oxides of sulphur. Efficient combustion and control of the sulphur quantity of the burned coal will control the output of some of the chemical oxides. The only way to reduce the amount of carbon dioxide created through the combustion of coal is to burn less coal.

One of the issues facing Greenhills in the current market has been supplying coal to the dryer for the purposes of burning. As with coke plants, the specifications of coal entering the coal burner in the dryer needs to be maintained within ash and moisture specifications to ensure optimum combustion. In the past, coal for consumption in the dryer has either been produced during an oxide coal production run, or taken from clean metallurgical production in small amounts so that production is not affected on a large scale. The benefit of taking coal from the clean coal production in small amounts is that the plant can continue to produce metallurgical coal and not have to switch into a specific oxide run to produce coal for burn. The downside of this scenario is that metallurgical coal is burned in the dryer and not oxide coal, and there is a resulting opportunity cost due to the value differences between the two coals. If Greenhills is able to use raw 010-seam coal in its metallurgical coal products, the lower moisture of the raw coal will mean that the clean coal it is blended with will require less drying and therefore less combustion of natural gas and coal for drying.

4: PROJECT RATIONALE AND SCOPE

010 coal represents a substantial portion of the coal reserves available to Greenhills, and the pockets of comparatively low raw ash – lower than the ash specifications of the actual coal products – has raised the question of whether or not the coal could be added to our blended coal products without being processed, in much the same way that Greenhills uses unprocessed 010 oxide coal as fuel for the dryer.

This chapter will go through each effect of bypassing the raw coal, describing the operational and other benefits and challenges, and describe the potential financial impact for each one. Despite there being significant benefits to enacting a raw coal bypass for 010-seam coal, there are a number of challenges that are important to consider due to their potential for financial impact the project. There will also be recommendations where further information is required in order to make this project feasible.

4.1 Raw Coal Bypass Considerations

4.1.1 Processing

The cost of processing a clean tonne of coal is approximately $6 per MTCC. This cost includes the cost of the breaker, transportation to the plant facility, washing and drying costs, and loading onto the train. There are still costs that will be incurred if the clean coal is bypassed, but they will be reduced in some respect. These changes will be described below.

4.1.1.1 Sizing

Whether the coal is being washed in the plant or is raw coal being bypassed, there is a need to properly size the coal. There will still be a need to remove the oversize rocks that get into the raw coal, as well as the need to reduce the size of any of the large lumps of coal that are part of the run-of-mine coal.

In order to ensure that the raw coal can be bypassed, an additional screening process will need to be employed for the 010-seam coal selected for bypass. This will remove any small particles of rock that get into the coal. The 010-oxide that is currently used as dryer fuel at Greenhills is screened for particles greater than 0.5”. At this screening size, there is very little material that does not pass through the screen, and the material that the screen catches is predominantly coal pieces. However, there will be a far more stringent requirement for the raw coal to be blended into the clean coal product and the screen size will need to remove particles greater than 0.25”, or probably less. This size will still provide easy pass through of the fine coal, and the material that is screened off can be included in the raw coal feed into the plant so coal is not lost during this additional screening process.

There are currently no options that exist on site at Greenhills to screen the coal in this manner, so additional infrastructure will have to be added. The cost of this infrastructure will be included in Section 5.

4.1.1.2 Delivery

At Greenhills, the load out facility for loading trains is located several kilometers away from the mine and breaker, and raw coal is transported to the plant via conveyor belt. There is currently only one conveyor available to do this with a maximum capacity of 1,050 tonnes per hour raw feed. The cost to bypass the coal using the existing conveyor would be similar to the cost of transporting raw coal to the plant. Since this is the only way of feeding raw coal into the plant, regular clean coal production would be forfeited when this conveyor is being used to bypass raw 010-seam coal, resulting in lost opportunity cost.

It would be possible to build a second conveyor that would be capable of bypassing the coal. This conveyor would essentially twin the first conveyor and be used for transporting the raw coal to bypass the plant. There are many benefits to constructing this conveyor in addition to using it to transport the bypassed coal down to the plant. It could also be used as back-up plant feed conveyor should the primary conveyor go down for any reason. This would allow Greenhills to recover some of the lost opportunity cost associated with the plant being unable to process coal due to lack of availability on the existing conveyor. It would also help to mitigate the risk of a production interruption should the existing conveyor suffer a catastrophic failure and end up being offline for an extended period of time.

The issue with constructing a second conveyor is the capital cost. Conveyors are the most economical way of transporting bulk materials over great distances due to their consistent operation and high availability. After construction, maintenance of a conveyor is minimal and conveyors usually operate with availability greater than 95%. However, due to their high capital cost, they are considered a long-life asset and are employed where the extensive capital cost can be depreciated over a long period of time. It is currently not know what amount of 010-seam coal would have the appropriate specifications for use as plant bypass, but the payback period of constructing an additional conveyor will be sensitive to it. However, the benefits of having the second conveyor may still be attractive to Greenhills and outweigh the risk of not having a large and continuous volume of 010-seam coal to bypass.

Greenhills also has the option of using haul trucks to transport the coal to the rail load out location. Using larger trucks similar to those used in the mine to move material would present the most productive and lowest cost method of transporting the coal, but the existing road infrastructure from the mine down to the plant area would need to undergo extensive upgrades in order to accommodate haulage trucks of that size. This makes this option unattractive.

There is also the option to use smaller haul trucks still in order to bypass the coal. These trucks would be small enough to use the existing road infrastructure with only minor costs to upgrade but would represent a higher transportation cost per tonne of coal. This is the method of transporting the raw

010-seam oxide coal that is used as fuel in the dryer but would need to be scaled up to accommodate the volumes required to bypass raw coal for blending into the final product. This size of truck would have limited additional function on site if there were no coal available for bypass at any given time, although they could be sold if the project should prove unfeasible at any time.

4.1.1.3 Wash Plant and Dryer

The cost that would not be incurred if raw coal were bypassing the plant would be the cost associated with the washing and drying necessary to produce clean coal. However, the actual money saved because the bypassed coal does not have to run through the plant is only a small amount of the overall benefit that occurs in the wash plant.

As mentioned before, 010-coal is extremely fine. Increasing the amount of fine coal through the plant reduces plant efficiency and throughput because it takes longer to separate the fine fraction of the coal being processed than the course. The current fine circuit capacity in the plant limits the feed rate from the 1,050 tonnes per hour it is capable of receiving and processing on a normal basis, allowing the plant to only process 750 tonnes per hour when 010-seam coal is 50% of the blend. The feed rate varies based on the feed percentage of fine coal. The consequence of running the plant too fast with a high percentage of fine coal is that fine coal does not get separated and leaves the plant via the tailings circuit in a waste stream rather than being included as final product. If fine coal in the feed blend can be removed from the feed blend and added to the final product without having to be processed, it is going to improve plant production on two fronts – increasing the feed rate of the plant as the percentage of fine coal is reduced, and increasing the overall plant capacity because the plant production plus the raw coal that is added to the final product can exceed the overall capacity of the plant. Overall, this should allow Teck to increase total production capacity at the Greenhills site without additional plant upgrades.

It is important to note that the current limitation of the plant feed rate based on the percentage of fines is being addressed with planned fines circuit upgrades that are due to be completed in the summer of 2011. At that time, the bottleneck for the plant will become the conveyor rather than the fines circuit and production may still be able to be pushed beyond the 1,050 tonnes per hour with the addition of a second conveyor as mentioned in the 4.1.1.2. These economics are not included in this analysis due to lack of necessary information.

4.1.1.4 Yield and Moisture

Predicted yield is important to understand when determining the coals to blend into final products. If the predicted yield is lower than expected, it may be impossible to achieve production targets based on available resources. This is especially important when determine the amount of equipment hours required when scheduling coal delivery and can even affect the scheduling of waste production. It is important to achieve the highest yield possible as any percentage increase in yield gains additional coal production.

Yield can be increased a variety of different ways. Better coal seam preparation in the pit reduces overall dilution of raw coal and increases yield in the plant. In the plant, coarse coal can have a higher yield than fine coal because less coal is lost as tailings. Bypassing coal will completely eliminate losses on the bypassed coal attributed to processing, and the yield of 010-seam added to the final product as raw coal will be 100%, increasing overall yield.

Related to yield in the plant is carbon recovery. This is a true measure of plant efficiency because it relates to how well the plant is actually separating the coal from the waste delivered without losing coal in the process to tailings – the coarser the coal in the blend that passes through the plant, the better the carbon recovery. Less coal lost to tails equates to more coal available for sale for the same processing cost, increasing revenue and reducing margin.

