MINING URBAN ORE: A STRATEGY FOR E-WASTE AND E-SCRAP PROCESSING AT TECK RESOURCES' TRAIL OPERATIONS

by

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Abstract

Teck's Trail Operations is facing a critical decision regarding the construction of facilities for entering the electronic scrap processing industry. This action will affect the long-term profitability of Trail Operations.

This paper evaluates the existing and future market for the generation and recovery of electronic waste. It also describes the electronics recycling chain from generation to the end-processing of all waste streams. The paper reviews global trends in legislation to assess the potential impact on the electronic waste recycling industry.

Using Porter's Five Forces methodology, an industry analysis reveals prospective opportunities and threats that could affect Teck's entry into the industry. An internal assessment of Trail Operations' strengths and weaknesses enables the identification of the firm's competitive advantage in the industry.

The paper concludes with recommendations to guide Teck in the establishment of a competitive strategy for Trail Operations in the electronic scrap processing industry.

Keywords: Teck; Trail Operations; Electronic Waste; E-waste; Electronic Scrap; E-scrap; Electronics Recycling.

Executive Summary

Introduction

Teck's Trail Operations is at a point in time where a critical decision must be made. The challenging industry environment for primary zinc and lead refiners is expected to worsen in the coming years as a structural shift is projected to move the supply and demand balance in favour of the miners. Teck must determine what actions it needs to take to maximize the value of its existing assets and to ensure the long-term viability of Trail Operations. The #4 Slag Fuming Furnace and the Setting Furnace have the potential to be the cornerstones of a revised business model that increases the amount of secondary materials processed at Trail Operations.

Trail Operations has been operating at the same site for over 110 years as a primary smelter focused mostly on the production of zinc and lead. It was not until the 1980s that Trail Operations began processing appreciable amounts of secondary feed materials through the inclusion of lead from used lead acid batteries in the feed to the smelter. Teck added to its recycling activities in 2006 with the introduction of e-waste recycling. This business has grown due to increased recovery of e-waste from the municipal waste stream into the recycling chain as a result of new legislation in Western Canada. Over the past five years, optimization of the shredding and treatment processes has continued to improve the returns to Trail Operations. Further expansion of the existing e-waste processing business is limited due to the lack of available economic feed materials. Whole e-waste is expensive to transport, which creates a relatively small region from which feed material can be sourced economically. There are also legislative hurdles to processing e-waste from the North Western United States. Although incremental expansion of the e-waste processing business would be a positive strategy for Trail Operations from both economic and sustainability perspectives, the lack of economic feed materials limit the opportunity for this strategy to have a material impact on the long-term profitability of Trail Operations.

An alternative approach for Trail Operations is to invest in the construction and operation of the #4 Slag Fuming Furnace and the Settling Furnace to allow for the economic processing of e-scrap. E-scrap is uneconomic to treat in the existing process because the current infrastructure does not allow for the recovery to a saleable product of copper and precious metals contained in e-scrap. This paper explores the expanding supply of e-waste and e-scrap, the regulatory environment affecting the collection and processing of e-waste and e-scrap and the forces impacting overall industry structure. The strengths and weaknesses of Trail Operations will be examined to identify Trail's competitive advantage in this industry and where Trail should be positioned in the market. Finally, the paper proposes recommendations on how Trail Operations should proceed in the e-waste and e-scrap industry. Four specific exclusions of this project include the technical feasibility study, the financial business case, a detailed supply and demand analysis and an evaluation of the required administrative systems. Work is being completed in these areas outside the scope of this project and the recommendations arising from this project must be considered in conjunction with this other work.

Growth in E-Waste Recycled and the Impact of Government Regulation

The amount of e-waste generated is growing and it is being driven by three key sources: the addition of new electronics consumers due to greater global accessibility; the greater scope of use of electronics in the daily lives of existing electronics users; and the continued obsolescence of electronics. The total amount of e-waste generated in 2009 from Canada, the United States and the European Union was estimated to be 7.78 million metric tonnes. This is expected to increase to 11.37 million metric tonnes by 2020 with the greatest growth occurring in the United States. The disposal of this increasing amount of e-waste has become a global problem. The majority of e-waste generated in developed countries still reports to landfills and incinerators or is exported. The exported e-waste is often transported to developing countries, which also have increasing internal e-waste disposal problems, where 'backyard' processing techniques are used to recover the valuable metals. These unsafe processing techniques and the dumping or burning of the residual e-waste are causing significant health and environmental problems in developing countries.

Although the amount of e-waste generated is growing, the other important factor that will determine the market supply for e-scrap is the amount of e-waste that is recovered to the recycling chain. In 2009, the combined amount of e-waste recycled in Canada, the United States and the European Union was estimated at 2.46 million metric tonnes for a recovery rate of 32%. The recovery rate is forecast to reach 44% by 2020, which will increase the amount of e-waste recycled to 5.00 million metric tonnes. Assuming that the mass of e-scrap from e-waste is approximately 10% of the total recycled e-waste stream, a total of 250,000 metric tonnes of e-scrap was available for processing in 2009 from North American and European markets and an increase to 500,000 metric tonnes of available e-scrap is forecast by 2020. This growth in available e-scrap suggests there is a need for additional processing capacity to ensure the environmentally responsible recovery of the valuable metals contained in e-scrap.

The single largest influence on the recovery rates of e-waste to the recycling chain is the enactment of new legislation and regulations by governments around the world. The patchwork of legislation at various levels of government has resulted in a wide variety of laws and regulations, but the clear global trend is to expand legislation to promote the recycling of e-waste. Most provinces in Canada have passed or are drafting e-waste legislation to apply to the recycling of e-waste. In the United States, 30 states have passed or have introduced electronics recycling legislation by the end of 2010. The European Union is the leader in regulating the recycling of e-waste with the passage of the WEEE and RoHS Directives in 2003. More recently higher recovery targets have been introduced in the European Union to further increase the amount of e-waste diverted to recycling processes. The European Union has also implemented regulations to prevent the export of e-waste to developing nations, but similar laws have yet to be passed in Canada and the United States. Harmonized recycler qualification regulations, like the one used in several Canadian provinces, and third-party certification standards for e-waste management will help reduce export of e-waste to developing countries from North America until legislation is passed.

Industry Analysis

An analysis of the e-waste recycling industry structure using the Porter's Five Forces approach was completed. The groups examined in this analysis were suppliers, customers, competitors, potential entrants and substitutes. An evaluation of the balance of power between potential suppliers and customers of Teck was one aspect of this analysis. With respect to suppliers, the balance of power should be with Teck, assuming no great supply and demand imbalance exists between the suppliers and end-processors. This is due to the ease with which Trail Operations can switch to alternative feed sources; the limited number of smelters that the e-scrap suppliers can sell to; and the inability of suppliers to vertically integrate into the end-processing operations due to high barriers to entry. The buyer group would also have limited power in its relationship with Teck since the black copper product from the Settling Furnace is simply a commodity that could easily be sold to numerous buyers.

The analysis of the competitors provides information on the history, capabilities and strategies of the existing companies that are processing complex e-scrap streams in integrated smelters. The 'big six' companies competing in this environment are Aurubis, Boliden, Dowa, LS Nikko, Umicore and Xstrata. An improved understanding of these companies will assist Teck in identifying where it should be positioned within the industry. The factor that will drive rivalry between these firms is the availability of e-scrap and other secondary materials. Current supplies of e-waste and e-scrap and expected growth rates for the amount of e-waste entering the recycling chain indicate that there should be sufficient supply for the existing firms and a new entrant such as Teck. There have been announcements by several of these companies regarding the construction of additional processing capacity. Since capacity must be added in large increments due to the capital intensity of these projects, the industry could see alternating periods of under and oversupply. When there is an undersupply of e-scrap, it is essential that Teck have the ability to increase or to switch to other secondary materials for processing.

New entrants into the e-scrap processing portion of the industry would augment the processing capacity of the industry and increase competition for the supply of e-scrap. Although a new entrant could have a large impact on the supply and demand balance, there are several barriers to entry that would limit the number of new entrants. The key barriers are the financial resources for the capital investment required, the large economies of scale required and the technical knowledge to construct and operate an integrated smelting facility.

For the purposes of this paper, the threat of substitutes is considered to be the alternative activities that could occur to reduce the mass and/or the value of e-waste and e-scrap in the recycling chain. The first possible substitute is to send e-waste to the municipal waste stream. In this case, the amount of e-scrap available for treatment may be held constant or grow more slowly than predicted due to low recovery rates to the recycling chain. Another substitute is the export of e-waste to locations with poor recycling infrastructures. This would also impact the amount of e-waste entering the formal recycling chain. Another substitute would be a change to the types or amount of materials used by electronics producers in the manufacture of their products. This would reduce the mass and/or the value of the e-scrap generated.

Scenario planning is a technique of developing a sequence of possible events outside the control of a firm and then testing proposed decisions against those alternative possibilities. A scenario analysis was completed for this paper to evaluate the impact of metals prices and government regulations on the implementation of the #4 Slag Fuming Furnace and the Settling Furnace project. This analysis indicated that the strategy of entering the e-scrap processing business is reasonable under each of the scenarios considered. Overall, the e-scrap market brings the potential for both greater risks and rewards to Teck, but Teck can take actions to improve its position in the industry under the less favourable conditions. A more rigorous financial evaluation outside the scope of this paper could provide numerical support for the upside and downside potential of each scenario.

Additional issues were considered in the development of recommendations on entering the e-scrap processing business. The first issue was administrative systems. A brief review is provided of the administrative systems that would need to be evaluated, if a decision is made to enter this business. A second issue for consideration was the numerous stakeholders that could be impacted by the implementation of this project. The key stakeholder groups are identified and a description of the key issues for each of these groups is given. The final issue was strategic fit with the current organization. This section of the paper describes how expansion into the processing of e-scrap and other secondary materials is a good strategic fit with Trail Operations and Teck Resources as a whole.

Trail Operations Strengths, Weaknesses and Competitive Advantage

An analysis of a firm's internal strengths and weaknesses is needed to fully understand the source of a firm's competitive advantage. As the business environment around a firm shifts and evolves, a firm must find new ways to apply their existing strengths to maintain a competitive advantage. An examination of Trail Operations' strengths and weaknesses was used to determine whether or not Trail Operations could develop and maintain a competitive advantage in the e-waste and e-scrap processing industry. The six key strengths identified for Trail Operations were financial resources; unique smelting technology; integrated processing capabilities; management of hazardous metals; knowledgeable human resources; and Western North American location. Four important weaknesses were also identified for Trail Operations consisting of being a new entrant to the industry; no precious metal refining capacity; high labour and construction costs; and lack of required organizational structure.

The analysis of these strengths and weaknesses indicate that Trail Operations could develop a competitive advantage in the e-scrap processing industry through the adoption of an appropriate strategy. Teck should adopt a focus strategy that allows it to capitalize on its most valuable, rare and difficult to imitate capabilities, which are unique smelting technology, integrated processing facilities and knowledgeable human resources. This strategy should target e-scrap and other secondary feed materials that compliment Trail Operations' processing capabilities and are a poor fit with the metallurgy of other facilities. Implementation of this approach will reduce competition for feed materials and will assist Teck in securing a niche within the e-waste and e-scrap processing industry.

Recommendations and Conclusions

The recommendations put forward in this study are based on the assumption that the technical feasibility study and economic evaluation support the approval of the #4 Slag Fuming Furnace and Settling Furnace project. If this assumption holds true, there are several actions that should be taken to position Teck in the e-scrap market and increase the probability of a successful entry into the e-scrap processing industry.

- Continue to inform key stakeholder groups regarding Teck's decisions concerning the new strategy to expand the processing of secondary materials at Trail Operations. This will assist in maintaining Teck's social license to operate.
- Develop a marketing plan to promote Teck's entry into the e-waste and e-scrap processing industry and to increase industry knowledge of Trail Operations unique processing capabilities and preferred feed materials. Assign the necessary resources to establish a network of business relationships within the industry.
- Trail Operations should target e-scrap feeds such as low-grade e-scrap, high zinc and lead bearing streams and irregularly sized materials as feed to the #4 Slag Fuming Furnace. A feed specification should be established to assist with the evaluation of potential secondary raw materials from e-scrap feed streams and recyclables from other industries.
- Teck needs to evaluate the optimal business structure for entry into the e-scrap processing industry. It is recommended that Teck investigate options for strategic partnerships with firms already in the recycling industry rather than using a vertical integration approach. This should help Trail Operations access e-scrap from areas of high generation in North America such as California and the North Eastern US.
- Trail Operations must ensure the business systems are in place to support business expansion. This applies to areas such as contract management, accounting systems, transportation, regulations and certifications.
- Teck should assign a resource to monitor the industry environment given the new and dynamic nature of the industry. This would involve monitoring of e-waste generation and recovery forecasts, changes to international waste legislation, evaluation of competitors and estimates of the supply and demand balance for e-scrap.

- Trail Operations should consider assigning an individual to co-ordinate these business activities as part of the implementation team for the #4 Slag Fuming Furnace and Settling Furnace Project.

As an overall strategy for e-waste and e-scrap processing, Teck should target achieving a global leadership position in the processing of e-scrap amongst the existing ‘big six’ players in the market within the next five years. Trail Operations must focus on the sourcing of feed materials from around the globe that are uniquely suited for treatment at Trail Operations and will increase the profitability of the facility. This would include lower-grade e-scrap feeds, without payable terms for gold, silver and PGMs; e-waste and other secondary feeds that are a particularly good fit with the metallurgy of a zinc – lead smelting complex; and irregularly sized feeds that cannot be treated in many competitors’ facilities. By selecting feed materials that are uniquely suited to Trail Operations, Teck will be able to leverage its unique smelting technology, integrated processing facilities and knowledgeable human resources to secure a competitive advantage over existing firms.

Recycling will be a key component in the future of metals production. Increased global demand for metals will outstrip the capacity of the primary resource industry to provide feed materials. Additionally, the expectation of the global society is for increased recovery of metals from secondary sources to reduce the environmental footprint of metals production. Entry of Teck’s Trail Operations into the processing of e-scrap and other secondary materials will enable the company to participate in the mining of the future, not just the past.

Dedication

To my family – Mike, Dylan, 'Jo', Maryetta, Hugh, Helen, Rick, Angela, Trevor, Anne & Bryan.

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Glossary

#2 SFF	#2 Slag Fuming Furnace
#4 SFF	#4 Slag Fuming Furnace
ACES	Atlantic Canada Electronics Stewardship
ARMA	Alberta Recycling Management Authority
BAN	Basel Action Network
CAGR	Compound Annual Growth Rate
CRT	Cathode Ray Tube
EHF	Environmental Handling Fee
EPSC	Electronics Product Stewardship Canada
ESABC	Electronic Stewardship Association of British Columbia
E-scrap	The components of e-waste with a high metal value. This is primarily PWBs from computers, televisions, cell phones, etc.
e-Stewards	e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment
E-waste	End-of-life electronics. Typically includes computers, monitors, peripherals and televisions. Definition is expanding to include most items with a power cord including small and large appliances.
EU	European Union
ISRI	Institute of Scrap Recycling Industries
LME	London Metal Exchange
NGO	Non-Governmental Organization
OECD	Organization for Economic Co-Operation and Development
OEM	Original Equipment Manufacturer
OES	Ontario Electronic Stewardship
PGM	Platinum Group Metals, which include platinum, palladium, iridium, rhodium, osmium and ruthenium
Primary material	New source of raw material from mines
PWB	Printed Wire Boards. Also, another term for circuit boards
R2	Responsible Recycling Practices for Electronics Recyclers
RIOS	Recycling Industry Operating Standard
Secondary material	Raw material sourced from previously manufactured products
SF	Settling Furnace
Shredded e-waste	E-waste that has been broken down and reduced in size for further processing.
SWEEP	Saskatchewan Waste Electrical Equipment Program
Treatment Charge	The fee paid by miners to refiners for the processing of the mine output
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency
WEEE	Waste Electronic and Electrical Equipment. Another term for e-waste.
WEELABEX	Standard for operators in the European WEEE management industry
Whole e-waste	E-waste that exists in its original manufactured form.