The third related component is the moisture content of the clean coal product. Raw coal enters the plant with a lower moisture content than the required clean specification, so moisture content is added during processing. Too little moisture in the clean product creates a dust problem, especially when fine coal is involved. If there is too much moisture, many other problems occur. The rail company is being paid coal transportation rates to transport water, customers are unhappy because they do not get the same amount of coal they expected so they recover those losses through price penalties, and the overall quality of coke is diminished as too much moisture in a coke oven charge can reduce the CSR of the resulting coke.

Blending raw coal into the final product can be used to buffer the amount of moisture in the final product, and can help compensate for higher moistures in products from other operations, when blended at the port. There are also environmental benefits as well, which will be discussed below.

4.1.2 Environmental Impacts

All coal that enters the processing plant at Greenhills requires drying beyond the mechanical dewatering that is done within the plant. Coal exiting the wash plant has a moisture content around 17%. This moisture content needs to be reduced through drying to 8.5% to achieve target product specifications. At Greenhills, this is accomplished in the dryer by using heat to drive off the additional moisture from the processed coal. The heat required to accomplish the drying is generated through the combustion of natural gas and coal.

The combustion of fossil fuels is receiving more scrutiny as the world deals with the issue of climate change. Specifically, the combustion of coal receives a lot of consideration because not only does the combustion of coal create greenhouse gases, there are a number of additional chemical compounds released that classify as pollutants as well, oxides of nitrogen and sulfur being chief among these, as well as fine particulate matter from smoke can create environmental concerns.

Bypassing the plant and adding raw coal to the final clean coal product reduces the amount of coal that needs to be burned per tonne of production.

This will reduce overall emission intensity. Additionally, since the raw coal will have significantly lower moisture content than the clean coal, the blend of the two products will have a reduced moisture as well. This means that the clean coal coming from the dryer will not require the same energy to dry it to historic levels, resulting in less overall coal being burned in the dryer for similar production. Not only are emission levels less, they are also less intense.

Financially there is a benefit to reducing the amount of coal burned in the dryer. British Columbia enacted a carbon tax back in 2010 whereby users pay a tax on fossil fuels that are involved in combustion. The tax is set to increase on an annual basis. Burning less coal in the dryer will reduce the amount of carbon tax collected from Greenhills. Additionally, coal burned in the dryer cannot be sold for profit, and therefore reduces overall production. Burning less coal in the dryer will increase the amount of coal available for sale. It also reduces the opportunity cost impact when plant time is used to produce coal to be burned in the dryer rather than coal that can be sold to customers. In the future there may also be a federal carbon tax, so reducing the amount of coal burned in the dryer will help reduce the taxes resulting from that program.

There is also benefit from the reduced emissions of SO_x and NO_x gases. Greenhills reports the quantity of these emissions annually through the National Pollutant Release Inventory program in Canada. The results of this reporting are public knowledge and therefore have the potential to impact Greenhills and Teck negatively. However, if Greenhills can demonstrate a reduction in reported levels it will be seen as a favourable step in the context of sustainability. The importance of even these small improvements cannot be overlooked, since Teck is listed on the Dow Jones Sustainability index and has indicated a strong desire to continue to improve its performance.

Dust is an issue when dealing with fine coal, and this is particularly evident when dealing with 010-seam coal. Fine, dry low-density particulate matter can create problems with air quality. The increased feed rate of 010-seam coal in the breaker has created a lot of problems, particularly at the breaker. Huge clouds of black dust obscure vision and are extremely unpleasant for employees to have to work in. Long-term exposure to coal dust can have long-term health effects on personnel exposed to it (black lung, bronchitis, etc.). Dust issues at the breaker can limit the amount of 010-seam coal that is fed into the breaker, causing the mine to alter the feed blend to use less 010-seam. If this practice continues, the ratio of coals available for blending could potentially go askew, requiring that the mine increase again the percentage of 010-seam coal in the blend.

The air quality of the mine has effects not only on the mine site, but also on residents of the town of Elkford. Billowing black dust plumes can be seen from town and represent a potential concern for residents. There have been few complaints to date, but that does not mean that the dust should not be viewed as a concern at Greenhills.

In addition to the visibility and air quality issues associated with the dust, the fine carbonaceous coal dust can also represents a significant explosive hazard. There are many documented cases of underground coal mine explosions that were a result of coal dust particles in the air. On the surface, grain elevators have also been susceptible to explosions from fine grain dust – although the substances are quite different, the mechanism and effects of the explosions are the same.

Coal dust is released every time the coal is handled or otherwise disturbed, and this occurs a lot with mining – digging, dozing, hauling, dumping, tramming, sizing, screening, conveyor belt transfers, and wind all contribute to the dusting problem. Greenhills mine is currently working with consultants to mitigate the risks and concerns that result from the large amount of dust. Within the scope of this project, there are methods that can be used to minimize the handling of 010-seam coal in the production process, reducing the overall dust generated on site. Capital to mitigate dust is included in the project.

4.1.3 Additional Infrastructure

As mentioned in section 4.1.1, there are a number of infrastructure upgrades that would be required in order to transport the raw coal down to the rail loadout. This presents a number of challenges, as infrastructure needs space that may not be available. There may be physical limitations when upgrading the existing road or adding a second conveyor that could dramatically increase the cost of these items.

In addition to transferring the coal to the rail loadout, any raw coal that is included in the raw coal blend will have to be blended for constancy with the clean coal products so that the product being loaded on the train is a consistent blend. The final product will also have to be sampled at regular intervals during loading to ensure that the entire product being loaded on the train falls within the required specifications.

There are a number of options for implementing the required blending. The most obvious solution would be to blend the raw coal into the product as the clean coal is exiting the dryer. The blending would occur before the coal is transferred to either the clean coal silo or the clean coal stockpiles.

4.1.4 Coke Quality

At this point, it is difficult to determine what the effects of using raw coal in a blend would be in the coking process. According to Technical Marketing experts, rock particles in the coke ovens reduce the overall size of coke produced, as rock creates fissures within the coke that reduce the size of the coke pieces when they are pushed out of the coke ovens. It may be that the presence of rock also reduces the CSR of the coke.

However, 010-seam coal is different than most coals. Most coal would not pass through a screen the way that 010-seam coal does, and the ash in the low-ash portion of 010-seam coal is different than typical raw ash. In order to fully understand the effects of including raw coal in the clean blends, full coking tests would need to be performed on the different blends. These tests lie outside the scope of this project.

4.1.5 Pricing

Despite the technical limitations, there may still be a market for coking coal with these parameters. If the coke is of a smaller size, it is classified as either nut coke (<4mm) or breeze coke (< 25 mm), and it still may have value to the customers. In fact, it may produce coke of sufficient quality to make it attractive to existing and potential customers if the price was discounted sufficiently. This represents a potential destruction of value of the asset for Greenhills and Teck, as getting a lower price for a product that could otherwise receive full price would result in lost margins. This does not, however, mean that the project is not viable. Whether or not value is created or destroyed due to reductions in price for the coal depends greatly on changing market conditions. With coal prices at elevated levels, it might still be advantageous to increase production levels by adding raw coal to the clean coal blends if it is expected that the prices for coking coal could decrease in the future. For instance, if coal is priced at a nominal US$200/tonne today, and the price for coal that includes raw coal fetches a value of US$150/ tonne, it makes more sense to produce the extra coal now and sell it for the reduced price than to hold on to it and sell it a few years from now as good metallurgical coal if the market price at that time is US$150/tonne.

Unfortunately it is impossible to predict what the market for metallurgical coal will do in the future, but it still warrants consideration in the scope of this project to assess the different market conditions that would allow for Greenhills and Teck to accept a lower coal price to sell the coal today, rather than hold on to it and sell it for less money in the future if the market price for metallurgical coal were to fall.

4.1.6 Customer Relationships

It is going to be extremely difficult to get this coal out in the marketplace, and it will require some collaborative work with our current customers in order to prove the final product, should the economics be favourable. Extensive testing of the product will be required in order to determine the effect, if any, that using raw coal will have on the end product.

Greenhills will have to perform its own tests on the clean coal products that include raw 010-seam coal in order to determine how the coal affects key coking quality parameters such as CSR, stability, and size distribution. A reduction in any of these parameters could, at the very least, reduce the price that the coal would be able to achieve on the market relative to the benchmark price.

Language in the contracts may have to be changed to reflect that the coal that customers are receiving is not clean coal, as contracts are currently worded specifically stating that the coal is to be cleaned. Discussions would need to be opened with the customer to indicate that there is a potentially new product available and provide the specifications. Once the product is in the market place and proven to perform as expected in an actual setting, it would be easier to gain customer acceptance.

4.1.6.1 POSCAN Joint Venture Relationship

In the past, the joint venture relationship with POSCAN has been beneficial when testing new product blends. When mining first started to produce 010-seam coal in large proportions, the first coal blends were shipped to POSCAN so that they could test the blends that included clean 010-seam coal. This relationship has provided many such instances throughout its history, and it would be a good place to start using the coal in the marketplace. POSCAN should be open to the idea as more coal production at Greenhills translates into more lower-cost coal production from their 20% ownership in the operation (and thus the coal production), should the blend work.

5: OPTION ANALYSIS

The purpose of this chapter is to examine the different options available to Greenhills for bypassing the 010-seam coal and determine which scenarios can maximize economic benefit, while also accounting for potential risks.

I examined three separate blending scenarios under three different capital spending options and compared them to the LOM plan production and revenue in order to determine the net benefit to Greenhills Operation. Greenhills produces two primary metallurgical products – a premium blend with lower volatile matter content and a mid-volatile blend. As mentioned, mining at Greenhills has been progressing over many years and the higher volatile, younger coal seams have been mostly mined leaving the older, lower-volatile seams to dominate the product blend. As such, the mid-volatile product is not produced every year. 010-seam coal is used in both products, although the proportion of 010-seam coal in the mid-volatile blend is substantially less than in the premium blend.

5.1 Base Assumptions

5.1.1 Economic Assumptions

The economics for each scenario will be determined using an after-tax Net Present Value (NPV) analysis comparing each blend option to the current plan at Greenhills. Each of the three capital scenarios will be evaluated under each scenario.

For the purposes of the NPV calculation, a base discount rate of 14.1% will be used. This represents the 2010 weighted annual cost of capital (WACC) for Teck calculated using an average beta of 3.238 (based on both the 60-month and 104-week beta calculated in Appendix B), a risk-free interest rate of 4.00% and a risk premium of 3.5% (TD Economics, 2011). Capital Cost Allowance

(CCA) for capital purchases used in the project will be at 30%, depreciating as Class 43 items as per the Canada Revenue Agency (CRA). The selected tax rate of 25% reflects both the federal corporate tax rate of 15% and the provincial rate of 10% (note that for 2011 the federal rate is actually 16.5%, but a total of 25% was used for all years). Mineral tax for British Columbia is collected as 13% of revenue for the operation, after adjusting for capital spending.

US exchange rate for all calculations involving US exchange is done at US1.00/C$1.20, and base long term price forecasts for coal are assumed to be US$100 for coking coal. PCI and Thermal coal is valued at 75% and 67% of coking coal prices in this project, respectively. Both of these values reflect the estimates used to calculate reserves at Greenhills, as published in the Teck 2010 Annual Information Form (AIF). Coal price sensitivity will be modeled in the analysis to reflect the high prices in the current market, as well as sensitivity to foreign exchange. Unless otherwise stated, all monetary values are in Canadian dollars.

Production costs for Teck coal were $91.00/MTCC in 2010, based on coal revenue of $4.35 billion, a coal operating profit of $2.25 billion (not including depreciation and amortization), and coal production of 23.1 million MTCC (2010 Annual Report). This total cost includes mining, processing, rail, and port costs, as well as the 2010 annualized carbon tax as it appears in Table 5-2. While this cost of production is not reflect the true cost experienced at Greenhills, actual Greenhills costs have been normalized to this value to reflect the average costs experienced by Teck Coal in general. Costs at Greenhills were separated into variable and fixed costs and normalized to $91.00/MTCC. Fixed costs were then held constant for the life of mine, and variable costs were allowed to fluctuate with annual production levels and varied according to changes in the appropriate production metric. Rail and port costs were considered variable, and were held constant at 2010 levels. Teck has recently entered into long-term agreements with both CP and Westshore terminals for pricing although the terms of both of these agreements are confidential and not available for this analysis. See Appendix C for detailed information on fixed and variable costs.

In June of 2010, Greenhills experienced an explosion in the coal dryer, incapacitating the dryer for the remainder of the year. This reduced the amount of coal burned in the dryer, as well as the cost of natural gas and electricity used in processing the coal. Since these results do not represent processing costs typical of Greenhills, thermal coal, natural gas, and power consumption rates were included in the costs at 2009 levels so they would accurately reflect a full year of production.

All scenarios considered were based on the Greenhills 2010 Life of Mine (LOM) plan. Waste volumes and raw coal release were held constant at LOM plan levels through each scenario. This kept mining capacity constant, isolating the economics of the project from the requirement for additional mining equipment to increase waste and coal mining capacity. Raw coal stockpile levels were monitored through each scenario to ensure that all coal being used in the blends was available. Cost differences will therefore be dependent on reduced processing costs for the bypassed coal, increased transportation costs for the bypassed coal, and reduced carbon tax on coal burned in the dryer.

All calculations are performed on a 100% Greenhills basis. Although 80% of any benefit will transfer to Teck because of the level of their ownership in the joint venture, the remaining 20% would benefit POSCO and will therefore be considered as benefit to Greenhills in total. This is consistent with justification of other projects at Greenhills.

Inflation was not considered for any of the financial calculations and analysis performed in the project.

5.1.2 Production

Annual production targets at Greenhills will increase to 5.0 million MTCC per year (100% basis) starting in 2012 (Teck, November 2010). The increase in productive capacity is a result of plant upgrades that allow the plant to achieve the coal production rates it was capable of prior to the inclusion of high quantities of 010-seam coal in the blend. This will limit the amount of production increase available from the raw coal bypass, but incremental increases in production are still possible. Total reserves at Greenhills from the Teck AIF are summarized in Table 5-1. All financial calculations used in the project will be concerned only with depleting the current reserve base and will make no assumptions that additional reserves will be added in the future. All mining sequences occur in accordance to the 2010 Greenhills Life of Mine (LOM) plan. The LOM plan was created based on current equipment configuration and replacement schedule. Only the coal blends were adjusted, leaving all parameters such as coal release, waste production, strip ratios, and haul distance unchanged.

Table 5-1: Greenhills' Proven and Probable Reserves 2010 (Teck, AIF, 2011)

	Proven	Probable	Total	%
Metallurgical	61,200	14,500	75,700	94%
PCI	2,400	700	3,100	4%
Thermal	700	1,000	1,700	2%
Total	64,300	16,200	80,500	100%

5.1.3 Environmental

The government of British Columbia (BC) has levied a carbon tax based on consumption of fossil fuels by both industry and the public. Teck currently pays carbon tax on every litre of fuel, every cubic metre of natural gas, and every tonne of coal burned. The two most important for the dryer are natural gas and coal. As of July 1, 2010, the price paid per tonne of coal burned was $41.54 (coal burned in the dryer is considered high heat value coal at Greenhills), and the price per cubic metre of natural gas is $3.80. These costs are equivalent to $20 per tonne of carbon dioxide (CO_2) emissions, and will increase by $5 per tonne of CO_2, by year, until 2012. The carbon tax rates paid by Teck on consumption basis are summarized in the Table 5-2. Coal burned for drying coal in the dryer is reduced when raw coal is added to blend products because less water needs to be driven off of the coal in order to obtain moisture that falls within the proper specifications. The raw coal has a moisture content of 2%, and therefore clean coal exiting the dryer can have a moisture content above the target specification of 8.5% moisture and still achieve specification moisture when blended with the raw coal. This reduces the evaporative load on the dryer, reducing the amount of coal burned. The saved coal can then be sold.

Table 5-2: BC Carbon Tax on Coal and Natural Gas

	2010	2011	2012 →
As of July 1 of Year:			
Natural Gas ($/m^3)	$3.80	$4.75	$5.70
Coal ($/tonne)	$41.54	$51.93	$62.31
On a January 1 - December 31 Annualized basis:			
Natural Gas ($/m^3)	$1.90	$4.28	$5.23
Coal ($/tonne)	$20.77	$46.73	$57.12

Source: British Columbia Ministry of Finance

5.1.4 Capital

Three capital options are considered in this evaluation, representing low, moderate, and high capital spending options. Each option has advantages and disadvantages relating to the project, which will be explained below.

Each of the described options will require equipment for screening the coal, as well as infrastructure for blending with the clean coal from the plant and loading onto trains. The cost of this equipment is $6.1 million and includes a raw coal silo to store raw coal near the loadout. Due to the high amount of fines in the 010-seam coal, an additional $2 million in capital is included to mitigate issues arising from dust. These measures will help to preserve both the health and wellbeing of the employees working in the plant, and will be beneficial to the environment.