1 The Contribution of Recycling to Teck's Trail Operations

1.1 Mining of Urban Ore and the Long-Term Viability of Trail

The recent markets for zinc and lead refiners have been challenging and further pressure on refiners is expected in the future, which could threaten the viability of Trail Operations. The growth in demand for zinc has been flat or has declined over the past 10 years, except in Brazil, Russia, India and China (BRIC). (Agg & Stonkus, 2010) A sharp drop in demand for zinc in 2007 and 2008 resulted in mine and refinery closures as well as production curtailments as London Metal Exchange (LME) prices for zinc dropped from a high of $US 2.10/lb in November 2006 to a low of $US 0.48/ lb in October 2008. (London Metal Exchange) Prices have since rebounded to over $US 1.00/lb and many of the mines and refineries have restarted. Going forward in the next ten years, refining capacity is expected to grow as new facilities come on-line while mine production is not expected to keep pace with refined capacity due to mine closures and insufficient new mine openings. (Agg & Stonkus, 2010) This structural change in the industry is expected to push down the treatment charges paid to zinc refiners, which is the fee paid by a miner for the processing of concentrates. Since the supply and demand balance for zinc concentrates will strongly favour the zinc miners, it will squeeze the profitability of zinc refiners.

The lead market has been somewhat different in terms of supply and demand. The refined lead balance was negative for 2004 through 2007, and small surpluses in the subsequent years have left stocks for refined lead well below the 25-year average. (Agg & Stonkus, 2010) Lead concentrate production and refined lead capacity have both expanded in efforts to match increased global lead consumption, which has benefited both miners and refiners. (White, 2010) Looking to the future, the mine production of lead concentrates is forecast to be flat over the next five years while modest increases in refined lead capacity are expected. (Wilson, 2010) This situation will also push down treatment charges for lead concentrates and reduce the revenue to lead refiners.

Trail Operations is a zinc and lead refiner and it has been affected by these market changes, but there are other factors at Trail Operations that threaten its profitability. The location of Trail Operations is based on historical mining properties. Its land-locked position, far from ports and the United States Interstate road system, is not ideal to receive raw materials and ship final product, and increasing transportation costs will have a measurable impact on the profitability of Trail Operations. The current feed mix at Trail Operations includes large stockpiles of historical materials. These materials contain significant metal value at low cost to the Operation. The realized margin from filling the process streams in the smelter with new feeds is expected to decrease in the future as these low cost stockpiles are consumed and the market for zinc and lead concentrates favours the miners. Labour costs are another consideration for Trail Operations. The labour force at Trail Operations is highly skilled, but the cost is higher than the cost of labour at the new facilities being constructed in China and India.

Trail Operations does have significant assets that can be leveraged for business success. An important factor contributing to the current low cost of production at Trail Operations is the access to low cost power through the Waneta dam. This is a secure, long-term source of power and it is a competitive advantage in the refining business. Relative to other zinc producers in the world, Trail Operations is a low cost producer of zinc and is in the upper quartile of all refineries on a cost per pound of zinc produced basis. (Agg & Stonkus, 2010) The large, complex metal refining infrastructure at Trail Operations, which can be used to process a wide range of feed materials, not just zinc and lead concentrates, is another critical asset. Trail Operations also has the technical skills and the culture of innovation necessary to produce a variety of high quality metal products.

The mining of urban ore presents an interesting opportunity for Trail Operations that is worth exploring. Urban mining can be described as "the process of reclaiming compounds and elements from products, materials and waste" and is often considered a secondary source of materials. (UrbanMining.org) In contrast, primary materials are substances that are sourced directly from mines. Although many items can be considered urban ore, the mining of e-waste and e-scrap is particularly attractive to a smelting operation. E-waste is defined for the purposes of this paper as all end-of-life waste electrical and electronic equipment (WEEE), either in its original manufactured form or shredded. It includes computers, monitors, televisions, computer peripherals, cellphones, audio equipment, household appliances, digital cameras, lighting equipment, telecom equipment, electrical tools, etc. E-scrap is defined as the high metal value streams separated from the combined e-waste stream and typically consists of various printed wire boards (PWBs) from computers, televisions, cellphones, etc. and can be graded based on the value of the contained metals. The high value in the PWBs comes from the contained copper, gold, silver and platinum group metals (PGMs) used in the manufacture of these items. The volume of e-waste and e-scrap is increasing due to higher consumption of electronics and to increased recycling activities brought about by societal demands for protection of the environment and by waste management legislation. The contained metal value of the e-waste and e-scrap is significant. One source has estimated that 1 tonne of personal computers contains more gold than what is recovered from 17 tonnes of gold ore. A tonne of cell phones, which is about 6,000 handsets, contains 3.5 kilograms of silver, 340 grams of gold and 130 kilograms of copper. At February 2011 metals prices, the value of this metal is over $US 19,000. (Electronics Takeback Coalition, 2010)

Currently, there are six major smelters in the world that are processing appreciable quantities of e-scrap. Announcements of capacity increases at some of these smelters and indications from sellers of e-scrap suggest that the supply of e-scrap is already close to, if not greater than, the existing capacity of smelters to process it. The potential for significant industry growth, high metal values in feed material and insufficient smelting capacity suggest that that an investigation into the processing of e-waste and e-scrap as a business strategy to improve the long-term viability of Trail Operations is a worthwhile undertaking.

This first chapter will provide background information on the history of Trail Operations and the existing recycling activities on the site. This will provide information on the general capabilities and strengths of Trail Operations as well as a brief account of Teck's first steps into mining of urban ore. A detailed description of the development and current status of e-waste processing at Trail Operations will set the stage for an evaluation of potential business opportunities relating to future e-waste and e-scrap processing. The first chapter closes with an outline of the key areas discussed in this paper, a description of the project scope and a listing of the specific project inclusions and exclusions.

1.2 History of Trail Operations

The processing of metal began in 1896 at what was to become the City of Trail, British Columbia (BC) when a copper and gold smelter was built to process the metal ore generated by the mines from nearby Rossland. (Reference for Business) The smelter was purchased by the British Columbia Southern Railway Company, a subsidiary of the Canadian Pacific Railway (CPR), in 1898. The Consolidated Mining & Smelting Company Ltd., also a subsidiary of the CPR, was incorporated in 1906 by joining together the smelting operation with the local mines that were supplying the ore. The company became known as Cominco Ltd. in 1966. The 1980s were a difficult decade for Cominco with poor economic times, high interest rates and high debt from modernization activities and the start-up of new operations. In 1982, Cominco recorded its first loss since 1932 and by 1985 the company had accumulated $CDN 1 billion in debt. To improve its balance sheet, Cominco sold many of its non-core assets during this time. In addition, CPR sold its controlling stake of Cominco in 1986, part of which became Teck Corporation's initial interest in Cominco. Teck purchased a controlling stake in Cominco in 2001 and Trail Operations became part of Teck Cominco Metals Ltd. (Rossland Museum Archives, 2002) The name of the company was changed to Teck Metals Ltd. in 2009.

Trail Operations began as a copper and gold processing facility, but lead was soon added as a product with the installation of three lead blast furnaces by 1901. Silver was the next major product at Trail with the first silver refinery beginning operation in 1904. Zinc was considered a waste metal from the Sullivan lead mine in Kimberly, BC until demand for zinc increased during World War I and Canada's first electrolytic zinc plant began operation in 1916 at Trail. Synthetic fertilizer production began in 1931 to capture the environmentally damaging sulphur dioxide gas from the metal refining operations. Cadmium, indium and germanium were also added as products over time. Trail Operations has developed into one of the largest and most complex zinc and lead smelting operations in the world. (Rossland Museum Archives, 2002)

The operations at Trail have also been known for technical innovation and advancement. (Fish, 2006) The first commercial-scale lead electrorefining process, known as the Betts process, was constructed in 1902 and started the lead refining business in Canada. Ralph Diamond and his research team at Trail developed differential flotation to separate the lead, zinc and iron sulphide ores at the Sullivan mine leading to the construction of a concentrator that began operating in 1923. Lead smelter slag fuming was pioneered in 1930 to improve metal recovery and enhance environmental performance and is still in use today. Indium and germanium processing capability was added over the years using proprietary technologies. Large gains in productivity were made over the past 30 years through innovations that allowed production to be maintained while reducing employees from about 4,000 people to about 1,500 people today. The Russian developed Kivcet flash lead smelter began operation in 1997. It significantly improved the overall environmental performance of Trail Operation and added to the capacity for treating a unique blend of feeds. In 2006, the novel process of treating electronic waste in a slag fuming furnace was added.

1.3 Lead Acid Battery Recycling

Over the years, Trail Operations has developed various methods for the processing of secondary materials such as lead acid batteries and electronic waste to compliment the processing of primary feeds. Lead acid battery recycling was the first step for Trail Operations into the world of processing large quantities of secondary materials. Lead from vehicle batteries now accounts for up to 25% of the refined lead produced at Trail Operations. The closed-loop process provides a cradle-to-cradle solution for the management of lead that protects the environment and preserves natural resources. (Teck Metals Ltd., 2010) Lead acid battery recycling began around 1982 when Murray Bayley started collecting and breaking used lead acid batteries in Innisfail, Alberta and shipping the lead from the old batteries to Trail Operations for processing into new lead ingots. Due to transportation issues between Innisfail and Trail, Murray decided to relocate his operations about 10 km south of the smelter and established K.C. Recycling in 1988. These facilities have continued to prepare batteries for processing at Trail Operations for over 20 years. (Bayley, 2011) (Hamilton, 2011)

Teck worked with the British Columbian government and other stakeholders to establish the BC Used Lead Acid Battery Collection program in June 1991 as an environmental protection initiative, the first of its kind in Canada. (Government of British Columbia) At the time, it was estimated that 60% of used lead acid batteries were being stockpiled or sent to landfill because it was uneconomic to transport the batteries for processing. The BC program charges a $5 consumer levy on the sale of new lead acid batteries to subsidize the cost of transportation of used batteries to processors. The objective of the program is to recover at least 98% of all used lead acid batteries to the recycling program. (Government of British Columbia, 2007)

1.4 E-waste Recycling

Electronic waste recycling at Trail Operations began as a development project in 2003. The old #2 Slag Fuming Furnace (#2 SFF), which had been shutdown with the start of the Kivcet furnace in 1997, had been refurbished and restarted in 1999 to process a 260,000 tonne stockpile of zinc-rich slag. This slag is a by-product of the lead smelting operations and the fuming process can recover the contained zinc and other metals into a saleable product. This furnace provided the installed infrastructure to handle e-waste with only minor equipment modifications. At the same time, the generation of e-waste was starting to be recognized as a growing environmental issue that needed a solution. Legislation around the world was being proposed for the collection and processing of e-waste. Since the processors of e-waste are paid a fee for providing this service, the addition of e-waste through the #2 SFF presented an opportunity to increase the revenue generated from existing infrastructure.

1.4.1 Trail Operations Process Description and Government Approval

A brief process description of the unit operations at Trail Operations is helpful for understanding the current e-waste and e-scrap processing capabilities of the facility. The treatment of e-waste at Trail Operations begins by blending shredded e-waste with the slag feed material and charging the mixture to the #2 SFF (Figure 1). The furnace operates at 1200°C and separates the feed material into three phases – fume, slag and matte. Some elements, such as zinc, lead and cadmium, deport to the fume phase, and are captured in a baghouse prior to being processed into products at downstream facilities. The clean slag contains the silica, lime and iron and has become a value-added product used in the manufacture of cement. The matte phase currently travels with the slag and is not recovered as a separate product. The lack of recovery of the matte phase currently limits the ability of Trail Operations to process e-scrap, which contains copper, gold, silver and platinum group metals that deport to this phase. Plastics, wood and other organics in the e-waste stream provide fuel to the furnace resulting in the generation of steam that is used to heat process vessels elsewhere on the property.

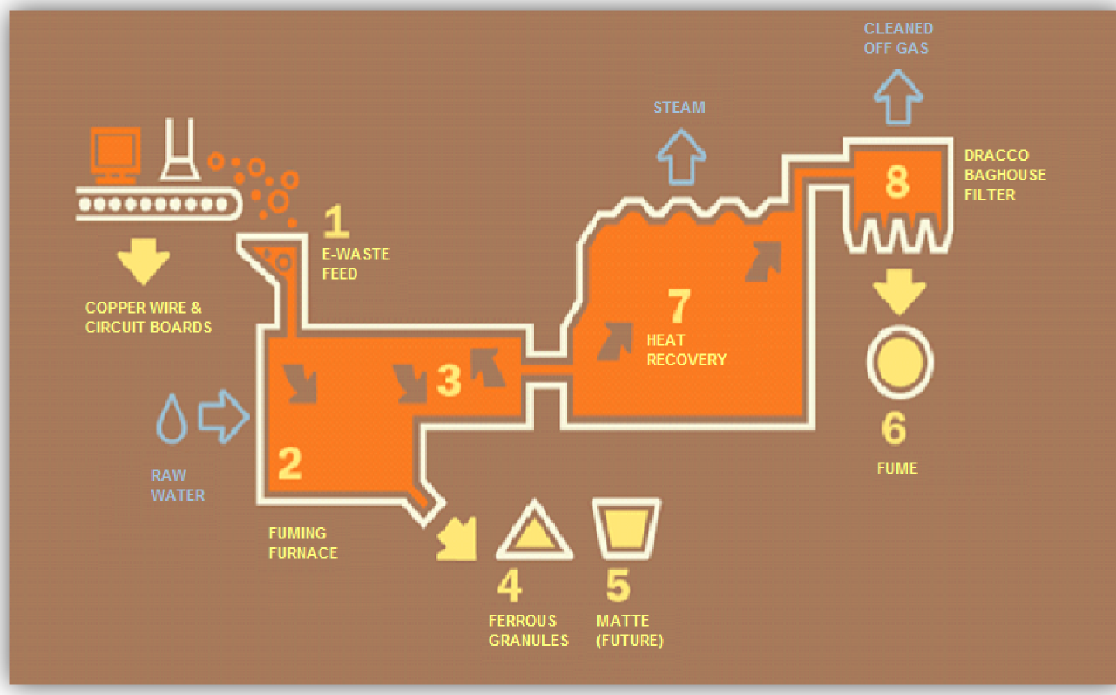

Figure 1. Trail Operations' E-waste and E-Scrap Process. (Ford, 2006).

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Extensive testing was required to prove the concept of treating e-waste through the #2 SFF. Two large-scale tests were conducted in 2004 to test the environmental impact and the technical feasibility of the process. The results of these tests were documented and submitted to the BC Ministry of Environment and Teck was granted a temporary 12-month permit to test continuous operation of e-waste processing in #2 SFF beginning in May 2006. Close monitoring of the operation in 2006 and 2007 enabled Teck to demonstrate the negligible impact of processing e-waste along with the existing slag feeds to the furnace. A long-term permit for the processing of e-waste through #2 SFF was granted in 2007.

1.4.2 Improvements and Expansion of E-waste Pre-Processing

Whole e-waste and cathode ray tubes (CRTs) are collected as part of recycling programs in Canada, typically in their original manufactured form. These materials must be pre-processed before they can be included in the feed stream to #2 SFF. K.C. Recycling provides the service of shredding the whole e-waste into small enough pieces for treatment through the #2 SFF. When the operation began in 2006, all of the e-waste was processed through the shredding process, without any dismantling or sorting. Everything, including the pallets and shrink wrap, reported to the shredded e-waste stream to #2 SFF and nothing reported to landfill.