5.1.4.1 Conveyor Network

The first option involves building a new 600t/hr conveyor from the breaker to the plant. The new conveyor would run parallel to the existing conveyor but be smaller in size. The cost of a conveyor of this size would be approximately $47,000,000. The length of time it would take to design and build the appropriate conveyor limits its usage in 2011, and therefore it would not be available until 2012. Costs to transport the raw coal for bypass in 2011 are therefore inflated to indicate that the coal could still be used to bypass but at increased cost. In addition to providing a means of transporting bypassed 010-seam coal to the rail load out, the conveyor would be configured so that it could be used as a primary feed conveyor to the plant if the existing conveyor were to suffer a substantial failure. The conveyor at Elkview Operations was damaged in 2009 and took several months to repair, resulting in severe production losses for Elkview. Adding the additional conveyor capacity at Greenhills would reduce the risk of a similar outage at Greenhills. Additional conveyor capacity also does not allow Greenhills to increase productive output, since plant throughput would still be limited by dryer capacity. Operating costs for transporting the coal via conveyor were included at $0.14/MTRC. Although the operating costs are very low, the extensive capital required to build a conveyor depreciates over many years and therefore the project must provide economic payback for the whole duration. This option therefore assumes that the there is geologic certainty of the amount of 010-seam coal that can be bypassed, and market certainty of how these products will be accepted in the market.

5.1.4.2 Off-road Trucks

The second capital option involves purchasing small, 40 tonne haul trucks to transport the coal down to the load dryer area. Five trucks would be purchased at an estimated cost of $600,000 each. The trucks would transfer the raw coal to the plant at a unit operating cost of $5.00/MTRC, including road maintenance. This would provide sufficient capacity to transport the coal down to the plant throughout the year. These trucks would be utilizing the existing road from the mine to the plant, but the road would require upgrading and resurfacing to withstand the additional traffic. The cost of upgrading the road is estimated at $2 million.

This option allows for flexibility if the market changes or the products are not welcome in the market place as the trucks are not fixed and can be sold at any time if economic conditions change. The additional cost of transporting the coal this way almost negates the savings realized on the coal that bypasses the dryer, and therefore the economic benefit comes only from the increases in production. The cost of upgrading the road to operate large haul trucks was considered but dismissed as the road would require widening, involving the movement of substantial material and far more capital cost than the high capital conveyor case.

5.1.4.3 Using Existing Infrastructure

The final capital option involves using the existing conveyor to transport the raw coal to the dryer for bypass. This option represents the minimum capital expenditure required to perform the raw coal bypass, although it also represents the highest cost impact due to lost opportunity for coal processing in the plant. Under this option, the plant cannot be receiving feed from the mine for processing when it is being utilized for transporting raw coal, reducing processing capacity dependant on the amount of coal that is transported. The processing plant is effectively idle during the bypass. Despite the high yield of the raw coal when it is used in the blends, idling the plant still represents a lost opportunity to Greenhills due to the revenue and profit lost on the 1,050 MTRC/hr feed production lost to the plant while the plant is bypassing coal (output lost varies per year, depending on yield). Lost plant production for each year was calculated based on the amount of coal available for bypass and used to calculate the opportunity cost of bypassing the coal. Opportunity costs were included in the summation of all costs under this option.

5.1.5 Financial Results

The financial results for each scenario will be evaluated under each of the three different capital options and compared to the financial results for the baseline LOM plan. Baseline financial results appear in Table 5-3.

Table 5-3: Baseline LOM Plan Financial Results

BaseLine		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Total Sales	kMTCC	4,600	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,220
Processing	$/MTCC	6.12	6.18	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.22
Non-Processing	$/MTCC	88.67	86.00	85.88	84.81	83.36	83.52	81.12	80.16	79.62	74.87	74.65	74.66	74.38	71.46	67.85	50.66
Total Unit Costs	$/MTCC	94.79	92.17	92.14	91.07	89.62	89.77	87.38	86.42	85.87	81.13	80.91	80.91	80.64	77.71	74.11	56.87
Margin	$/MTCC	25.21	27.43	27.46	28.63	29.78	29.43	31.82	33.18	33.81	38.47	38.82	39.09	39.21	41.84	45.29	62.12

5.2 Scenario 1 – Raw 010-Seam Coal Displaces 010-Seam Coal in Blends

The first scenario examined involves replacing a portion of 010-seam coal that is processed in the plant with raw 010-seam coal. This scenario keeps overall total coal feed the same as in the LOM plan, but production increases result from the higher yield of raw 010-seam coal when it is added to the blend. Coal was replaced in the plan in both of the metallurgical coal blend products produced by Greenhills – the lower-volatile premium blends, as well as the mid-volatile blend. All other coal blends (PCI, thermal, and burn) were unchanged.

Under this scenario, the volume of feed is kept constant and therefore the ore reserves are depleted at the same rate that is currently planned. Total mine life is not changed.

5.2.1 Production Results

Production increases in the first scenario result from the increased yield substituting 010-seam coal in the processing blend. Overall production increased by an average of 139 kMTCC per year, with a minimum increase of 84.0 kMTCC in 2011 and a maximum of 165 kMTCC in 2018. Over the current remaining reserve life, this results in a total clean coal production increase of 2.2 million MTCC, representing an overall yield increase of 2.6%. The raw 010-seam coal is added only to metallurgical coal products, and the increases in production are sold as coking coal. There is a small amount of thermal coal, due to the reduced load on the dryer and reduction in coal burned. Coal that is not burned is sold as thermal coal. Production results for Scenario 1 are found in Figure 5-1.

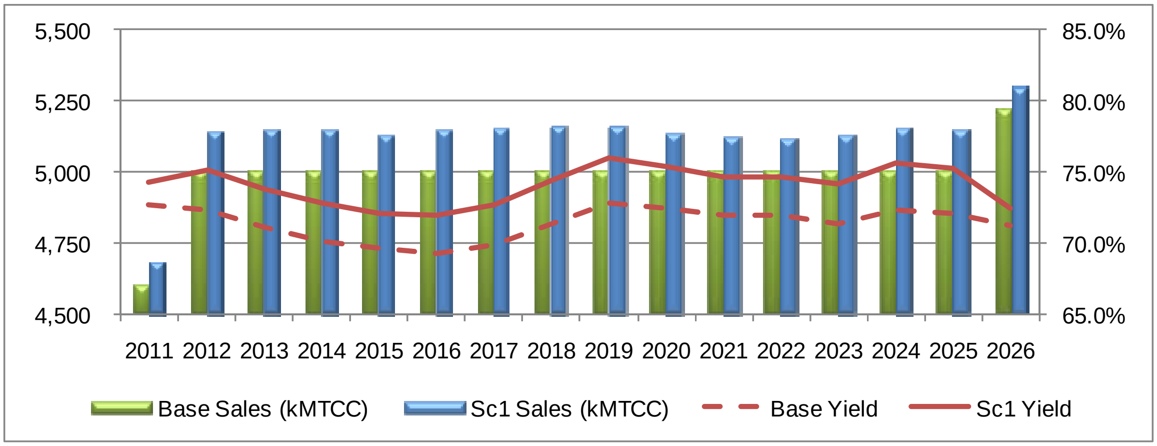

Figure 5-1: Scenario 1 Production Results (figure by author)

5.2.2 Product Quality

One of the primary questions surround the issue of blending raw coal into clean products is how it will affect the final quality of the metallurgical coal products. Substituting raw 010-seam coal for 010-seam processed coal produces very little impact to volatile matter content and $\bar{R}o_{\max}$ values, with changes that are less than one tenth of a percent lower than the standard blends. Ash is reduced for all blends using raw 010-seam coal. Fluidity increases in premium blends and is reduced in mid-volatile blends but still remains at acceptable levels. Dilatation remains unchanged, as do phosphorus and sulphur content. Coking coal parameters stay within acceptable limits, although the effect on CSR and coke stability will not be understood until proper testing can be performed.

Regarding fines, the addition of higher-yielding raw coal into the final product does increase the quantity of fines in the final product, but only by around a half percent. This increase is very small and is not expected to impact the ability of the rail, port or customers to handle the coal beyond the challenges normally encountered when handling coal products containing significant amounts of fine coal from Greenhills.

5.2.3 Financial Results

Under the first scenario, the only available capital option is Option 3 because under this scenario, there is available plant time to utilize the existing conveyor, since the inclusion of raw coal in the clean reduces the total amount of product that is processed in the plant. Doing this does incur an opportunity cost because the plant is not fully utilized in any year. Unit costs are summarized in Table 5-4. The opportunity cost is included in the unit processing cost. The lost opportunity cost is valid because of the current market dynamic where there is more demand than there is supply.