The operations at K.C. Recycling have evolved to maximize the value gained from processing the e-waste and to reduce environmental impact. Rather than shredding all of the e-waste into a single stream to be processed, it is now segregated into multiple streams as shown in Figure 2. The steel, aluminium, copper wire and PWBs are sold to downstream processors who recover the metal values into new metal products. Since Teck cannot process these streams into new metal products, this approach has greater value to Teck than including these materials as constituents in the sale of slag to cement manufacturers. It also reduces the requirement for new primary sources of these metals in society. The CRT glass is now treated separately in the Kivcet furnace, which expands Teck's capacity to treat CRTs and reduces the need to purchase silica from a mine. Wooden pallets, which used to be included in the feed to #2 SFF, are now reused where possible or are shredded and consumed in a local cogeneration facility to generate steam and electricity. The remaining material is the shredded e-waste feed to #2 SFF and includes plastics, materials that were not fully segregated in upstream processing and other miscellaneous items.

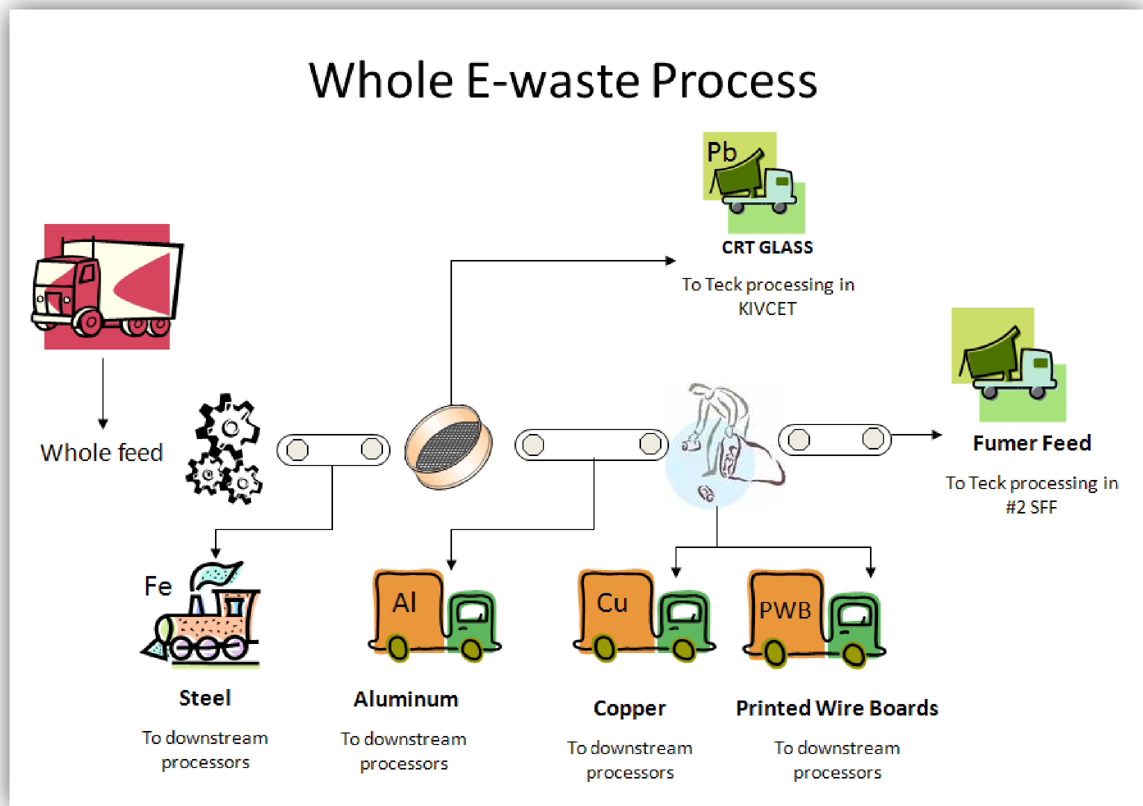

Figure 2. Pre-processing of Whole E-waste at K.C. Recycling. (Ford, 2009)
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1.4.3 Current Status of E-waste Recycling

The collection of e-waste is expanding in Canada as more programs become established and as consumers become more educated about these programs. The Alberta program began in 2004 and was followed in 2007 by the British Columbian and Saskatchewan programs. (ARMA), (SWEEP, 2007), (ESABC, 2008) Nova Scotia started the Atlantic e-waste program in 2008 with Prince Edward Island joining that program in 2010. (ACES) Ontario began an e-waste collection program in 2009. (OES) In British Columbia, the 2009 Electronics Stewardship Association of British Columbia (ESABC) annual report showed a year-over-year increase of almost 30% in the amount of e-waste collected, totalling over 14,000 metric tonnes in 2009. The report also stated that consumer awareness of the provincial e-waste recycling program had increased to 84% of the population in BC. (ESABC, 2010) The BC program began with only computers, computer peripherals and televisions, but it has continued to expand the types of items that are accepted in the program. On July 1, 2010, the program added other consumer electronics such as VCRs, DVD players, stereos, MP3 players and cameras. (ESABC, 2010) Further expansions are planned including the addition of small household appliances in April 2011 and large appliances, tools and lighting equipment in July 2012 (Table 1). (BC MOE)

	Phase 1	***Phase 2***	***Phase 3***	***Phase 4***
E-waste Products	• Televisions • Computers • Computer monitors, keyboards, mice and other peripherals • Printers	• Audio-visual and consumer equipment • Thermostats • Cell phones • Residential fluorescent lamps • Batteries used in Phase 2 products	• Small appliances • Smoke detectors • Batteries used in Phase 3 products	• Large appliances • Electrical and electronic tools • Medical devices • Automatic dispensers • Lighting equipment • Toys, leisure and sports equipment • Monitoring and control instruments • IT and telecommunications equipment • Batteries used in Phase 4 products
Stewardship Plan Submitted to Ministry	Completed 2007	January 1, 2010	July 2010	October 1, 2011
Launch Recycling Program	Completed 2007	July 1, 2010	April 2011	July 1 2012

Table 1. The Implementation Phases for E-Waste Product Recycling in BC. (BC MOE)

Trail Operations has benefitted from increased collections in the British Columbia program as well as the other Western Canadian programs (Figure 3). Whole e-waste is received from the BC program, plus CRTs are accepted from other e-waste processors in BC, Alberta and Saskatchewan. Trail Operations will achieve 50,000 metric tonnes of e-waste processed by the middle of 2011 from these sources.

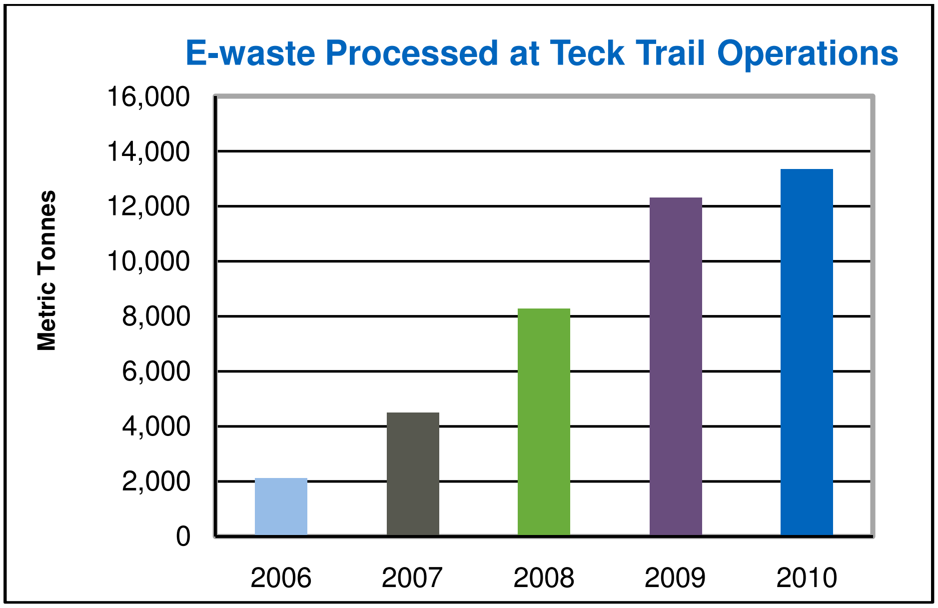

Figure 3. Growth in E-waste Processed at Teck Trail Operations. (Ford, 2011)

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1.4.4 Incremental Expansion of E-waste Processing at Trail Operations

Incremental expansion of the processing of e-waste using the existing infrastructure is one possibility for improving the financial performance of Trail Operations. Trail Operations would continue to source whole e-waste, contract K.C. Recycling to separate it into various material streams, process the fumer feed stream through #2SFF and sell the other segregated streams to external companies for further processing. Both K.C. Recycling and Teck have the infrastructure to significantly increase the processing of whole e-waste and the fumer feed stream to #2 SFF. Some additional operating costs would be incurred due to increased treatment of these materials, but the margin per additional unit processed should be the same or better than the existing margins.

The challenge with incremental expansion of the existing e-waste processing business is with sourcing additional feed materials. Currently, all of the whole e-waste processed through K.C. Recycling originates from the British Columbia recycling program. There are several primary recycling contractors who disassemble whole e-waste in BC, and the ESABC program decides how the material collected is allocated between the various primary recycling contractors. Since market share is controlled by the ESABC, the only opportunity to increase the supply of whole e-waste from British Columbia to Trail Operations is for overall collections to increase or if another company exits the business. Whole CRTs from other recyclers in the province are sent to Trail for final processing since it is the closest facility for final disposition of the lead containing glass. Increasing the mass of whole CRTs would be dependent on increased collections in BC.

Sourcing e-waste from other jurisdictions is also problematic. Both the Alberta and Saskatchewan programs require that all of the disassembly of the whole e-waste collected through primary contractors be located within their respective provinces. These recyclers send whole CRTs to Trail Operations for final processing because of Trail Operations' capability to process lead bearing materials, but nothing else is received from these provinces. The states of Washington and Oregon also have e-waste recycling regulations. In 2009, Washington collected and processed over 17,900 metric tonnes of e-waste and Oregon processed over 8,500 metric tonnes compared to 14,000 metric tonnes processed in British Columbia. (E-Cycle Washington, 2011), (Oregon E-Cycles, 2010) None of the whole e-waste or CRT glass collected in those programs are sent to Trail for processing. It is unlikely that material from these programs would come to Trail because of legal concerns regarding the application of state environmental laws to Trail Operations and the rights of state government departments to audit Trail Operations. Other states within close proximity to Trail, such as Idaho, Montana and Wyoming, do not have electronic waste collection regulations. The fee charged for the processing of whole e-waste is insufficient to cover the cost of transportation of e-waste from jurisdictions that are much farther away.

Another possibility for increasing e-waste processed at Trail Operations might be to work with large corporations to be the sole processor of e-waste generated by those organizations. Signing contracts with organizations such as Telus, Future Shop or Dell to process their e-waste could increase the supply to Trail Operations. There are some potential problems with this approach. First, the cost of transportation of e-waste generated in Eastern Canada would be prohibitive, so Trail Operations could not offer a national program. Second, these firms can already access the existing e-waste recycling programs in Western Canada. Teck would have to agree to substantially lower processing fees to offer sufficient value to the companies that might consider this approach. Overall, it is unlikely that attempting to establish contracts to process e-waste from large corporations would add much, if any, to the profitability of Trail Operations.

Some opportunities do exist for expanding the current mass of e-waste processed. The supply of leaded cullet, which is the crushed, high lead funnel glass from a CRT, is expected to increase in the near term. This is due to declining global CRT demand causing a reduction in the flow of CRT glass being recycled back to glass-to-glass manufacturers while significant quantities of old CRTs are still being recycled. Leaded cullet is produced by some e-waste disassemblers by separating the low lead panel glass from the high lead funnel glass of the CRT. The low lead glass stream can be used in many applications and can be sold into many markets. The high lead stream, called leaded cullet, is considered a hazardous material and needs to be processed in a facility that can separate the lead from the glass in an environmentally sound process, such as the Kivcet furnace. Leaded cullet could be sourced from both Canada and the United States. The amount of CRT glass being collected for recycling in North America is expected to start declining in the middle of the current decade with the collection rate in 2020 being less than half of 2010 levels. By treating leaded cullet, Trail Operations can increase lead production while providing an environmentally acceptable outlet for the high lead glass. The higher revenue generated by processing leaded cullet over crushed, whole CRT glass allows these materials to be transported over longer distances while maintaining a reasonable margin. (Gregory, Nadeau, & Kirchain, 2009).

Teck's experience with processing e-waste has also opened up alternative feeds that can be processed using the same fee-for-service business model. The ability of Trail Operations to process mercury bearing materials has enabled the treatment of fluorescent light bulbs as another secondary feed material. This feed stream is just starting to grow, but it could eventually expand to overtake CRT glass and leaded cullet treatment as the quantity of these materials decline in about five years. Zinc alkaline batteries present another recyclable feed option to Trail Operations. About 10,000 tonnes of end-of-life zinc alkaline batteries were forecast to be generated in Canada during 2010. The vast majority (>90%) are thrown into landfills each year, but legislation to collect batteries and to prevent disposal in landfills is expanding. Although regulations in North America prevent the use of mercury in these batteries, mercury is still found in batteries manufactured elsewhere in the world, which are consumed in North America. (US EPA) Trail Operations has the capacity to recover the zinc while effectively managing other metals such as mercury and would collect a material processing fee for this service. Trial shipments of both fluorescent bulbs and zinc alkaline batteries are currently being tested at Trail Operations to confirm technical and environmental feasibility. Some minor capital investment may be required to process these materials in larger quantities and would be assessed as individual cases for each feed material.

There is little financial risk of pursuing the strategy of incrementally expanding the treatment of e-waste since no additional capital investment in the business is required. Increasing throughput would simply maximize the value of existing assets. The true risk or limitation of this business opportunity is that it will only provide a small increase in the profitability of Trail Operations due to the lack of economic feed materials. It is a positive economic and social activity to pursue, but it is not a game changer that could alter the direction of Trail and impact the long-term viability of the Operation. To conclude, Teck should continue to expand e-waste processing as the opportunity arises, but it should not be the core of the strategy to improve the future financial performance of Trail Operations.

1.5 Capital Investment in E-scrap Processing Capacity

Rather than expanding the processing of whole e-waste, an alternative approach for Trail Operations is to invest in the construction and operation of additional smelting capacity to allow for the economic processing of the higher value e-scrap feed stream. This would involve the building of an additional slag fuming furnace and an electric settling furnace. The newly constructed and modern #4 Slag Fuming Furnace (#4 SFF) would enable significant increases in processing capacity for additional e-scrap feed, while the Settling Furnace (SF) would allow for separation of the slag phase from a concentrated copper phase called black copper. The black copper would be an unrefined copper stream containing high values of gold, silver and PGMs that would be sold for further refining. E-scrap is uneconomic to treat in the existing process because the current infrastructure does not allow for the recovery of a black copper stream. Copper and precious metal inputs from the processing of whole e-waste through #2 SFF are currently minimized by segregating these streams at K.C. Recycling and selling them to other processors. Additionally, this project would require the facilities at K.C. Recycling to be upgraded to adequately prepare and sample the e-scrap prior to processing at Trail Operations.

Deciding whether or not to pursue this expansion is an important decision for the future direction of Trail Operations. The rest of this paper will explore the expanding supply of e-waste and e-scrap, the regulatory environment affecting the collection and processing of e-waste and e-scrap and the forces impacting overall industry structure. The strengths and weaknesses of Trail Operations will be examined to identify the Operation's competitive advantage in this industry and where Trail Operations should be positioned in the market. Finally, recommendations will be proposed on how Trail Operations should proceed in the e-waste and e-scrap industry.

1.6 Project Scope

The scope of this project is constrained by confidentiality concerns and time constraints. This section outlines the specific inclusions and exclusions for the project.

1.6.1 Project Inclusions

This project will specifically examine the e-waste and e-scrap industry and the forces that are affecting the industry structure. A brief introduction to the e-waste and e-scrap market will be included. The current and likely future direction of government intervention and regulation will be discussed. An expanded Porter's Five Forces analysis will be completed on the major groups in the industry to identify the balance of power between the players. This will also include the role of the government and industry standards on shaping the industry. There are also key factors affecting the industry that are generally outside the control of those within the industry. Two of these key factors are government regulation and metals prices. A scenario analysis will be completed to examine the impact of changes to these factors on the overall industry.