Table 5-4: Scenario 1, Option 3 Costs

Sc1-Op3		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Total Sales	kMTCC	4,683	5,134	5,141	5,141	5,124	5,140	5,149	5,153	5,149	5,129	5,117	5,111	5,122	5,144	5,139	5,301
Processing	$/MTCC	6.78	7.49	7.36	7.37	7.29	7.38	7.62	7.99	8.35	8.40	8.24	8.25	8.14	8.79	8.88	7.35
Non-Processing	$/MTCC	87.77	84.75	84.58	83.53	82.27	82.28	79.88	78.91	78.42	73.95	73.82	73.86	73.52	70.52	67.05	50.47
Total Unit Costs	$/MTCC	94.55	92.23	91.93	90.90	89.55	89.66	87.50	86.90	86.77	82.35	82.06	82.11	81.66	79.31	75.93	57.82
Margin	$/MTCC	25.55	27.56	27.83	28.95	29.99	29.71	31.88	32.90	33.14	37.45	37.85	38.06	38.36	40.46	43.68	61.24

Based on the above unit costs and margins, the project has a net present value (NPV) of $8.1 million and an internal rate of return (IRR) of 41.0% compared to the current LOM plan.

5.3 Scenario 2 – Raw 010-Seam Coal is Added to Existing Metallurgical Blends

Under this scenario, raw 010-seam coal is substituted for clean 010-seam in the mid-volatile blends, and the remaining raw bypass 010-seam coal is added to premium blends. Although total raw coal feed to the plant remains consistent with the LOM plan, total raw feed increases each year by the amount of 010-seam coal deemed acceptable to be blended raw into the final product. This increases overall production to the mine both from increasing the total raw coal consumed, as well as the increased yield of the raw 010-seam coal used in the final product.

Production of mid-volatile coal blends was not increased by adding raw 010-seam coal to the blend because of the target volatile matter in those blends.

Increasing the proportion of 010-seam coal would reduce the average volatile content of these blends with the possible risk of pushing the volatile content below the acceptable mid-volatile range.

5.3.1 Production Results

Production increases under this scenario result by adding the raw 010-seam coal to the existing LOM plan blends in the same proportion as 010-seam coal exists in the blends of both the premium and mid-volatile products. Therefore, production is increased each year by the amount of 010-seam coal that can be added raw to the blend. Production increases vary from a maximum of 495 kMTCC in a year to a minimum of a production loss of 1.6 million MTCC in the final year of the plan due to more rapid consumption of the reserve base. Coal production increases by a total of 2.2 million MTCC over the LOM case, and overall yield increases by 2.6% compared to the LOM blend. Full results appear in Figure 5-2.

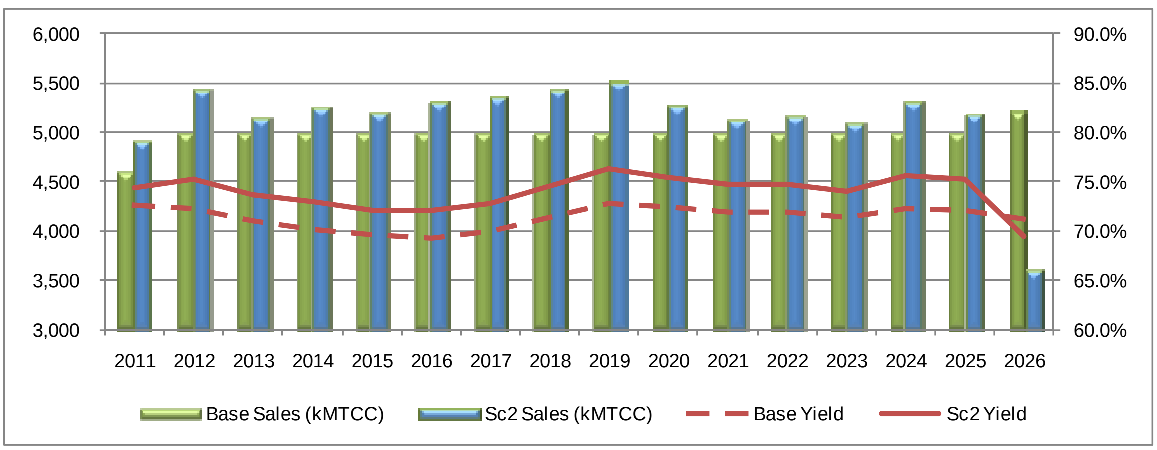

Figure 5-2: Blend Scenario 2 Production Results (figure by author)

5.3.2 Product Quality

Quality parameter results for the mid-volatile blends are the same as for Scenario 1, since the swapping of raw 010-seam coal for clean 010-seam coal in the final product occurs identically, with the biggest changes being the reduction of ash content and reduction in fluidity.

The additional raw 010-seam coal in the premium blends does not affect the volatile matter content of these blends, however it does lower the ash and increase the fluidity of the blends. Dilatation does not change by a significant amount.

Again, CSR and coke stability results are not known and testing would be required to evaluate any changes resulting from the addition of the raw 010-seam coal.

The one issue that does arise, though, is the increased fine content of the finished product. Fine content of the final product increases by up to 3% in some years, which may present some handling challenges for the rail, port and customers.

5.3.3 Financial Results

Under the second scenario, all capital options were considered and produced the following results, found in Table 5-5.

Table 5-5: Financial Results for Scenario 2

Sc2-Op1		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Sales	kMTCC	4,904	5,408	5,124	5,229	5,173	5,273	5,336	5,407	5,486	5,241	5,107	5,133	5,058	5,282	5,147	3,569
Processing	$/MTCC	6.06	5.62	5.77	5.78	5.83	5.78	5.74	5.66	5.58	5.68	5.73	5.73	5.76	5.64	5.68	6.41
Non-Processing	$/MTCC	85.53	82.38	84.73	82.77	81.85	81.17	78.42	77.00	75.94	73.18	73.89	73.71	73.97	69.68	67.01	56.45
Total Unit Costs	$/MTCC	91.60	88.00	90.51	88.54	87.68	86.95	84.16	82.66	81.52	78.86	79.62	79.44	79.72	75.31	72.69	62.86
Margin	$/MTCC	28.44	31.74	29.26	31.29	31.86	32.41	35.20	37.09	38.33	40.92	40.30	40.73	40.31	44.43	46.92	56.31

Sc2-Op2		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Sales	kMTCC	4,904	5,408	5,124	5,229	5,173	5,273	5,336	5,407	5,486	5,241	5,107	5,133	5,058	5,282	5,147	3,569
Processing	$/MTCC	6.06	6.10	6.22	6.20	6.21	6.19	6.18	6.17	6.15	6.20	6.22	6.22	6.23	6.19	6.21	6.65
Non-Processing	$/MTCC	85.53	82.38	84.73	82.77	81.85	81.17	78.42	77.00	75.94	73.18	73.89	73.71	73.97	69.68	67.01	56.45
Total Unit Costs	$/MTCC	91.60	88.48	90.95	88.97	88.06	87.36	84.60	83.17	82.09	79.38	80.11	79.93	80.20	75.86	73.22	63.10
Margin	$/MTCC	28.44	31.26	28.81	30.87	31.48	31.99	34.76	36.58	37.75	40.40	39.80	40.24	39.84	43.88	46.39	56.07

Sc2-Op3		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Sales	kMTCC	4,904	5,408	5,124	5,229	5,173	5,273	5,336	5,407	5,486	5,241	5,107	5,133	5,058	5,282	5,147	3,569
Processing	$/MTCC	6.70	7.37	7.36	7.34	7.27	7.32	7.54	7.86	8.16	8.33	8.24	8.24	8.18	8.70	8.88	8.36
Non-Processing	$/MTCC	85.53	82.38	84.73	82.77	81.85	81.17	78.42	77.00	75.94	73.18	73.89	73.71	73.97	69.68	67.01	56.45
Total Unit Costs	$/MTCC	92.24	89.75	92.10	90.11	89.12	88.49	85.95	84.86	84.10	81.51	82.13	81.95	82.15	78.37	75.88	64.81
Margin	$/MTCC	27.80	29.99	27.67	29.73	30.42	30.86	33.41	34.89	35.74	38.27	37.78	38.22	37.89	41.37	43.72	54.36

Based on capital Option 1, the project under Scenario 2 has an NPV of $42.6 million and an IRR of 34.4%. For capital Option 2, the project presents a more attractive NPV of $64.4 million compared to the current plan, and an IRR of

128%. Option 3 produces an NPV that is lower than that from Option 2 at $39.1 million but has a greater IRR of 167%, because of the reduced capital expense.

5.4 Scenario 3 – Raw 010-Seam Coal Blend as Separate Product

For the final scenario, an additional metallurgical coal blend was included that replaces all raw 010-seam coal for processing with raw 010-seam coal for bypass. All 010-seam coal is removed from the plant feed, and the blend is processed without any 010-seam coal in it. All 010-seam coal to be included is added to the blend as raw coal. The amount of this product available in each year is determined by the amount of appropriate 010-seam coal released, with the assumption being all 010-seam coal that can be added raw to a product is consumed (no carry-over inventory). This product blend scenario allows the finished products containing raw 010-seam coal to be isolated from the other products for potential pricing differentials. This scenario also represents the production if the raw 010-seam coal is substituted for clean 010-seam coal in the premium blends similar to scenario one, except the feed from the additional blending coals is increased through the plant so that plant throughput is maintained.

5.4.1 Production Results

Total production is slightly greater than that achieved in Scenario 2. Maximum additional production is 536 kMTCC in a year, but the final year production is decreased by 3.2 million MTCC to account for the accelerated production.

Overall yield increases by 2.3%, slightly less than the previous two scenarios due to the fact that the proportion of lower-yielding coals are increased over Scenario 1 to keep the plant running at capacity. Production results are found in Figure 5-3. In the individual product containing the 010-seam coal, yield comes in at an average of 86%.

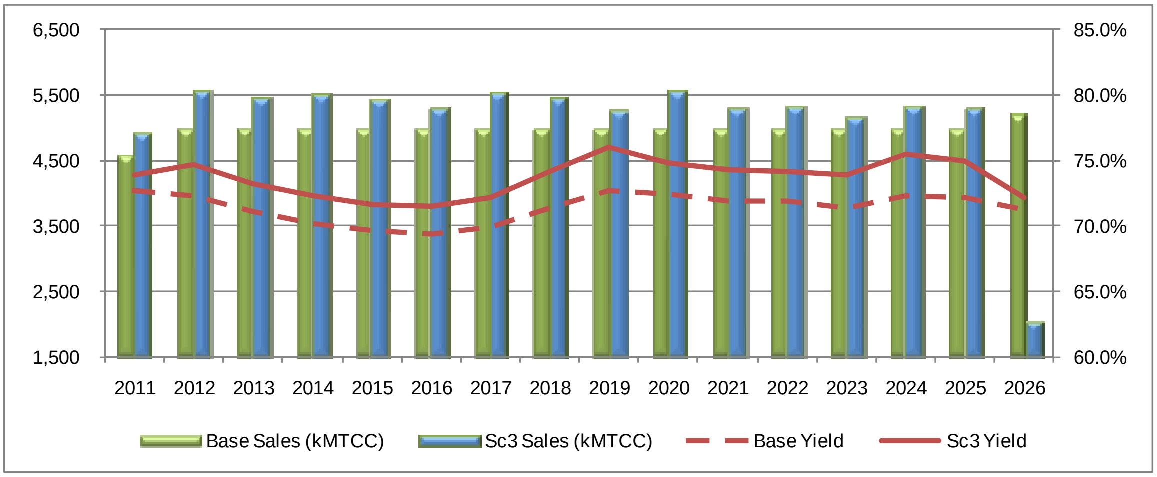

Figure 5-3: Scenario 3 Production Results (figure by author)

5.4.2 Product Quality

The quality parameters for the final scenario will focus on the parameters of the single product where the raw 010-seam coal is blended, since the qualities of the remaining products are kept consistent and there is no raw coal included in those clean blends.

The use of raw 010-seam in its own product produces favourable results regarding coking properties. The ash is lower than the LOM premium blend, and the fluidity increases. Volatile content and $\bar{R}o_{\max}$ remain essentially unchanged. Fines values are consistent with normal premium blends at Greenhills.

CSR and coke stability results would again require additional testing.

5.4.3 Financial Results

The results for Scenario 3 are found in Table 5-6. The DCF analysis for Scenario 3 produced an NPV of $67.8 million under capital Option 1 with an IRR of 46.4%. This compares to an NPV of $89.6 million and an IRR of 152.1% under capital Option 2. The final capital option under Scenario 3 resulted in an NPV of $64.3 million, with an IRR of 197.2%.

Table 5-6: Scenario 3 Financial Results

Sc3-Op1		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Sales	kMTCC	4,886	5,531	5,432	5,470	5,403	5,257	5,499	5,412	5,233	5,526	5,264	5,295	5,133	5,287	5,260	1,979
Processing	$/MTCC	6.07	5.61	5.74	5.75	5.81	5.78	5.73	5.66	5.59	5.65	5.72	5.71	5.75	5.64	5.67	7.33
Non-Processing	$/MTCC	85.71	81.40	82.09	80.80	79.99	81.30	77.23	76.96	77.77	71.37	72.82	72.62	73.44	69.65	66.39	71.14
Total Unit Costs	$/MTCC	91.78	87.01	87.83	86.56	85.80	87.08	82.95	82.62	83.36	77.03	78.54	78.34	79.19	75.28	72.06	78.47
Margin	$/MTCC	28.27	32.71	31.88	33.24	33.71	32.28	36.39	37.13	36.53	42.70	41.34	41.79	40.83	44.45	47.53	40.98

Sc3-Op2		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Sales	kMTCC	4,886	5,531	5,432	5,470	5,403	5,257	5,499	5,412	5,233	5,526	5,264	5,295	5,133	5,287	5,260	1,979
Processing	$/MTCC	6.07	6.08	6.17	6.16	6.17	6.20	6.15	6.17	6.19	6.15	6.19	6.19	6.22	6.19	6.19	7.77
Non-Processing	$/MTCC	85.71	81.40	82.09	80.80	79.99	81.30	77.23	76.96	77.77	71.37	72.82	72.62	73.44	69.65	66.39	71.14
Total Unit Costs	$/MTCC	91.78	87.49	88.25	86.96	86.16	87.49	83.38	83.12	83.96	77.52	79.02	78.81	79.66	75.84	72.58	78.91
Margin	$/MTCC	28.27	32.23	31.46	32.83	33.35	31.86	35.96	36.63	35.93	42.21	40.86	41.32	40.36	43.90	47.01	40.55

Sc3-Op3		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Total Sales	kMTCC	4,886	5,531	5,432	5,470	5,403	5,257	5,499	5,412	5,233	5,526	5,264	5,295	5,133	5,287	5,260	1,979
Processing	$/MTCC	6.71	7.32	7.24	7.25	7.18	7.33	7.47	7.86	8.30	8.17	8.16	8.15	8.14	8.69	8.80	10.85
Non-Processing	$/MTCC	85.71	81.40	82.09	80.80	79.99	81.30	77.23	76.96	77.77	71.37	72.82	72.62	73.44	69.65	66.39	71.14
Total Unit Costs	$/MTCC	92.42	88.73	89.33	88.05	87.17	88.62	84.69	84.82	86.07	79.54	80.98	80.77	81.58	78.34	75.19	81.99
Margin	$/MTCC	27.63	31.00	30.38	31.74	32.34	30.73	34.65	34.93	33.82	40.19	38.90	39.36	38.44	41.40	44.40	37.46

5.5 Summary of Results

Using the base assumptions described above in the first section of this chapter, each scenario represents an attractive return for each capital spending option. A summary of each combination appears in Table 5-7.

Table 5-7: NPV and Cash Flow Analysis of Each Option and Scenario

Base	**Cash Flow (Undiscounted)**	**NPV**	**IRR**	**Payback (yrs)**
Option 1				
Scenario 2	$207,889,426	$42,619,481	34.4%	2.44
Scenario 3	$207,165,210	$67,837,469	46.4%	1.99
Option 2				
Scenario 2	$171,724,495	$64,394,456	128.0%	0.77
Scenario 3	$171,000,279	$89,612,444	152.1%	0.81
Option 3				
Scenario 1	$36,207,125	$8,068,305	41.0%	2.32
Scenario 2	$36,271,951	$39,090,762	166.8%	0.57
Scenario 3	$35,547,736	$64,308,750	197.2%	0.61

The total undiscounted cash flows are the highest for all scenarios under Option 1, but the high capital cost of Option 1 keeps the NPV and IRR comparatively low. Undiscounted cash flows under Option 1 are the highest because the conveyor used in Option 1 transports the raw coal to be used in bypass for the lowest cost, at approximately $0.14 per MTRC. It also does not incur any opportunity cost because the plant can be operated at maximum capacity.

Undiscounted cash flows under Option 2 are lower than for Option 1 due to the increased cost of transporting the raw coal for bypass via truck instead of a low-cost conveyor. Transportation costs under this option are approximately $5 per MTRC taken for bypass. Option 2 produces the highest NPV when the cash flows are discounted at the specified discount rate.

Undiscounted cash flows under Option 3 are substantially lower than for the other two capital options because of the opportunity cost of utilizing the existing conveyor to transport the raw coal for bypass. However, because of the low initial capital investment, the IRR for these scenarios are the highest.