Once the industry has been evaluated, this project will analyse Trail Operations' particular strengths and weaknesses. This analysis will be used to identify potential competitive advantages that could be leveraged by the company in the e-waste and e-scrap industry. Additional items will also be considered such as the impact of the new facilities on key stakeholder groups and the overall strategic fit of entering the e-scrap industry with corporate objectives. Finally, recommendations will be put forward regarding where Trail Operations should position itself in the e-waste and e-scrap industry and whether or not Trail should consider pursuing an expanded strategy as an urban miner that would reshape the vision for Trail Operations.

1.6.2 Project Exclusions

There are four specific exclusions for this project: technical feasibility study; financial business case; detailed supply and demand analysis; and administrative system evaluation. The technical feasibility study is being completed by a team of Trail Operations employees and external engineering consultants. The technology proposed for this expansion is well known and there is minimal conceptual uncertainty, but this study is needed to obtain engineering details and construction cost estimates. The financial business case is being developed internally using existing and new metallurgical models, various economic inputs and the capital cost estimate from the technical study. A detailed supply and demand analysis has been compiled using published secondary data and primary research from contacting companies within the industry. All of the technical, financial and supply information from these studies are critical to the decision on whether or not to proceed with the capital investment, but are confidential and are excluded from the scope of this project. The recommendations arising from this project must be considered in conjunction with this other work.

A detailed administrative systems analysis is being excluded from this report due to time constraints. This type of analysis would look at issues such as how to establish and maintain relationships with suppliers; managing contracts and setting contract terms; understanding the regulatory environment; optimizing transportation and logistics; modifying metallurgical and financial accounting systems; etc. A brief discussion of these items will be included in the paper. Although this analysis is not critical in the decision on proceeding with the capital investment, a thorough review of these items early on will improve the profitability and efficiency of the business.

2 Introduction to E-waste and E-scrap Recycling

2.1 The Generation of E-waste

Consumers expanding the use of electronics in all aspects of their lives and the electronics are becoming obsolete at an ever increasing pace. This translates into rapid increases in the both the sales and disposal of electronics. Televisions were once considered a durable good that was used for a decade or more, but with rapid changes in technology, many televisions are replaced after a shorter time span of only five to seven years. Computers have a replacement cycle of three to four years (Grobart, 2011) and almost one-third of all laptops fail within three years. (Square Trade, 2009) Cell phones are replaced, on average, less than every two years in North America, while the replacement rate in many other regions are closer to every four to five years. (Choney, 2009) According to an Accenture study, global consumer spending on electronics ranks third amongst all categories of lifestyle spending. This is after clothing and personal transportation but is ahead of recreation, travel and household furniture / appliances. The top items purchased in 2010 were high definition televisions, smartphones and computers and this trend is expected to continue in 2011. Other devices, such as CRT televisions, VCRs and standard mobile phones, are quickly declining in terms of both sales and ownership. (Accenture, 2011) The Consumer Electronics Association recently reported that it expects global retail sales of consumer electronics to increase by 10% in 2011 to reach $964 billion. (McGrath, 2011)

As new electronics are purchased, the end-of-life equipment is being added to the waste stream. A report on electronic waste recovery in Canada in March 2006 stated that 165,429 metric tonnes of e-waste were produced in Canada in 2005. (PHA Consulting Services, 2006) The report expects a growth rate of 11% over the next five years or 2.2% per year resulting in the generation of 184,301 metric tonnes of e-waste in 2010. Actual e-waste generated in Canada in 2009 was estimated to be 186,454 metric tonnes resulting in a higher compound annual growth rate (CAGR) of 3.0%. (Ford, 2011) The electronic waste recovery study also provided e-waste generation data on the United States. It reported 2.30 million metric tonnes were generated in 2005 and this was forecast to grow by 19% to 2.74 million metric tonnes by 2010 for a growth rate of 3.6% per year. (PHA Consulting Services, 2006) According to the United States Environmental Protection Agency (US EPA), consumer electronics make up less than 2% of the entire municipal waste stream, but it is growing at a steady rate. Over 2.38 million metric tonnes of electronic waste were placed in the municipal waste stream in 2005, which is close to the 2.30 million metric tonnes reported in the Canadian study. This had risen to almost 2.90 million metric tonnes by 2009, which is an increase of 21% or a CAGR of 5.0%. (US EPA, 2010) The generation of e-waste in the European Union (EU), which is more commonly described as waste electronic and electrical equipment (WEEE) in the EU, was estimated to be between 8.3 and 9.1 million tonnes in 2005 and is expected to grow at a rate of 2.5 – 2.7% annually to reach 12.3 million metric tonnes by 2020. (Huisman, et al., 2007) A key difference between the North American and European numbers for the amount of e-waste or WEEE generated is the North American data focuses on various consumer electronics sources of e-waste (i.e. televisions, computers, mobile phones, etc.), while the European definition also includes large and small household appliances, electrical tools, lighting equipment, etc. Many North American programs are expanding their definition of e-waste to be similar to the European approach, but this is not reflected in the historical values. Approximately 50% of the weight of e-waste generated in Europe consists of materials not included in North American e-waste numbers.

2.2 The E-waste Disposal Problem

The scope and consequences of the e-waste disposal problem varies based on national, regional and local legislation and regulations. For jurisdictions with well-established waste management programs but either new or poor e-waste collection programs and no e-waste disposal bans, most of these end-of-life electronics are discarded in the waste stream destined for landfills. This situation applies to much of North America and some countries in Europe. The consequences of sending e-waste to landfills include:

- Materials that are toxic to human health and ecosystems can be released to the environment (e.g. lead and cadmium).
- Access to recyclable material are lost, which translates into a greater need to process primary materials.
- Pressure on the capacity of landfills is increased.
- Opportunities to reduce greenhouse gas emission through the use of recyclable materials in new products is lost, since there is typically a net reduction in greenhouse gases released when recyclable materials are used as opposed to primary materials. (PHA Consulting Services, 2006)

As of 2005, it was estimated that less than 10% of end-of-life electronics were recycled in Canada. (PHA Consulting Services, 2006) This percentage is thought to have increased in the last 5 years based on increased collection infrastructure resulting from new legislation in many provinces. The US EPA report on Municipal Solid Waste indicates that the amount of electronic waste recovered from the municipal waste stream was about 170,000 metric tonnes in 2000, which is equivalent to 10% recovered. The amount recovered had increased to 540,000 metric tonnes or 19% recovered by 2009. (US EPA, 2010) This increase also supports the likely increase in recovery of e-waste in Canada due to the establishment of new recycling programs. The original EU WEEE Directive set collection targets of 33% of all WEEE generated. A 2007 report indicated that some member countries were above this target, such as Norway and Switzerland, while others like Austria and Hungary were below it, suggesting quite a range of collections between the member countries. The report also indicated the percentage of WEEE collected for various categories of WEEE varied significantly. For example, 26.6% of small household appliances were collected while to 40.1% of consumer electronics were collected. Overall, the WEEE collected in Europe was estimated to be 26.5% in 2005 and this is forecast to increase to 54.6% by 2011. (Huisman, et al., 2007) The new recycling target recently proposed in the European Parliament is to achieve 50 to 75% collection of all WEEE generated by 2016 depending on the category of WEEE. (Hall, 2011)

Even for material that is collected for recycling, not all of these electronics are managed in an environmentally and socially acceptable manner. Although exact numbers are not known, it is estimated that there are "large and often illegal export streams of e-waste into regions with no or inappropriate recycling infrastructure in place." (Schulep, et al., July 2009, p. 6) Part of the reason for the lack of data on the global e-waste trade is that the harmonized tariff schedules used for the export for most commodities do not exist for e-waste. (Schmidt, 2006) Data from 2002 estimates that as much as 50 to 80% of the e-waste collected for recycling in the United States was exported to developing countries rather than being recycled domestically. (Puckett, Westervelt, Gutierrez, & Takamiya, 2005) Although that number may be lower today due to a growing e-waste processing infrastructure in North America and the European Union, the problem of exporting e-waste continues. The US EPA recently fined two North American companies for the illegal export of e-waste to Vietnam. (Waste Management World, 2011)

The environmental and social costs of sending e-waste to locations with inadequate facilities for the processing of e-waste are severe and have been well documented. (Puckett, Westervelt, Gutierrez, & Takamiya, 2005) (Puckett, et al., 2002) The dumping of e-waste in countries with inadequate laws and regulations to manage the proper handling and recycling of the e-waste results in the exposure of people to heavy metals in the e-waste, such as lead and cadmium, as well as to the toxic chemicals and hazardous by-products (e.g. dioxins, furans, acids, cyanide) from the 'backyard' processing techniques. The well publicized images of piles of old computers, often burning in a field with a large amount of black smoke being expelled, or of children playing amongst discarded televisions with toxic pools of liquid all around them provide some perspective on the consequences of poor processing techniques. In addition to the direct environmental and social costs, there is also a significant resource impact to not recovering and re-using the materials that is similar to the negative impacts of landfilling these materials in developed countries. This includes the need to mine additional primary materials and increased greenhouse gas emissions. (Schulep, et al., July 2009)

Legislation and the enforcement of legislation to prevent the export of e-waste to certain countries is slowly expanding in both the exporting and importing countries. Public opinion and the desire of companies to demonstrate their adherence to socially and environmentally sustainable recycling is also causing a shift towards more responsible recycling practices. E-waste recycling standards are being developed, such as eStewards, R2, RIOS and WEEELABIX, which require recycling companies to meet strict guidelines on the handling and final disposition of e-waste. These standards do not allow for "backyard" recycling methods or the dumping of these materials. The increased generation and collection of e-waste along with the growing desire of society to ensure proper recycling of these materials may provide a unique opportunity for Trail Operations. There is the potential for Teck to gain a piece of this growing market and to increase the profitability of Trail Operations while also demonstrating its core value of being a sustainable and responsible corporation.

2.3 Estimate of the E-waste and E-scrap Market for Recycling

Although a detailed supply and demand analysis is specifically excluded from this paper, a rough estimate of the supply of e-waste and e-scrap can be generated from the published data that is described in sections 2.1 and 2.2 and is summarized in Table 1. Data for e-waste generated in Canada and the United States for 2005 and 2009 is available. (PHA Consulting Services, 2006) (Ford, 2011) (US EPA, 2010) For 2020, the e-waste generated was estimated by extrapolating from the 2009 data using CAGRs of 3.0% and 5.0% for Canada and the United States. Actual e-waste generation data in the European Union was available for 2005 along with a forecast CAGR of 2.5% for the period of 2006 through 2020. (Huisman, et al., 2007) The data for Europe in Table 1 is only 50% of the total e-waste generated to exclude the contribution from household appliances and to allow a better comparison with the North American data. For estimates of the amount of e-waste recycled in Canada, the actual and forecast recycling rates in the United States were applied to the Canadian generation data. This assumption was made based on the knowledge that the regulatory and collection environments are at similar levels of maturity in both countries, as will be described in chapter 3. Actual recovery of e-waste from the United States waste stream was 10% in 2005 and 19% in 2009. (US EPA, 2010) Recovery in 2020 was assumed to be 25%, which seemed reasonable given the European experience and the increase in government regulations regarding the collection and disposal of e-waste. The actual recovery of e-waste in the European Union was 26.5% in 2005 and was forecast to reach 54.9% by 2011. A recovery of 40% was used in Table 2 as the estimated recovery in 2009 based on a rough interpolation between these points. Assuming recently proposed legislation in the European Parliament is passed and enforced, an estimated recovery of 60% was used for 2020. (Hall, 2011)

million metric tonnes/year	***Generated***			***Recycled***		
	2005	***2009***	***2020***	***2005***	***2009***	***2020***
Canada	0.17	0.20	0.27	0.02	0.04	0.07
United States	2.38	2.89	4.94	0.24	0.55	1.24
European Union	4.25	4.69	6.16	1.13	1.88	3.69
Totals	6.80	7.78	11.37	1.38	2.46	5.00
	Note: EU values are 50% of published values due to removal of household appliance amounts.					

Table 2. Amounts of E-waste Generated and Recycled in 2005, 2009 and 2020.

Based on the data presented in Table 2, the total North American and European market for e-waste from consumer electronic sources was approximately 7.8 million tonnes in 2009 and it is expected to grow to 11.4 million tonnes by 2020. The actual amount collected for recycling is estimated to be 2.5 million and 5.0 million tonnes in 2009 and 2020 respectively. The proposed capital expenditure at Trail Operations requires e-scrap feed, not e-waste, so these numbers must be translated into quantities of available e-scrap. Research completed at Teck suggests that the mass of e-scrap from e-waste is approximately 10% of the total recycled e-waste stream. (Adams, 2011) This translates into a total of 250,000 tonnes of e-scrap available for processing in 2009 from North American and European markets and an increase to 500,000 tonnes of e-scrap available for treatment by 2020. The amount of e-scrap in household appliances is negligible, so the assumption that the European numbers should exclude these items in the estimation of the total e-waste stream, and subsequently the e-scrap stream, is reasonable when estimating the total generation of e-scrap. This growth in available e-scrap suggests there is a need for additional processing capacity to ensure the environmentally responsible recovery of the valuable metals contained in e-scrap.

2.4 The E-waste and E-scrap Recycling Industry

2.4.1 Process Description

The recycling process for e-waste consists of three main steps: 1) collection; 2) sorting, dismantling and pre-processing; and 3) end-processing (Figure 4). (Schulep, et al., July 2009) The collection process involves gathering individual units of e-waste at one location in preparation for pre-processing. Collection activities take many forms from consumer drop-off at various locations, such as specified recycling depots or retail stores, to producer mail-in programs to community collection days. Collection of sufficient material in one location is important to ensure transportation to a pre-processor is economical. The success of a collection system is based on many factors including ease of access and cost to the consumer; legislation including the requirement to establish a collection system and disposal bans; potential for financial gain to the recycler; and societal influence such as recycling being considered the "right thing to do". Using British Columbia as an example, as of August 2009 there were 97 permanent locations for returning e-waste, plus there were several collection days organized in smaller communities throughout the year and some major retailers will accept e-waste for recycling. (eStewardship, 2010)

The purpose of sorting, dismantling and pre-processing e-waste is to breakdown the original manufactured product into its constituent streams prior to distribution to final processors. These processes can take many forms such as manual disassembly, mechanical shredding and mechanical sorting. It is critical that material streams generated from these processes match the quality requirements for the inputs to the end-processors to avoid the creation of difficult to recycle materials. (Schulep, et al., July 2009) Figure 2 provides a good overview of a typical process used in North America and Europe that combines mechanical shredding along with a combination of manual and automatic sorting.