5.5.1 Price Sensitivity

The economics for this project are most sensitive to metallurgical coal price. Base economics were performed using a coal price of $120 per MTCC, which is conservative given the current high demand for good quality coking coal. Reproducing Table 5-7 based on coal at US$200 per MTCC (Table 5-8) indicates just how sensitive to price the economics are. Under the new pricing that reflects the coal price experienced over the past year, the economics of Option 3 quickly disappear as the opportunity cost of taking the plant out of production to bypass raw coal on the existing conveyor dominate the economics, resulting in undiscounted cash flows approaching a loss of over $294 million. The NPV of the discounted cash flows remains high at over $74 million for Scenario 3, but this is a result of the negative difference in cash flow at the end of mine life because of the accelerated schedule. The impacts on the NPV of cash flows that exist far in the future are minimal, especially at the specified discount rate of 14.1%.

Table 5-8: DCF Results with US$200 per MTCC Coal

US$200 Coal	**Cash Flow (Undiscounted)**	**NPV**	**IRR**	**Payback (yrs)**
Option 1				
Scenario 2	$467,921,501	$157,118,293	82.7%	1.11
Scenario 3	$466,048,628	$222,068,959	103.7%	1.12
Option 2				
Scenario 2	$431,756,570	$178,893,269	322.5%	0.32
Scenario 3	$429,883,697	$243,843,935	344.0%	0.34
Option 3				
Scenario 1	($294,201,998)	($70,683,227)	N/A	N/A
Scenario 2	($294,141,575)	$9,162,735	11.9%	0.34
Scenario 3	($296,014,448)	$74,113,401	5.7%	0.37

Another pricing variable that the economics of the project are sensitive to is the potential for price discrimination under Scenario 3, if the product that includes the raw coal does not receive the same price as regular clean coal in the market. Under all options, a 5% reduction in the price received for the individual product containing raw coal reduces the NPV by $28.1 million. The associated IRRs for Options 1, 2, and 3 are 37%, 128%, and 160% respectively, representing significant loss in value and indicating the sensitivity to small reductions in pricing.

6: Recommendations

The export metallurgical coal market is currently very strong, driven by strong growth in the steel industry in China whose economy continues to grow. The steel industry in other developing nations, such as India, is starting to increase as well and will require raw material from the seaborne market. In such conditions where demand and margins are high but barriers to entry are also high, incumbent companies can maximize profits by increasing production from existing operations by as much as possible.

The potential for incorporating raw 010-seam coal into the metallurgical coal blends at Greenhills presents an attractive option for increasing production tonnage without having to spend extensive capital on new mining equipment to expand. Production capacity is currently limited by the plant, but planned upgrades that will be completed in 2011 will push the production bottleneck from the capacity of the fines circuit in the plant, to the capacity of the existing feed conveyor from the breaker to the plant. Adding raw 010-seam coal does not have any significant impact on the quality parameters of the coal that are easy to identify and calculate

Incorporating raw coal as part of the clean blended product raises many questions regarding quality. Coking coal is processed and cleaned for a reason; if raw coal worked as well as clean coal in coking blends, contracts would not specify clean coal. But the 010-seam coal at Greenhills is different. The ash does not exist as easily identifiable particles within the worked coal seams. Typically, larger ash particles are what produce the negative effect on the coke quality and it is understood for this project to work that those larger particles will need to be screened off.

Practice has shown us that there are significant portions of 010-seam coal that exist within the structure that have raw ash content below 10%.

Unfortunately these zones are difficult to predict with current drilling techniques due to the extent of variability in the deposits compared to the density of drilling. Recovery of a good representative sample of drill cuttings is problematic and would not recover a sufficient sample to adequately predict zones of low ash. The best method currently employed is to remove the waste from the seam and push the coal to the bench floor where the geological department can sample the seam to determine the ash content. The geologists use an electronic tool to determine ash quantity in a sample of coal in a very short time frame and can assess the ash content in a pile of coal in a matter of minutes. Greenhills has found success separating low ash from high ash zones of the oxide coal in this way, and this method is just as effective with raw metallurgical coal.

Looking at the different scenarios modeled, the most likely scenario would be Scenario 3. This scenario represents the effects on production from either using the raw coal exclusively in one product, or using it supplement all products while adjusting the blend to keep the quantity of fine coal consistent. Production is increased, and it does not produce any additional handling issues at the different points in the chain between the mine site and the end customer. Financial results between Scenario 2 and Scenario 3 were very close and keeping the amount of fine coal at current levels would more than make up for any favourable economic advantage that Scenario 2 might hold over Scenario 3. Scenario 1 should not be considered, although should remain an option in case of a change in market conditions where supply was greater than demand and Teck was required to once again compete on price.

Determining the most appropriate capital option is a little more challenging than determining the best blend scenario. From a purely economic perspective, the purchase and use of a fleet of small trucks to transport the coal to the load out area resulted in the highest net present value calculations for Scenario 3. This is also the easiest capital option to design and plan for, and a haul could be started using contractor trucks in a very short amount of time. There would be some engineering work to determine how the screening plant and the coal blending system would work, but the engineering work required for these processes would be minor compared to the detailed engineering required for a full-scale conveyor system. The existing road network will require upgrades to ensure that it is able to handle the additional traffic flow, but extensive upgrades to the road would not be needed.

The conveyor system does represent the most economic method of transferring the coal to the load out facility for loading on trains, but unfortunately the overall economics are hampered by the significant capital expenditure required to build a conveyor system. While there are several advantages to installing a second conveyor, the economics of this specific project are not concerned with mitigating conveyor risk or determining additional bottlenecks that may exist in the plant. What we do know is that the existing conveyor systems and the dryer capacity both constrain throughput capacity, and this project examines an option for increasing production without increasing the work demanded of those two systems. The additional conveyor would help insulate Teck against the risk of production loss in the event of a catastrophic failure of the conveyor system that resulted in substantial down time, although this event is considered unlikely and interruptions of this nature would be covered under business interruption insurance.

The purchase of a small fleet of trucks to transport the raw coal for bypass to the plant under capital Option 2 also represents the lowest risk to Teck should the new product be unattractive in the market place. The truck type being considered is quite common on construction sites, and should the project terminate after being started, the trucks could easily be sold to partially recover the capital expenditure. Capacity can be added or removed as necessary.

The project also represents an opportunity for Teck to decrease its carbon dioxide emissions, therefore reducing the amount of carbon tax paid by Greenhills. In addition to the economic benefit of reduced CO_2 output, additional emission reductions from the reduced dryer burn coal are of benefit to Greenhills, as well. Both CO_2 and emissions results are reported under the Greenhouse Gases and National Polluters Release Inventory programs respectively. Any step toward lowering overall emissions reported in both programs is representing an improvement for the air we breathe.

The biggest risk facing the project is the quality considerations, and how the existing customers are going to view the product. The acceptance of this product is going to require a lot of test work prior to determining its true feasibility. The economics certainly suggest moving forward with a testing program to determine the effect on the coking properties when raw 010-seam coal is included as part of a coking blend. The biggest question is whether or not the CSR and the coke stability will remain unchanged between the current clean blends and a blend consisting of raw 010-seam coal and clean coal. Second to that is what the actual size of the coke pieces made from the blend would be, since larger coke pieces produce better results in the coke ovens. If the quality diminishes to reduce the price of the raw-blends versus their clean coal counterparts, the economics of the project become unfavourable, even at a small pricing differential of 10% (based on US$100/MTCC). NPV remains high, but the IRR is reduced well below the discount rate specified for the analysis.

If the test results prove favourable, POSCAN, our joint venture partner, could be approached for involvement in the full scale testing and coking of the product. In the past, this relationship has provided opportunities for testing new coal blends, such as when 010-seam coal became a significant part of the feed blend at Greenhills.

The world market for coal is currently very attractive and does not show any signs of letting up, due to the industrial growth in population juggernaut China, with more and more steel consumption in other emerging economies like India. Teck can extract value for every incremental tonne that it can get to market, and creative methods of circumventing existing bottlenecks must be evaluated to determine whether or not they present real opportunity to increase productive capacity. The inclusion of raw 010-seam coal represents an excellent opportunity for Teck to increase production from its existing operations and aligns well with Teck’s state growth strategy for coal. The potential of reduction in product quality does exist, but the extent of the issue – if it is an issue with this particular coal seam – is not understood and will need to be assessed through product testing. This opportunity to increase production for minimal cost in the existing market conditions should be pursued so that the truth can be known about what effect on final product quality the inclusion of raw 010-seam coal will impart.