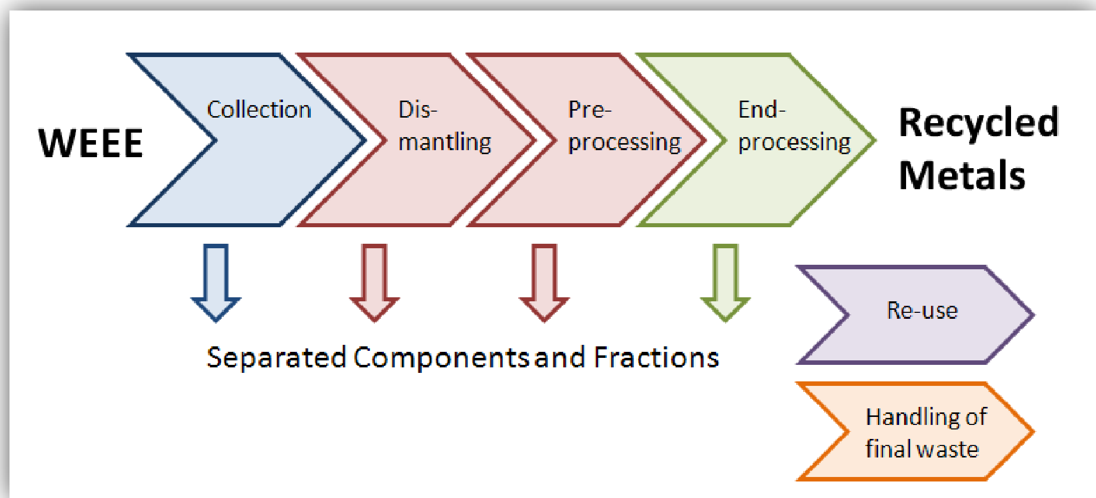

Figure 4. Overview of the E-waste Recycling Chain. (Schulep, et al., July 2009)

The efficiency and effectiveness of the separation of the various streams is highly dependent on the specific practices and equipment used in each operation. For example, some pre-processors may manually remove PWBs from computers prior to mechanical shredding and sorting while others may shred first prior to automatic and/or manual sorting. With CRT glass recycling, some processors will separate out the whole tubes to be sent for further processing. Other recyclers will separate the high lead funnel glass and the low lead panel glass from the CRT and then crush the two separated glass streams to create a leaded and a non-lead glass cullet to ship to end-processors. In British Columbia, Teck accepts CRT televisions and monitors as originally manufactured, which are dismantled and separated into the constituent streams prior to final processing, and as whole CRT tubes for crushing and treatment at Trail Operations from dismantlers throughout Western Canada. Note that some small, high value electronics, like mobile phones, can be treated by many end-processors without pre-processing other than battery removal. In countries where labour costs are low, full manual disassembly is common and may also include 'backyard' processing techniques, including leaching and melting, to produce crude metal streams containing gold, silver and PGMs.

Various end-processors are involved in the final disposition of the three main segregated e-waste streams: plastics, glass and metals. Plastics are either recycled into other plastic products or are used as a fuel in smelting processes. Glass from CRTs is usually sent to glass-to-glass manufactures or to smelters. If the glass is low in lead, it can be used in multiple glass applications. High lead glass is usually treated by CRT glass producers, which is a declining market, or by lead smelters, which use the glass as flux in their processes while recovering the lead as a saleable product. (Mossholder, 2010) Metals are usually segregated into ferrous fractions, which are sent to steel facilities; aluminium fractions, which are sent to aluminium processors; and complex copper / lead / PWB mixtures, which are sent to integrated metal smelters. (Schulep, et al., July 2009)

2.4.2 Classification of E-waste and E-scrap Materials

Streams generated from the disassembly, sorting and pre-processing of e-waste can vary widely in chemical composition and particle size depending on the processing methods used. These streams can often be classified into broad categories that determine which end-processors they are sent to for final processing and what payment terms are used for the sale of the different streams. The two groups of streams that are most important to Trail Operations are the classification of e-scrap and glass streams.

E-scrap streams are typically graded by the quantity of gold contained in each stream. Low-grade e-scrap typically contains less than 100 grams of gold per tonne of e-scrap and is sourced from televisions, monitors and cordless phones. Low levels of gold are also found in the left over un-segregated material, also known as 'fluff', that remains at the end of a mechanical e-waste processing line. Medium-grade e-scrap ranges from 100 to 200 grams or gold per tonne of e-scrap and is generated from PWBs in personal computers and some mobile phones. The high-grade e-scrap contains more than 200 grams of gold per tonne of e-scrap and is sourced from mainframe computer boards, some mobile phones and capacitors. The grades of e-scrap according to gold content are summarized in Table 3. E-scrap streams can also be further segregated into high or low copper streams.

Glass streams are segregated first by whether or not they are CRTs or flat panel displays. CRTs are then separated into whole tubes, which must be further crushed before final treatment, or as crushed glass cullet. Glass cullet can be further divided into clean cullet (low lead), mixed cullet glass (medium lead) or leaded cullet (high lead). Flat panel displays can be further classified as whole displays, which often include a plastic frame, copper wiring and a lamp containing mercury, or as strictly the glass panels. The glass panels can be shipped as either whole panels or shredded pieces.

	Minimum gold content (g/t)	*Maximum gold content (g/t)*
Very low grade PWB	0	50
Low grade PWB	50	100
Medium grade PWB	100	200
High grad PWB	200	400
Very high grade PWB	400	

Table 3. Classification of E-scrap According to Gold Content.

2.4.3 Industry Players

There are many industry players that have important roles in the e-waste recycling industry. Figure 5 provides a description of the interrelationships between these groups. This figure excludes the direct disposal of e-waste that is never collected for recycling as well as e-waste that is collected, but is still directed to landfill or is exported rather than recycled. A highly influential group that affects the overall industry is government. Governments in various local, regional and national jurisdictions set laws requiring the establishment of e-waste collection and recycling programs. The laws influence what materials are collected and may also impose disposal bans on the dumping of e-waste to landfills in their areas. Some laws require the recyclers participating in the programs to be qualified against specific criteria and audited to ensure compliance. In Canada, four of the provincial programs have agreed to a common recycler qualification program to define the minimum requirements to ensure e-waste "is handled in an environmentally sound and socially responsible manner that protects the environment and safeguards worker health and safety". (Electronics Product Stewardship Canada, 2010, p. 2) An overview of the legal framework for the management of e-waste in Canada, the United States, the European Union and other jurisdictions is provided in Chapter 3.

The e-waste recycling industry begins with the original equipment manufacturers (OEMs) and retailers. The OEMs determine what products are available, what materials are used in the manufacture of the products and how they are designed for disassembly. The retailers make the decisions on what products are sold to consumers within a specific region or country.

This group also has an impact on consumer recycling behaviours and recycling collectors in that extended producer responsibility laws require many OEMs and retailers to ensure there is an acceptable mechanism for the collection of their products for recycling. Laws in some areas extend the responsibility of the OEMs and retailers further down the recycling chain and require the auditing of downstream processors.

Consumers make decisions on what products they buy, how frequently the products are replaced and how the end-of-life products are disposed of. It is important for consumers to be educated about e-waste recycling since it is still new to many consumers. Stewardship programs, which various OEMs, retailers, recyclers, governments and non-governmental organizations participate in, often assist with the education of consumers on local options for recycling of e-waste and the potential impact of improper disposal. In addition, the actual mechanism and location for recycling must be convenient for consumers to increase the likelihood of high collection rates. Recycling is not the only option for end-of-life electronics. Refurbishment and re-sale of electronics is a positive option for electronics that are no longer useful to the original consumer. Companies and non-profit organizations exist to refurbish electronics and to sell or donate them to organizations and individuals who can put them to use again.

The members of the recycling collector group are numerous and varied. Collectors could include small, local waste companies; provincial or state-wide collection organizations; OEMs and retailers; large national or international recycling companies; and others. Some collectors are for-profit companies while others may be non-profit organizations. Governments attempt to push the cost of collection programs to OEMs, retailers and consumers. This is achieved in a variety of ways in different areas. Some retailers will accept products at their retail outlets. Some OEMs offer collection days at different locations or will allow end-of-life products to be mailed in to a collector. Other programs take the approach of having the consumer pay an environmental handling fee (EHF) that is typically paid when a new product is purchased, which is then used to fund a collection program. This approach is common in Canada. (eStewardship, 2010)

Disassemblers are another unconsolidated group with members of different sizes and capabilities. Dissassemblers range from small operations with manual disassembly and minimal capital investment to large-scale, multi-million dollar operations with primarily mechanical dismantling and separation of e-waste into its constituent streams. Some of the largest recycling companies have disassembly operations at multiple locations within a country and around the world. For the small to medium sized disassemblers, the quantity of the various streams produced are too small to be shipped directly to a large end-processor. These smaller companies will often sell their products to a consolidator or broker or they will sell to an intermediate refiner. A consolidator or broker is a company that will collect material from multiple disassemblers to create shipments of material that are sufficiently large to be sent to an end-processor. Consolidators may also do further segregation of streams from the smaller companies to upgrade stream quality and maximize the value they receive from sales to end-processors. An intermediate refiner would typically process very specific e-waste streams to generate an intermediate product that would be sold for further refining by an end-processor. A typical process may involve melting down e-scrap including PWBs to produce impure copper refiner bars that are sent to end-processors for final refining of the contained gold, silver and PGMs while purifying the copper. An intermediate refiner is more likely to take smaller shipments and charge higher fees than a large, end-processor.

The end-processors are a smaller, more consolidated group of companies compared to the other groups in the industry. The large capital investment required to build a facility with the required pollution abatement equipment and the necessary technical knowledge to successfully operate a complex operation are significant barriers to entry, which reduces the number of players in the end-processor group. This is particularly true for the integrated smelters processing complex e-scrap feed streams. The high value of the e-scrap streams relative to the mass of the stream allows the e-scrap to be transported long distances while still being economical. This allows end-processors for e-scrap to participate in a global market whereas collectors and disassemblers typically operate in a local or regional markets.

The e-waste and e-scrap industry complex and evolving. Consumers continue to purchase consumer electronics as technology develops with new features that integrate into the everyday lives of people. Although the purchase of most electronics is a lifestyle choice rather than a necessity, it remains high on the list of discretionary spending. As more electronics are purchased, more become obsolete, hence the growth in the generation of e-waste. How much of this e-waste is collected and input to the e-waste recycling industry is a function of many factors, but the largest single factor is government regulations around the world. The next chapter explores the current state of government regulations pertaining to e-waste to better understand its impact on the global e-waste industry. The stage will then be set to analyze the competitive forces affecting the e-waste industry and how Teck Trail Operations may find a profitable place within it.

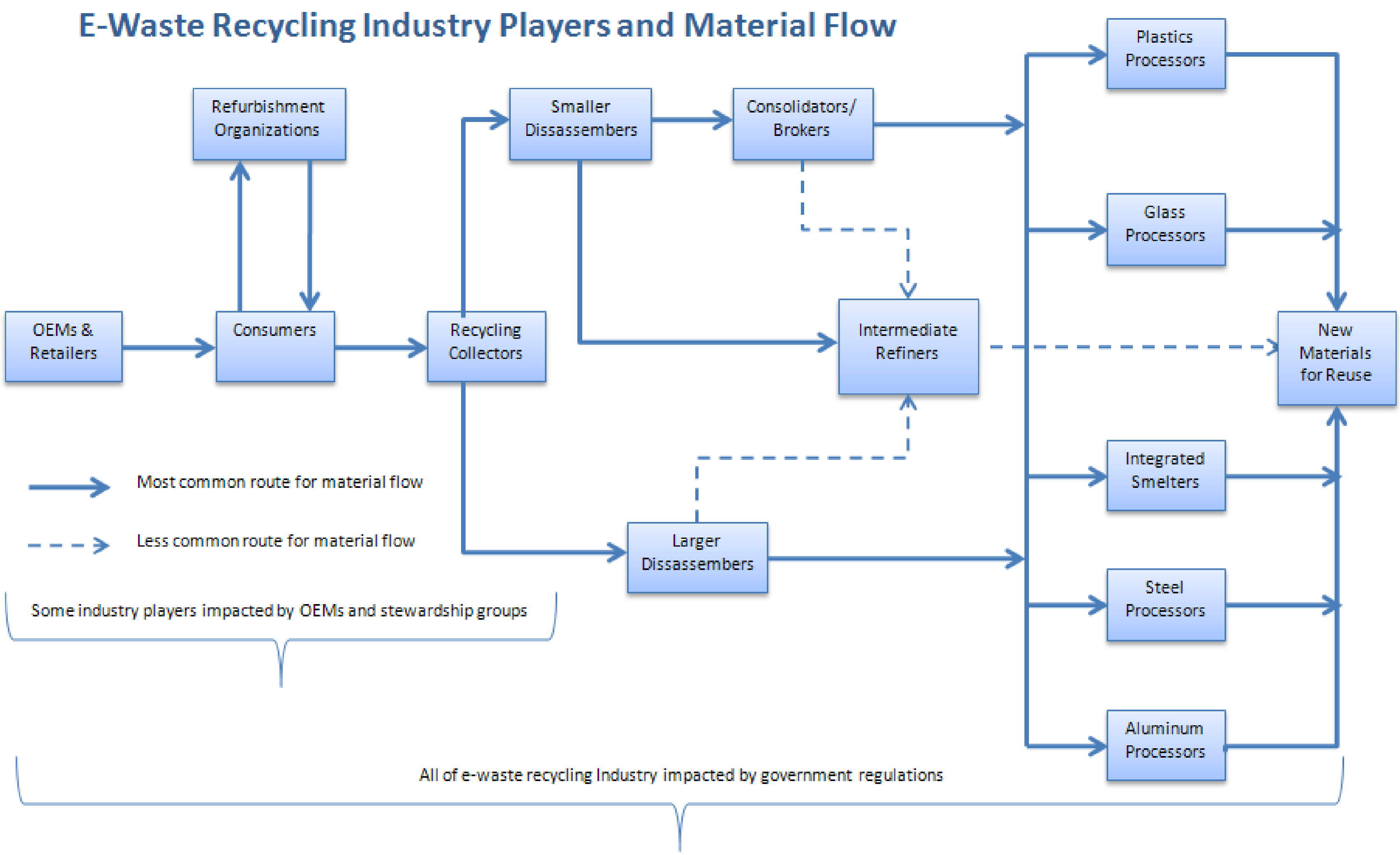

Figure 5. E-Waste Recycling Industry Players and Material Flow

3 The Regulatory Environment for the Disposal of E-waste

3.1 The Impact of Regulations on the E-Waste Recycling Industry

Government regulation has been the single largest factor leading to the growth of the e-waste recycling industry. Few laws existed that dealt with e-waste directly until this century. Some of the earliest laws included the WEEE Directive (Directive 2002/96/EC, 2003) and the Restriction of Hazardous Substances Directive (RoHS) (Directive 2002/95/EC, 2003) in the European Union, which were both passed into law in 2003. The Electronic Waste Recycling Act of 2003 (California ALS, 2003) was enacted in California as the first state-wide electronics recycling law in the United States. The Alberta Electronics Designation Regulation was passed in 2004 as the first province-wide regulation in Canada. (Alberta Regulation 94/2004, 2004) Rapid growth in the generation of e-waste and the limited availability of e-waste generation data contributed to the lack of e-waste laws. Early estimates of WEEE generated in the European Union only date back to 1997. (Crowe, et al., 2003) The United States did not start recording it as a separate classification in its waste management report until 1999 even though data had been collected on other waste streams such as rubber tires since 1960 and lead acid batteries since 1970. (US EPA, 2010) Early estimates of e-waste generation in Canada are from 2005, although there was recognition of the growing e-waste disposal problem earlier in the decade. (Legwork Environmental Inc., 2002) (Lura Consulting, 2003)

The driving force behind the need for regulation was the growth in the generation of e-waste as electronics sales continued to rise, equipment replacement rates became shorter and integration of electronic tools into day-to-day living expanded. As the United States waste report points out, e-waste is the fastest growing category of waste, which puts growing pressure on the capacity of landfills. Government regulation is often enacted when there is a perceived market failure, and the situation with e-waste can be considered a market failure due to negative externalities and information asymmetry. A negative externality occurs when a negatively valued impact results from any action that affects a person who did not consent to the impact through participation in a voluntary exchange. (Weimer & Vinning, 1999, p. 95) Since both producers and consumers often do not consider the total social cost of their actions on others in society, government regulation is often used to push the true cost back to the producer or consumer. The disposal of e-waste is an example of a negative externality since the environmental pollution caused by the improper disposal of e-waste and the wasteful loss of natural resources affects people who did not consent to the transaction. Additionally, taxpayers as a whole would incur the additional cost of disposal assuming government operated landfills or incinerators were the mechanism of disposal, even if they did not contribute to the generation of e-waste.

Information asymmetry in this context occurs when there is an imbalance of information between the externality generator, which are the producers and consumers of electronics, and the affected party, which is all of society. (Weimer & Vinning, 1999, p. 107) When consumers dispose of e-waste, they may not be aware that their televisions contain high levels of potentially toxic lead or that their cellphones contain valuable gold and copper that will no longer be recovered requiring the mining of additional primary metals. This situation of imperfect information is another motivator for the intervention of the government via public policy.

Depending on the jurisdiction, the laws and regulations relating to e-waste vary tremendously. Some areas of the world have no laws that pertain to e-waste or to any waste in general. Most developed countries have a minimum requirement to ensure the adequate disposal of general solid waste by an accepted process such as sending the waste to a landfill or an incinerator, but e-waste may not be managed any differently than general waste. Some jurisdictions have laws directly relating to e-waste in addition to general waste management laws. These e-waste regulations could include a requirement for OEMs and retailers to provide a 'take back' program to collect obsolete equipment that they produce and/or sell. Other laws establish local or regional collection programs to promote the diversion of e-waste from landfills or incinerators. Some areas now have complete disposal bans on all e-waste. There are other laws that restrict the use of certain hazardous substances in the manufacture of electronic equipment. Another aspect of e-waste laws and regulations is the definition of the items that are classified as e-waste. There are laws that only include monitors and televisions. Others include all computer related equipment, audio/visual equipment (e.g. stereos), televisions and communication equipment (e.g. phones). The broadest classification of e-waste is to include any item, including all household appliances, that has a cord and an electrical plug. One more debated aspect of e-waste related laws is the classification of the whole e-waste and dismantled e-waste. This impacts how the e-waste is identified for transport and can impact whether or not a particular material can be exported. (US EPA, 2006)

Laws relating to e-waste extend beyond the regional or national level to impact the transboundary movement of e-waste. The Basel Convention, which was signed on March 22, 1989 and became effective May 5, 1992, is a treaty that affects the international movement of hazardous wastes including e-waste. (Secretary-General of the United Nations, 1989) It prohibits the export and import of hazardous waste to countries that have signed and ratified the treaty without the prior informed consent of the receiving country, unless the waste is subject to another treaty that does not contradict the Basel Convention. It is easier for parties that have not ratified the Basel Convention, such as the United States, to lawfully export e-waste to less developed countries, as compared to a country that has ratified the Convention, such as Canada and most of the European Union member countries. The Basel Ban Amendment was passed at the 1995 Basel Conference of the Parties to expand the original agreement from only preventing export of hazardous waste if prior informed consent was not given to a full ban on the export of all hazardous wastes to less developed countries, even for the purpose of recycling. (Secretary-General of the United Nations, 1995) This amendment had not been ratified by a sufficient number of signatories to come into force as of July 2010. (Secretary-General of the United Nations, 2011) The Organization for Economic Co-Operation and Development (OECD) also has binding resolutions on the 30 member countries of that organization to control the transboundary movement of wastes for recovery operations between member countries and non-OECD countries and has been harmonized with the Basel Convention. (OECD, 2009)

The wide variation in e-waste related laws within a major geographic region is an area of weakness that can create an uneven playing field and cause ineffective implementation of e-waste laws. For example, if a disposal ban for e-waste exists in a particular US state and recycling of e-waste is too expensive, a collector of e-waste could transport the e-waste to a nearby state without an e-waste disposal ban and dispose of it in a landfill. This would be completely legal, but it misses the purpose of proper e-waste management and reduces the amount of e-waste that is actually recycled. One way provinces and states in North America are addressing this issue is to regulate the entire recycling chain from collection through to final disposition of the various e-waste streams at an end-processor to ensure acceptable recycling practices are being followed. In the European Union, having common overarching laws, such as the WEEE and RoHS Directives, provide the minimum standard required of all member states. Individual nations must then pass laws within their country that meets or exceeds this minimum standard. In fact, part of the justification for implementing these Directives is to address potential inequalities between nations. “The objective of improving the management of WEEE cannot be achieved effectively by Member States acting individually. In particular, different national applications of the producer responsibility principle may lead to substantial disparities in the financial burden on economic operators. Having different national policies on the management of WEEE hampers the effectiveness of recycling policies. For that reason the essential criteria should be laid down at Community level." (Directive 2002/96/EC, 2003, p. 24)

One of the inevitable questions that arise when developing any laws pertaining to the collection and recycling of e-waste is 'Who should bear the cost of the program?' If no law is put in place and the material goes to municipal or local landfills, it is the local government and taxpayers that pay for the increasing cost for the disposal of a growing stream of end-of-life electronics. This is one incentive for governments to implement laws to push this economic burden to other parties such as OEMs, retailers and consumers. For jurisdictions where the collection of e-waste is regulated, the most common way to pay for the cost of the disposal of e-waste is through producer responsibility laws. The details of these laws vary from one area to the next, but in general, they either involve a requirement for OEMs and retailers of electronics to establish their own collection and recycling programs or a fee-based system is implemented that charges consumers an environmental handling fee with the purchase of each new unit of electronics. In the first model, it could involve OEMs and retailers paying for the establishment and maintenance of state or province wide recycling programs, which is often funded based on a percentage of sales, or it could be directly driven by the OEMs and retailers through collection sites at retail stores, mail in programs or collection events on specific days. In the second model, the fees collected from the consumer are used to pay for the management of the collection system, the collection system itself and the recycling fees of primary recyclers. Fees to secondary recyclers are either paid by the primary recyclers out of the fee they are paid or the recyclable stream from the primary recycler contains enough value that the secondary recycler will pay to have this material sent to them for further processing.

The following sections provide highlights on the current status of e-waste related laws and regulations in Canada, the United States, the European Union and some other regions of the world. It is by no means an exhaustive review. It does provide information on areas with current e-waste laws and shows the general trend towards an increase in government intervention in the collection and recycling of e-waste around the world. These actions will lead to increased collection of e-waste and further implementation of responsible recycling practices, which will in turn lead to increased availability of e-scrap for processing by end-processors.

3.2 The Regulatory Environment in Canada

In Canada, there is no overall federal law that specifically governs the management, collection, recycling or exporting of e-waste. The Canadian Council of Ministers of the

Environment has developed 12 guiding principles for electronics product stewardship. (CCME, 2004) These principles include items such as the producer should be responsible for stewardship; programs should strive for equity and consistency between programs; costs of programs should not be borne by the taxpayer; environmental and human health impacts should be minimized and e-waste should only be exported to countries with adequate facilities and fair labour practices.

Federal laws do exist that impact the handling, classification, transportation, import and export of hazardous materials, which impacts some e-waste related material streams due to the inclusion of substances such as lead and cadmium in e-waste. A report prepared by Legwork Environmental Inc. provides a good description of the laws applicable to e-waste in both Canada and the United States, although it is now somewhat outdated. (Legwork Environmental Inc., 2002) The key pieces of legislation in Canada affecting the recovery and recycling of e-waste include: the Canadian Environmental Protection Act (CEPA, 1999); the Transportation of Dangerous Goods Act (TDG, 1992); the Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations (SOR/2005-149, 2005); and the Interprovincial Movement of Hazardous Waste Regulations. (SOR/2002-301, 2002) Canada has ratified the Basel Convention, is a member of the OECD and has signed the Canada – US Agreement on the Transboundary Movement of Hazardous Waste as amended in 1992. Provisions in CEPA allow Canada to meet its international obligations under all of these agreements.

Recycling of e-waste does exist to a greater or lesser extent within each province. Each province addresses the issue of the management of e-waste independently through provincial laws and regulations. There are four provincial electronics stewardship programs operating in Canada: British Columbia (ESABC), Alberta (ARMA), Saskatchewan (SWEEP) and Ontario (OES). A regional stewardship program is also in place for Nova Scotia and Prince Edward Island (ACES). A report by eStewardship.ca provides a description of each of these five programs and the relevant provincial regulations. The report also gives the status of e-waste legislation and stewardship programs in the other provinces and territories. Figure 6 provides an overview of the status of e-waste regulations in each province from the eStewardship report. (eStewardship, 2010)

	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NF
Phase I Electronics (displays, computers, printers)	✓	✓	✓	✓ April 2011	✓	★	★	✓	✓ July 2010	★
Phase II Electronics (audio visual and selected telecommunication equipment)	✓ July 2010	★	✓ April 2010	✓* April 2011	✓* April 2010	★	◆	✓	✓ July 2010	◆
Phase III Electronics (Photocopiers, printers, gaming consoles, servers, peripherals)	✓ July 2012	◆	◆	✓ April 2011	◆	◆	◆	◆	◆	◆
Batteries (rechargeable & non-rechargeable)	✓ July 2010	◆	◆	✓ April 2011	✓	★	◆	◆	◆	◆

✓ - Regulations currently in place (* includes copiers) ★ - Regulations drafted / expected in 2010

◆ - Regulations not expected until 2011 or later

Figure 6. Status of E-Waste Recycling Regulations in Canada as of August 2010. (eStewardship, 2010)

Electronics Product Stewardship Canada (EPSC), a non-profit organization funded by the electronics industry, was established in 2003 with the goal of creating "a national electronics end-of-life program for Canada allowing for maximum provincial and municipal flexibility." (Electronics Product Stewardship Canada) The EPSC is working to harmonize environmental stewardship for electronics across Canada. A common recycler qualification program has been approved and adopted by four of the industry-led stewardship programs including ESABC, SWEEP, OES and ACES. (Electronics Product Stewardship Canada, 2010) Establishment of new recycling regulations in provinces without e-waste related legislation may lead to further adoption of this recycler qualification standard, which could make it the de facto recycling standard for all e-waste recycling programs in Canada.

3.3 The Regulatory Environment in the United States

As in Canada, there is no overall federal law that governs the management, collection, recycling or exporting of e-waste. The Solid Waste Disposal Act, better known as the Resource Conservation and Recovery Act (RCRA) of 1976, is the federal law that governs the disposal of solid waste and hazardous waste, which impacts how e-waste is classified and managed. (Solid Waste Disposal Act (42 U.S.C 6901 - 6992k), 2002) Through the RCRA, the United States Environmental Protection Agency (US EPA) has set rules for the management of certain e-waste streams that are classified as hazardous waste. RCRA does not apply to most e-waste in the United States since it is classified by the EPA as either non-hazardous waste or non-waste. Even where some material may be considered hazardous, several exemptions and exclusions have been applied to encourage re-use and recycling. A presentation on the EPA's Regulatory Program for E-waste (Tonetti, 2007) and the EPA's Final Rules on Cathode Ray Tubes (US EPA, 2006) provide details on the classification, exemptions and exclusions for e-waste.

There have been concerns raised by environmental groups and in the media about various e-waste recycling and exportation practices in the United States being in violation of US EPA regulations. The principal concerns relate to worker health and safety, environmental protection and the exportation of e-waste that is dumped irresponsibly in developing countries. In response, third-party groups in the US have been behind the development of standards for e-waste recyclers. These standards allow recyclers to demonstrate to the public and governments that their particular process provides for worker health and safety and ensures a good chain of custody for materials to make certain these materials are recycled in a sustainable and secure fashion. (Toto, 2010) In a statement on the US EPA web site, the EPA states that it "supports and will continue to push for further safe and protective recycling efforts and encourage improvements in best management practices for recyclers. There are existing recycling certification programs, such as R2 and e-Stewards that EPA believes advance environmentally safe practices and includes standards for use in third party certification of such efforts." (US EPA) It is important to note that these standards are followed voluntarily and are not legally binding laws or regulations. Although the EPA supports these standards, they do not replace the recyclers legal obligations, and in cases where a certification program and the law conflict, the recycler must adhere to the legal requirement. (US EPA)

There are three well recognized certification programs for the recycling of electronic waste that are available in the United States: e-Stewards, R2 and RIOS. The American National Standards Institute-American Society of Quality National Accreditation Board (ANSI-ASQ ANAB) is the only accreditation board in the United States that can provide accreditation to certification bodies for these standards. Once a certification body is accredited, it can audit and provide certification to recycling companies for a given standard. (ANAB) The ANAB began accrediting certification bodies for e-Stewards, R2 and RIOS in 2010, 2009 and 2009 respectively. (Toto, 2010) (Steel Guru, 2009)

The e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment, introduced in 2010, was developed by the Basel Action Network (BAN) in consultation with other environment groups, recycling industry leaders, occupational health and safety professionals and certification bodies. This standard was preceded by the e-Stewards Pledge Program. The e-Stewards standard is an international standard available to electronics recyclers, refurbishers, processors and refiners in developed countries as defined by the OECD, the EU and the European Free Trade Association (EFTA). The standard currently does not apply to collectors, brokers and transportation businesses. (Basel Action Network, 2009) There are companies in the United States, Canada and the United Kingdom that are certified or in the process of becoming certified to the standard. The e-Stewards standard has several key elements including: (Basel Action Network)

- Requires a certified ISO 14001 environmental management system that builds in occupational health and safety requirements specific to the electronics recycling industry, minimizing exposure of recycling workers to hazards
- Prohibits all toxic waste from being disposed of in solid waste landfills and incinerators
- Requires full compliance with existing international hazardous waste treaties for exports and imports of electronics, and specifically prohibits the export of hazardous waste from developed to developing countries

The Responsible Recycling Practices for Electronics Recyclers certification program, usually referred to as R2, was issued in 2008. (Lingelbach, 2008) The US EPA facilitated the development of this document with input from government, OEMs, recyclers and certification bodies, but the EPA does not own the standard. (Toto, 2010) The R2 standard requires recyclers to implement an environmental, health and safety management system, although it not so prescriptive as to require ISO 14001 certification. The standard also encourages the re-use and recycling of e-waste according to a hierarchy of management strategies, but does permit the use of landfills and incinerators under certain circumstances. R2 allows for the export of toxic e-waste components to non-OECD countries if those countries legally accept them under the laws of the importing country. Some environmental groups that were originally involved in the development of the R2 standard, notably BAN and the Electronics Takeback Coalition, pulled out of this process because of concerns in a number of areas. (Basel Action Network; Electronics Takeback Coalition, 2008) This difference of opinion led to the development of the separate e-Steward standard.

The Recycling Industry Operating Standard (RIOS) was developed by the Institute of Scrap Recycling Industries (ISRI) as a mechanism to help companies in the scrap recycling industry manage the quality, environmental, health and safety issues in their operations. It also includes a systematic framework for achieving measurable continuous improvement in these areas. (Institute of Scrap Recycling Industries Inc.) The standard applies to all scrap recyclers, but electronics recyclers can choose to obtain a joint R2/RIOS certification. The environmental, health and safety program in RIOS meets the requirements of R2. The remaining components of the R2 standard are implemented in parallel to RIOS. (Certified Electronics Recycler)

In July 2010, the United States Government Accountability Office released a report recommending that the US EPA Administrator should work with the EPA's partnership programs to more effectively manage the large amount of US generated electronic waste and to work with other federal agencies to draft a legislative proposal on ratification of the Basel Convention. (US Government Accountability Office, 2010) This was followed in August 2010 with the US EPA Chief Administrator, Lisa Jackson, declaring that prevention of the generation of e-waste and its irresponsible management was one of the six top global priorities of the EPA. (Electronics Manufacture & Test Worldwide, 2010) In September 2010, US Representatives Gene Green and Mike Thompson introduced bill H.R. 6252 – The Responsible Electronics Recycling Act of 2010 to prevent the dumping of electronic waste in developing nations. (Green & Thompson, 2010) These actions indicate a growing awareness and action at the federal level to improve the management of e-waste and to prevent the export of e-waste to developing countries.