7: Conclusion

This project was envisioned as a method of increasing the productive output above the current plant capacity from Greenhills Operation. Plant capacity is below what the mine is able to provide due to a production bottleneck in the plant that switches between the conveyor delivery of raw coal and the evaporative capacity of the dryer, depending on yield. The bypass of raw 010-seam coal at Greenhills represents a solution to increase clean coal production above the current plant capacity without the need for extensive upgrades to the process. Through the sorting of raw 010-seam oxide coal for use in the dryer as fuel, Greenhills has proven that raw 010-seam coal exists in areas of the mine with sufficiently low ash content to be incorporated into clean coal products. This project examined three separate capital options available to Greenhills to achieve this end, and determined the effect on production and several quality parameters for three separate blend scenarios. The results indicate that there is massive value available for Greenhills and Teck attributed to the increased production. The only question that remains is whether or not the use of 010-seam coal in coke oven blends would have negative impacts on coke strength or stability.

The seaborne metallurgical coal industry is an exciting industry for producers as supply struggles to keep pace with explosive demand growth. Steel producers must obtain the necessary raw materials in order to keep pace with the growth in demand for steel, which is being driven by urbanization in developing countries such as China and India. Coal prices that are four to six times higher than what existed prior to the intense demand that China has placed on the seaborne metallurgical coal market. Scarcity of the metallurgical coal resource worldwide is putting pressure onto existing producers to produce and ship as much coal as they can from existing deposits. The rewards are there in the form of substantial revenue and profit gains, and the economics of this project indicate that the remaining questions regarding coke strength and stability be answered to prove or disprove the feasibility of incorporating raw 010-seam coal into the clean coal blends.

Appendices

Appendix A – Worldwide Steel Production 2010

		2010 Production		YOY Growth					2006-2010
Rank	Country	Mt	% of World	2010	2009	2008	2007	2006	Growth
1	China	626.7	44.3%	9%	15%	2%	17%	19%	50%
2	Japan	109.6	7.8%	25%	-26%	-1%	3%	3%	-6%
3	United States	80.6	5.7%	38%	-36%	-7%	-1%	4%	-18%
4	Russia	67.0	4.7%	12%	-12%	-5%	2%	7%	-5%
5	India	66.8	4.7%	6%	9%	8%	8%	8%	35%
6	South Korea	58.5	4.1%	20%	-9%	4%	6%	1%	21%
7	Germany	43.8	3.1%	34%	-29%	-6%	3%	6%	-7%
8	Ukraine	33.6	2.4%	12%	-20%	-13%	5%	6%	-18%
9	Brazil	32.8	2.3%	24%	-21%	0%	9%	-2%	6%
10	Turkey	29.0	2.1%	15%	-6%	4%	11%	11%	24%
11	Italy	25.8	1.8%	30%	-35%	-3%	0%	8%	-18%
12	Taiwan, China	19.6	1.4%	23%	-20%	-5%	4%	6%	-2%
13	Mexico	17.0	1.2%	21%	-19%	-2%	7%	1%	4%
14	Spain	16.3	1.2%	13%	-23%	-2%	3%	3%	-11%
15	France	15.4	1.1%	20%	-28%	-7%	-4%	2%	-23%
16	Canada	13.0	0.9%	40%	-37%	-5%	1%	1%	-16%
17	Iran	12.0	0.8%	10%	9%	-1%	3%	4%	22%
18	United Kingdom	9.7	0.7%	-4%	-25%	-6%	3%	5%	-30%
19	South Africa	8.5	0.6%	13%	-10%	-9%	-6%	2%	-12%
20	Belgium	8.1	0.6%	45%	-48%	0%	-8%	12%	-30%
21	Poland	8.0	0.6%	13%	-27%	-8%	6%	20%	-20%
22	Australia	7.3	0.5%	40%	-32%	-4%	0%	1%	-8%
23	Austria	7.2	0.5%	26%	-25%	0%	7%	1%	1%
24	Egypt	6.7	0.5%	22%	-11%	0%	3%	7%	12%
25	Netherlands	6.7	0.5%	29%	-25%	-7%	16%	-7%	5%
26	Czech Republic	5.2	0.4%	13%	-28%	-10%	3%	11%	-25%
27	Argentina	5.1	0.4%	28%	-27%	2%	-2%	2%	-7%
28	Saudi Arabia	5.0	0.4%	6%	0%	2%	15%	-5%	25%
29	Sweden	4.8	0.3%	71%	-46%	-9%	4%	-4%	-13%
30	Slovakia	4.6	0.3%	24%	-18%	-12%	0%	13%	-10%
31	Kazakhstan	4.3	0.3%	5%	-5%	-10%	12%	-4%	0%
32	Malaysia (e)	4.1	0.3%	2%	-38%	-7%	19%	9%	-29%
33	Finland	4.0	0.3%	29%	-30%	0%	-14%	9%	-22%
34	Romania	3.9	0.3%	39%	-44%	-21%	0%	0%	-38%
35	Thailand (e)	3.7	0.3%	3%	-31%	-7%	14%	-6%	-24%
36	Indonesia (e)	3.6	0.3%	3%	-10%	-7%	11%	3%	-5%
37	Viet Nam	2.7	0.2%	0%	17%	15%	5%	111%	42%
38	Luxembourg	2.6	0.2%	24%	-19%	-10%	4%	27%	-7%
39	Byelorussia	2.5	0.2%	4%	-8%	8%	4%	15%	9%
40	Venezuela	2.2	0.2%	-42%	-10%	-16%	2%	0%	-55%
	Others	25.6	1.8%	10%	-12%	-12%	4%	7%	-12%
	World	**1,413.6**	**100%**	**15%**	**-7%**	**-1%**	**8%**	**9%**	**13%**

Appendix B – Weighted Annual Cost of Capital Calculation

COST OF DEBT FINANCE

	2009	2010
Short Term Debt		
CurrentPortionOfLong-TermDebt	1,132	65
Short-TermDebt	-	-
ExchangeableDebentures	-	-
Long Term Debt		
Fair Value of LongTermDebt	7,856	5,811
ExchangeableNonCurrentDebentures	-	-
GrossDebtFairValue	8,988	5,876
Less Cash	1,329	832
NetDebtFairValue	7,659	5,044
AverageGrossDebtFairValue	10,525	7,432
AverageNetDebtFairValue	9,436	6,352
GrossInterestExpense	655	565
EffectiveTaxRate	28.4%	33.4%
ImpliedCostOfDebtFairValue	6.2%	7.6%
AfterTaxCostOfDebtFairValue	4.5%	5.1%

COST OF EQUITY FINANCE

RiskFreeRate	5.25%	4.00%
RiskPremium	3.30%	3.50%
60MonthBeta	3.225	3.297
104WeekBeta	2.742	3.178
AverageBeta	2.984	3.238
CostOfEquityAverage	15.10%	15.33%

CALCULATING THE WACC

Average Beta Basis		
Market Cap (Market Value of Equity)	21,691	36,496
Cost of Equity	15.1%	15.3%
Equity Cost	3,274	5,595
% of Total	73.9%	87.9%
Net Debt	7,659	5,044
After Tax Cost of Debt	4.5%	5.1%
Cost of Debt	341	255
% of Total	26.1%	12.1%
Total Equity + NetDebt	29,350	41,540
Total Cost	3,616	5,851
WACC_AverageFair	**12.3%**	**14.1%**

Appendix C – Cost Allocation Model

Cost Type	Processing/ Non-Processing	Variable % of Cost	Variable Unit of Production
Labour			
Plant Administration	P	0	MTCC
Administration	NP	0	BCMTM
Plant Maintenance	P	75	MTCC
Operations	NP	75	BCMTM
Plant Operations	P	75	MTCC
Energy			
Diesel	NP	100	BCMTM
Plant - Power	P	100	MTCC
Other Power	NP	100	BCMTM
Plant Natural Gas	P	100	MTCC
Other Natural Gas	NP	0	
Gasoline and other	NP	0	
Consumables			
Tires	NP	100	BCMTM
Lubes	NP	100	BCMTM
Explosives	NP	100	BCMW
Ground engaging hardware	NP	100	BCMTM
Magnetite	P	100	MTCC
Other plant consumables	P	100	MTCC
Crush	NP	100	BCMTM
Other Plant Supplies	P	100	MTCC
Other supplies	NP	100	BCMTM
Repairs			
Maintenance Parts	NP	100	BCMTM
Processing Parts	P	100	MTCC
Plant Contractors	P	100	MTCC
Plant Equipment	P	100	MTCC
External Services	NP	100	BCMTM
Insurance and Taxes			
Property Taxes	NP	0	
Insurance	NP	0	
Other Costs			
Light vehicle leases	NP	0	
Other charges	NP	0	
Equipment leases	NP	100	BCMTM
Head office allocation	NP	0	
Off-site Costs	NP	100	MTCC

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