There are 24 states in America that have passed a state law on electronics recycling and there are six additional states that introduced electronics recycling legislation in 2010. (Electronics Takeback Coalition, 2010) Figure 7 provides a map of the states that have passed or introduced electronics recycling legislation. There are numerous differences in the details of the laws between the various states such as when programs started, the scope of products covered under the laws, who pays for the collection of e-waste, collection targets, etc. The Electronics Takeback Coalition web site includes a useful summary table of key information on all of the state electronics recycling laws. (Electronics Takeback Coalition, 2011) It should also be noted that some states have laws that are stricter or use different definitions for waste and hazardous waste than the federal RCRA law. (Tonetti, 2007)

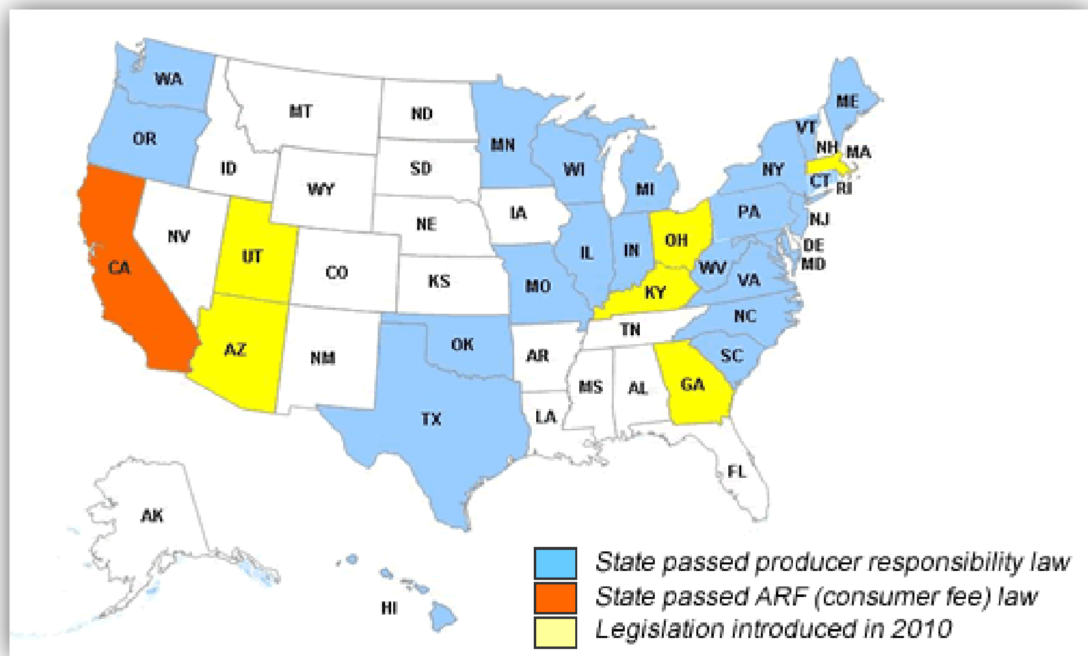

Figure 7. Electronics Recycling Legislation Status in the USA. (Electronics Takeback Coalition, 2010)

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3.4 The Regulatory Environment in Europe

It is important for Teck to consider the regulatory environment in Europe for two reasons. First, the European Union has been the world leader in establishing legislation related to the collection and management of electronic waste as well as in legislation related to the restriction of hazardous materials used in the manufacture of various electronic devices. The European regulations generally cover a wider range of products and have higher collection targets than current North American programs. These regulations will influence the development of North American legislation. Second, since e-scrap contains sufficient metal value for it to be transported globally for processing, the laws in Europe will impact the amount of e-scrap available on the global market to both Teck and other refiners.

There were two key directives passed by the European Parliament regarding electronic equipment. The Restriction of Hazardous Substances Directive or RoHS was adopted in February 2003 by the European Union. (Directive 2002/95/EC, 2003) The RoHS Directive took effect on 1 July 2006, and each member country was required to pass a national law to meet the minimum requirements set out in the RoHS directive by this date. This Directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment to reduce the toxicity of WEEE including mercury, cadmium, lead, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ethers.

The WEEE Directive (Directive 2002/96/EC, 2003), which sets collection, recycling and recovery targets for electrical goods to help address the problem of huge amounts of toxic e-waste in municipal waste streams, is closely linked to the RoHS Directive. The WEEE Directive required the European Union member countries to pass national laws to meet the obligations of the Directive by August 13, 2004, although some laws were not in effect until as late as 2007. (Institute for European Environmental Policy, 2009) The WEEE Directive uses the producer responsibility model to pay for e-waste recycling programs and requires producers to finance the collection, treatment, recovery and disposal of WEEE such that consumers can return WEEE at least free of charge. Both the RoHS and WEEE directives were passed at the European Community level to minimize the potential for variances in the national laws that could create barriers to trade or substantial financial burdens to companies in some jurisdictions. Recently, the European Parliament passed a resolution to increase rules on the collection and recycling of WEEE. This resolution sets targets for member countries including the collection 85% of the WEEE generated in their country with a target of recycling 50 – 75% of the material collected depending on the category by 2016. (European Parliament, 2011)

The European Union is also a signatory to the Basel Convention and the Basel Ban Amendment. The European Commission passed a regulation banning the export of hazardous wastes to developing countries in 1999. (European Parliament, 1999) This regulation was replaced with a new regulation that came into force as of July 12, 2007, which builds on previous legislation regarding the shipments of waste within and outside of the European Union and continues to include the ban on shipping of hazardous waste to non-OECD countries. (Europa, 2007), (European Parliament, 2006) The combination of the WEEE Directive and regulations banning the export of hazardous waste are the key drivers behind the higher collection and recycling rates for e-waste in the European Union compared to North America.

Despite the intentions of the RoHS and WEEE Directives to normalize the laws in the member countries regarding WEEE, the implementation of the national laws have created an uneven playing field for players in the industry. The WEEE Forum, a European group consisting of 38 member organizations representing electronics producers, supports projects to optimize the operations of these organizations while working within the WEEE framework. One such project is called WEEELABEX, which is developing a set of standards for operators in the WEEE management industry. (Leroy, 2010) The standards will address the collection, sorting, storage, transportation, treatment and disposal of all types of WEEE to prevent pollution and maximize the recovery of secondary feeds along the entire WEEE recovery chain. The standards will harmonize the requirements and rules of implementation and use audits to level the field for those in the industry. Only those operators who conform to the standards established through WEEELABEX will be able to do business with the organizations in the WEEE Forum. WEEELABEX will only apply to European operators and their downstream processors, even if those processors are not located in Europe.

3.5 The Regulatory Environment in Other Regions

Outside of North America and Europe, there are a few countries with some type of electronic waste specific legislation. For example, Japan passed two e-waste related laws in 2001: The Home Appliance Recycling Law, which includes televisions, and the Law for Promotion of Effective Utilization of Resources, which covers eco-design and recycling. (Ladou & Lovegrove, 2008) However, there are many countries, both developed and developing, in the world with little or no legislation on the management, recycling and disposal of e-waste. This has lead to the creation of informal recycling industries and dumping practices in places such as Nigeria, Pakistan, Ghana and China. (Schulep, et al., July 2009) In some countries where laws do exist, the enforcement of those laws can be weak. For example, China may have banned the importation of E-waste in 2000, yet there is documented evidence that the informal recycling sector still processes significant amount of imported e-waste. (Worldwatch Insitute)

When looking at the regulatory environment outside of North American and Europe, it is important to consider China, since it is the second largest generator of e-waste after the United States. It is estimated that China will produce 2.3 million tonnes of e-waste in 2010 compared to the approximately 3 million tonnes generated in the United States. (United Nations Environmental Programme, 2010) The Measures for Administration of the Pollution Control of Electronic Information Products, commonly known as "China RoHS", came into force on March 1, 2007. Although the Chinese legislation has no legal relevance to the European RoHS Directive, the China RoHS also has the objective of restricting the use of toxic and hazardous materials in electronic equipment. (Foreign Affairs and International Trade Canada, 2011) The Regulation for the Management of Waste Electrical and Electronic Products, also known as the "China WEEE" framework law, was issued by the China State Council on February 25, 2009 and became effective January 1, 2011. (Ferris, 2010) This regulation establishes a framework for items such as nationwide collection and treatment of WEEE; government certification of WEEE processing enterprises; and the establishment of a national fund to subsidize the cost of processing WEEE paid for by a combination of the national treasury and producers.

China is but one of the developing nations in the world with rapidly growing e-waste generation. Although there is a lot of media attention about banning and enforcing the importation of e-waste to developing countries, these countries have a rapidly growing internal source of e-waste without the necessary legislation and infrastructure to manage it appropriately. A report by the United Nations Environment Programme (UNEP) entitled Recycling: E-Waste to Resources, provides data on the growing generation of e-waste in the countries of China and India and across the continents of Africa and Latin America. It also assesses the current policies, skills, waste collection networks and informal recycling practices in 11 representative developing countries. The report suggests that some technologies and systems could be implemented in these developing countries that would reduce environmental harm, improve worker health and provide decent green jobs. (Schulep, et al., July 2009) Additionally, the report advocates facilitating exports of critical e-scrap fractions like circuit boards and batteries to OECD-level, certified end-processors. This recommendation was made based on the knowledge that the ability to fund the infrastructure expense and the technology skills required to create proper facilities for efficient and environmentally sound metal recovery are generally not present in developing nations. (United Nations Environmental Programme, 2010) Umicore, a precious metal refining company that processes e-scrap, has already started with the implementation of this approach. Umicore has formed a partnership with E-Parisaraa, an experienced recycling company in India, to promote the sustainable recycling of e-waste. Umicore will provide the financing and expertise to develop collection and dismantling mechanisms while linking the output streams of these processes to reputable end-processors. (Umicore Precious Metal Refining, 2010)

4 Structural Analysis of the E-waste and E-scrap Industry

4.1 Porter's Augmented Five Forces Analysis

A company must have a strategy to give a firm the direction it needs to outperform its rivals. Michael Porter discusses in his book *Competitive Strategy: Techniques for Analyzing Industries and Competitors* the five competitive forces that shape strategy within an industry, which are suppliers, customers, competitors, potential entrants and substitutes. Understanding these forces is essential because "the goal of competitive strategy for a business unit in an industry is to find a position in the industry where the company can best defend itself against these competitive forces or influence them in its favour." (Porter, 1980, p. 4) In addition to these forces, a business unit must also consider the roles of government, complementors and technology. Although not direct players in the industry, they can have a significant influence and can shape the industry. The following sections will analyze these forces in the e-waste and e-scrap industry to assist with the identification of opportunities for Trail Operations and to develop a strategy on where the company might position itself within the industry.

4.1.1 Supplier Analysis

For the purpose of this analysis, the suppliers in the e-waste industry can be defined as the OEMs, collectors, disassemblers, consolidators, brokers and intermediate refiners as described in section 2.4.3. OEMs are at the very start of the e-waste recovery chain. In an effort to demonstrate their commitment to the environment and sustainable practices, many large OEMs, such as Dell, Apple and Hewlett-Packard, have developed their own recycling programs. These are essentially collection programs organized and financed by these large companies. The materials collected are sent to downstream collectors and/or disassemblers for pre-processing. OEMs have not vertically integrated into the e-waste recovery chain. Collectors are companies, non-profit organizations or government funded groups that arrange for the local collection of e-waste to create sufficiently large shipments to be sent to a local or regional disassembler. The local nature of the collection operation and low barriers to entry has resulted in the creation of many different collector groups. These collection groups are essential to ensuring the input of e-waste into e-waste recovery chain. They are important to the overall industry in that material must be collected for recovery to create a flow of material for downstream players in the industry to process. The large influence of government regulation on the actual collection of e-waste and the large number of collector groups leaves the collector groups with low positional power in the industry and limited direct relevance to Teck.

The large disassemblers, consolidators and brokers would be the key suppliers of e-scrap to Trail Operations. Small disassemblers are unlikely to be direct suppliers to Teck since the quantity of e-scrap generated by them would be uneconomic for transportation to Trail. Their e-scrap output would potentially reach Trail via consolidators and brokers. The balance of power between the key suppliers of e-scrap and the smelters that are the end-processors can shift over time, but it tends to favour the smelters unless the supply of e-scrap is less than the capacity of the smelters. There are multiple large suppliers of e-scrap, while there are a limited number of smelters, so there are many options for the smelters to purchase feed materials. E-scrap is an important feed to the smelters, but it is not the only one. Other recyclable materials such as copper wire, car catalysts, brass scraps and various other metal production by-products can all be used as feed materials to the smelters. The smelters should be able to handle a range of physical and chemical characteristics, within the scope of typically available e-scrap materials, resulting in little or no switching costs for a smelter to source e-scrap from one supplier over another. A final component that supports the power of the smelters over the suppliers is that it is difficult for the suppliers to vertically integrate on a significant scale because of the large capital investment and the complex technical knowledge required to successfully operate a smelter.

Some power is maintained by the suppliers in their relationships with the smelters. The supply of e-scrap is not the only feed to the smelters, but it is a critical one due to the high metals values for the mass of material, which reduces logistics costs per tonne of material processed, and the favourable terms of sale for e-scrap when market prices for metals are high. The smelters also have very high fixed costs and low variable costs of operation. It is important for smelters to operate at capacity to maximize the value generated from the invested capital. In situations where the capacity of the smelters is greater than the supply of e-scrap, the suppliers may be able to negotiate better terms for the sale of e-scrap and the smelters may not be able to operate at capacity. Some firms, such as Electronic Recyclers International (ERI), has formed strategic partnerships with companies such as LS Nikko, a copper and precious metal producer, and Alcoa, an aluminium producer. These arrangements have involved the sale of the appropriate segregated streams to these companies while also securing investment dollars for ERI to use to expand its disassembly and pre-processing facilities. (Electronic Waste Journal, 2010) (Smith-Teutsch, 2011)

A final group that needs mentioning under the heading of suppliers is the intermediate refiners. These companies process e-scrap to produce an intermediate product that would often be sold to a smelter or other company for final refining. Some intermediate refiners, such as Colt Recycling & Refining and Gannon & Scott, produce refined precious metal products. The limitation of these companies is that they typically can only process a limited feed stream compared to the large smelters, which results in limited flexibility in the feeds they can purchase. Some small disassemblers may find it to be their advantage to sell their specific output streams to an intermediate refiner rather than a consolidator or broker. Intermediate refiners would be in direct competition with Teck in that feeds to an intermediate refiner could likely be processed at Trail as well. However, the intermediate refiners would tend to prefer the clean, high-grade e-scrap inputs rather than the complex, low-grade e-scrap that Trail Operations would target. The output of the intermediate refiners would not be of interest to Teck since the proposed technology for the Trail Operations site would not include final refining of copper, gold, silver and PGMs.

A survey published by Recycling Today magazine in June 2010 identified the top 21 recycling companies in North America and provides information on the company web sites, services offered and company CEO or president. (Taylor & Toto, 2010) The list includes disassemblers, consolidators and intermediate refiners. The largest companies include SIMS Recycling Solutions, Electronic Recyclers International (ERI), Intercon Solutions, GEEP, Universal Recycling Technologies (URT), Metech Recycling, Round2, ECS Refining and Intechra. All of these companies processed 20,000 tonnes or more of e-waste in 2009. A total of almost 580,000 tonnes of e-waste was processed by these 21 companies. SIMS is by far the largest of the recycling companies. They are reported to have processed 104,000 tonnes of e-waste in the United States, and they are the world's largest electrical and electronics recovery and recycling company with over 40 recycling centres on 5 continents. (SIMS Recycling Solutions) Teck needs to work towards developing relationships with the top e-scrap suppliers in North America to secure feed for Trail Operations. Additionally, Teck needs to learn more about the key European suppliers in order to begin to develop relationships with them.

4.1.2 Customer Analysis

From the perspective of Teck, the customers for the impure black copper product from the settling furnace would be a company that refines copper, silver, gold and PGMs. This is most likely a copper refiner that has the capability of refining silver, gold and PGMs or a specialty precious metal refiner. The balance of power between Teck and the customer group would be relatively balanced or be slightly in the buyers favour. The black copper product is a commodity and would not be significantly differentiated from other copper-based precious metal sources on the market. This lack of differentiation would keep switching costs low for the buyers allowing them to negotiate better terms for the black copper. Black copper customers of Trail Operations could also potentially be competitors for e-scrap feed materials since some customers are vertically integrated up the supply chain. Companies such as Umicore Precious Metals Refining Group and Boliden already have production facilities that are capable of processing the same e-scrap feeds that Teck could process. If the terms associated with the purchase of the black copper were less favourable than the terms for purchase of the e-scrap, the customers would be less likely to purchase the black copper.

Selling a commodity can also be in Teck's favour. Fewer companies are capable of processing the complex e-scrap feed stream than the upgraded black copper product. There are numerous companies that are capable of processing black copper. Having a large pool of potential buyers reduces the relative power of the customer group. The purchase of black copper may also be advantageous to vertically integrated firms, since black copper would be added to their processes further downstream in an e-scrap processing facility, which would provide an incentive to negotiate reasonable terms. Most modern integrated metal smelters use a pyrometallurgical process as the first step in the processing of e-scrap. These are capital intensive unit operations and are more likely to be the bottleneck of the process for treating e-scrap. By purchasing black copper, vertically integrated companies, which may be limited by their capacity to process e-scrap, can use black copper to fill downstream portions of their processing circuit.

4.1.3 Competitor Analysis

In this analysis, the competitors considered will be restricted to the six global integrated smelter complexes that are currently processing large volumes of e-scrap. Small intermediate refiners and the end-processors in the plastic, glass, steel and aluminium industries are being excluded since they would not be significant competitors to Teck. The six firms are Aurubis, Boliden, Dowa, LS Nikko, Umicore and Xstrata, and they will be described in more detail later in this section. To begin, the general forces acting to influence the behaviour of these companies within the e-waste and e-scrap industry will be discussed. A key driving force in the relationship between these firms and the extent of rivalry between them is the supply of e-scrap feed materials. The high growth of e-waste and e-scrap supply should work to reduce rivalry between the firms due to high availability of feed materials. Most of these smelters are currently running at capacity and some disassemblers and consolidators have indicated that they have excess supply of some feed materials. These materials would include the more difficult to sell e-scrap streams that are typically lower in value (i.e. lower copper, gold, silver and PGMs) and/or contain a more complex mixture of materials that are more difficult to process. If there is insufficient supply of e-scrap, the high fixed costs of operation for these smelting complexes would encourage competitors to modify contract terms for the purchase of e-scrap to favour the suppliers and squeeze margins for the smelters. The impact of a lack of available e-scrap feeds could be mitigated by the ability of these operations to process alternate feed materials such as other metal-based industrial wastes, scrap metal, batteries and car catalysts to fill their processing circuits. If Teck proceeds with the construction of the #4 Slag Fuming Furnace and the Settling Furnace, the process should be designed with the ability to treat alternate feeds as well.

Capacity in the e-scrap processing market is added in large increments due to the capital intensive nature of installing these processes. This leads to the condition where there will be an oversupply of e-scrap due to lack of processing capacity, forcing the balance of power to be in the favour of the end-processors and encouraging investment in new facilities. This would be followed by periods of undersupply of e-scrap as new capacity comes on-line, which drives up the purchase cost of raw materials for the smelters and favours the sellers of e-scrap until the supply of e-scrap catches up with the processing capacity.

There would also be high exit barriers from this industry, which could lead to excess capacity in the industry. The equipment used for processing e-scrap is somewhat specialized and the mix of feeds to the furnaces must be blended to be within a certain range to manage the physical and chemical capabilities of each process. These assets are much more valuable as operating entities than as surplus equipment. The processing of e-waste and e-scrap is sometimes the ‘greenest’ part of a smelting or mining company, so these operations can be held up as flagship operations demonstrating the company’s commitment to sustainable practices, even if the business itself is marginal.

4.1.3.1 Aurubis

Aurubis, which was known as Norddeutsche Affiniere until April 1, 2009, is a copper company that has been processing copper bearing feeds in Germany for over 135 years. The company claims to be the largest copper producer in Europe and the world leader in copper recycling. It produces about 1 million tonnes of cathode copper per year, which is processed into numerous finished copper products. Aurubis merged with Cumerio in 2008, which was previously the copper business from Umicore. Approximately two-thirds of Aurubis' copper production is based on the treatment of primary copper concentrates, while the remaining one-third is from recyclable materials. Aurubis treats 550,000 tonnes per year of secondary materials sourced from copper scrap, metal-based industrial residues as well as copper-bearing and precious metal-bearing fractions of end-of-life products including e-scrap. (Aurubis) The processing of e-scrap falls under the business unit Recycling/Precious Metals and the material is treated at the Lunen recycling centre in Germany. A secondary smelter and precious metal refining facilities are also used at the Hamburg site. (Aurubis, 2010)

The recycling process at Lunen begins with the Kayser Recycling System (KRS), which has an Isasmelt furnace at its core. (Edwards & Alevar, 2007) In October 2008, Aurubis announced the groundbreaking of a new warehouse for the storage of electronic scrap and the €62.5 million (about $86 million Canadian) KRS-Plus Project, which will expand the processing capacity at Lunen. This expansion will include the addition of a second Isasmelt furnace and increase the capacity of the plant to 350,000 tonnes per year of feed materials with up to 145,000 tonnes originating from metal-bearing industrial residues, copper-bearing shredded material and electrical and electronic scrap. The KRS-Plus Project is expected to be completed in 2011 and will increase the number of employees at the site to 500. (Aurubis, 2008)

Aurubis owns a 70% stake in the company Elektro-Recycling NORD (E.R.N). The company, located in Hamburg, helps obtain recyclable raw materials for metals recovery and offers their customers a one-stop solution for their scrap problems. (Elektro-Recycling NORD) E.R.N. has a catalogue of services offered including logistics, reutilization, disassembly and recycling. Vertical integration on the part of Aurubis helps secure e-scrap for their facility at Lunen.

Aurubis is a copper company that operates from the smelting step through to the fabrication of finished products. It is not a miner and must source its feeds through other companies. The company's strategy is to leverage its integrated copper processing capabilities in smelting, refining, extraction, recycling and fabrication. Aurubis has stated that its ability to extract and process a wide range of material and elements is a competitive advantage. A review of Aurubis' published data suggests it is a company that is focused on copper. Sourcing feed materials is important, since it has no internal sources of copper. Primary sources of material remain the largest portion of the feed to their facilities, but the company recognizes the importance of secondary sources as indicated by its investments at Lunen and in E.R.N. Although Aurubis has precious metal refining facilities, it does not seem to have a focus on obtaining materials high in gold, silver and PGMs. Aurubis will require new sources of feed to fill the expansion that will be completed later this year, and this analysis suggests that it will focus on sourcing high copper bearing materials. Additionally, Aurubis is believed to be acquiring its secondary feed materials from primarily from European sources. The focus on high copper bearing secondary sources from Europe should act to reduce the direct competition between Teck and Aurubis, but if the availability of these materials is limited, the need to fill the new capacity at Lunen could increase rivalry between all of the firms in this sector of the industry.

4.1.3.2 Boliden

Boliden is a Swedish mining and smelting company focusing on copper and zinc and has been in operation since 1924. (Boliden) Recycling operations began at Boliden in the 1960s and e-scrap is processed at the Ronnskar copper smelter. This smelter has a current capacity of 100,000 tonnes of recycled material with approximately 45,000 tonnes coming from e-scrap processed through its Kaldo furnace and fuming plants. Boliden is the only existing e-scrap processing facility that uses fuming furnace technology. Boliden claims to be the world's largest recycler of electronic and metal scrap. (Boliden) Boliden is currently expanding their capacity for processing e-scrap to 120,000 tonnes through the installation of a new Kaldo furnace (top-blown rotary converter), steam boiler, gas purification equipment and materials processing facilities at a cost of SEK 1.3 billion (about $195 million Canadian). The new plant is expected to come on line by the end of 2011 or the beginning of 2012. A payback of 4 years is expected due to synergies with existing copper production facilities. (Boliden, 2010)

The sourcing of copper-based raw materials is important to Boliden since the company is a major net purchaser of copper concentrates and secondary materials. Boliden's only copper mine is Aitik in northern Sweden. Boliden also plans to source much of its copper inputs from electronic scrap. Due to the increasing generation of e-scrap and stricter regulations regarding the collection and processing of WEEE in the European Union, Boliden is predicting the availability of e-scrap to grow quickly in the coming years. The capacity increase at Ronnskar is expected to be supplied primarily from the growth of e-scrap volumes in Europe. Boliden is also believed to be sourcing some material from North America, which is expected to increase at a faster rate than Europe, and could add to the feed to Ronnskar. This large investment in the capacity increase at

Ronnskar and the expected tight global market for copper concentrates suggests that Boliden could be very aggressive and increase rivalry between the firms, if sufficient e-scrap volumes or other copper-based recyclables are not readily available.

4.1.3.3 Dowa

Dowa Holdings Company, located in Japan, is a large holding company with five major operating companies. Recycling operations at Dowa are extensively vertically integrated and form a complex interconnection of different companies. The Dowa Recycling network consists of 11 recycling related companies from both the Dowa Metals and Mining Company and Dowa Eco-System Company, which are important in the processing of e-waste and e-scrap. The Dowa Metals and Mining Company has many operations, but two key sites are the Kosaka Smelting and Refining Company and the Akita Zinc Company, which are at the core of the Dowa Recycling network. (Dowa CSR Group) Although these two operations are not located at the same physical site, they are about 130 km apart, materials can be easily transferred between them. Mining and smelting has occurred at Kosaka for over 100 years. The actual processing of e-scrap occurs at the Kosaka plant in the new TSL Furnace, completed in August 2007, which is a submerged lance furnace similar to many of the other smelters that process e-scrap. In addition to e-scrap, this furnace also processes zinc plant residues and various other scraps containing copper, gold and silver. The combined facilities under the Dowa group of companies can process a wide variety of complex materials and can recover the copper, lead, gold, silver and PGMs present in e-scrap.

The Dowa Eco-System Company has an environmental management and recycling division, which includes multiple companies related to e-waste and e-scrap. Eco-Recycle Company and Act-B Recycling Company disassemble and pre-process e-waste from the Japanese market including household appliances, computers, phone systems and other electronic equipment, which is then processed at the Kosaka smelter. (Dowa Eco-System Company) The Platinum Group Metals Recycling company sources PGMs from car catalysts in Japan and another company, Nippon PGM America, sources the same materials in the United States. There is no indication of any direct ownership in any North American or European company disassembling or pre-processing e-waste or e-scrap. (Dowa Holding Company)

Dowa's literature focuses on being a recycling leader in Japan and Asia. Although the company has operations around the world, including North America and Europe, Dowa seems to be concentrating on the Japanese and Asian markets. (Dowa CSR Group) Additionally, its internal network of companies is likely to provide a large portion of the feed material to the

Kosaka plant. This indicates that there should be less rivalry between Dowa and the other smelters since it is focusing on a different market for sourcing its e-scrap feeds. Dowa's Recycling Network is closest of all of the e-scrap smelters to the facilities proposed by Teck in that it combines copper, lead and zinc processing capability with the recycling of e-scrap. Dowa has a large PGM business and will look to source high-grade e-scrap with high PGM values when purchasing external materials not supplied from internal companies.

4.1.3.4 LS Nikko

Copper smelting in Korea began in 1936, but it remained on a small scale until the 1970s and 1980s. The original processing facilities of the Korea Mining and Smelting Corporation at Janghang merged with the newly constructed Onsan Smelter and Refinery in 1982 to form LG Metals. In September 1999, LG Metals joined with the Japan Korea Joint Smelting Group, a consortium of Japanese companies, to form LG Nikko Copper, a 50/50 Korean and Japanese joint venture. The company was renamed LS Nikko Copper in 2005. (LS Nikko Copper) The company is the only copper supplier in Korea and claims to have 60% of the domestic market. The Onsan Smelter and Refinery has a capacity of approximately 510,000 tonnes per year of cathode copper, which is expected to increase to 600,000 tonnes by 2011. Janghang is a small refinery producing 60,000 tonnes per year of copper and is expected to close in the next few years. The Onsan facility uses an Outokumpu flash smelting furnace, which produces a copper matte containing about 60% copper. The matte is processed through three furnaces using the Mitsubishi continuous converting process to produce anodes for electrolytic refining of the copper. Gold, silver, platinum and palladium are all refined into final products at Onsan as well. (Duerden, 2007)

The main feed for LS Nikko's operations is primary copper concentrate. Over 1.4 million tonnes are imported to Korea each year. It is of strategic importance for LS Nikko to secure coalitions with custom mines and other industries to keep the plant at full capacity to meet the growing demand for copper in Korea and nearby China. One of LS Nikko's strategic tasks is to strengthen their general recycling business. LS Nikko invested $10 million in the company Electronic Recyclers International (ERI) to secure e-scrap feeds high in copper and precious metals in December 2009. They further increased their investment in ERI in December 2010. (Electronic Waste Journal, 2010) LS Nikko also opened a US liaison office at ERI's Fresno, California headquarters in May 2010. (Olinger, 2010)

There is little information on LS Nikko and its strategy regarding electronic waste recycling. The partnership with ERI and the brief comment on their web site that they want to strengthen their recycling business is all that seems to be published on the topic. It is difficult to know their capacity for e-scrap processing, or whether they would be aggressive in competing for e-scrap feeds beyond what they have secured through the ERI partnership. If they were to compete for e-scrap feeds, they would likely be looking for high copper and high precious metal bearing feed materials given the company focus on these materials.

4.1.3.5 Umicore

The Umicore Group has a long history of metal production in Europe and is the result of numerous mining and smelting companies coming together over the past 200 years. The company began to reposition itself in the late 1990s to become a materials technology company. It has since sold its mining assets and spun off both its copper business, which became the company Cumerio and was later acquired by Aurubis, and its zinc alloy and refining business, which joined with the zinc assets from Zinifex to form Nyrstar. (Umicore) Umicore currently has four corporate business groups, one of which is Recycling. Within the Recycling group, it is the Precious Metal Refining (PMR) business unit that processes e-scrap. Umicore claims to be the world's largest recycler of precious metals from electronic scrap and spent catalyst material.

The core operation of the PMR business unit is the Hoboken plant in Belgium. This operation went through a major modernization program from 1995 through 2008 at a reported cost of €250 million (about $345 million Canadian at current prices). (Umicore PMR, 2006) (Vanbellen & Chintinne, 2007) This modernization allowed the Hoboken facility to shift its focus from the processing of concentrates to the processing of secondary materials. The core of the modernization program was the installation of an Isasmelt, submerged lance furnace and the removal of a roasting plant, a sinter plant, one of two acid plants, a copper blast furnace and four copper converters. The overall feed capacity of the Hoboken plant is 250,000 tonnes per year, of which, 79% of the feed material is from secondary sources including 14% from end-of-life materials. This gives Umicore the capacity to process approximately 35,000 tonnes per year of e-scrap. (Hageluken, 2006) (Umicore, 2010)

The processing of secondary materials is central to the strategy of the PMR business unit at Umicore and the company is known for sourcing feed materials from around the world. The focus of this business unit is more on the capture and processing of precious metals than copper and would be more likely to source feed material from the higher value e-scrap streams. It is clear in the Umicore literature that they recover PGMs as well as refine gold and silver, unlike many of their competitors. Umicore is not known to be planning an increase to their capacity to process e-scrap and is currently investing in a battery recycling facility for end-of-life rechargeable batteries that will become operational in 2011. (Umicore, 2010) As more e-scrap becomes available in Europe and around the world, their strategy suggests they would look to increase the grade of material processed rather than the volume. Teck should consider sourcing lower value e-scrap streams to reduce rivalry between Teck and Umicore for the sourcing of e-scrap.

4.1.3.6 Xstrata

Xstrata is a diversified mining company with operations around the globe. The business unit involved in the e-scrap industry is Xstrata Copper, which is headquartered in Brisbane, Australia and has operations in eight countries including Canada. All e-scrap recycling activities occur at the Horne copper smelter in Rouyn-Noranda, Quebec and the Canadian Copper Refinery (CCR) in Montreal, Quebec. The Horne copper mine and smelter were developed in 1927 by the company Noranda. Noranda was purchased by Falconbridge in 2005, which in turn was purchased by Xstrata in 2006. (Wikipedia) The Horne mine closed in 1976, forcing the smelter to increase its focus on recycling and secondary feeds.

The Horne smelter has the capacity to treat 840,000 tonnes per year of primary and secondary copper and precious metal bearing materials. Xstrata claims that the Horne smelter is the world's largest processor of electronic scrap containing copper and precious metals. (Xstrata Copper) In 2008, Xstrata issued a press release announcing the expansion of its capacity to process electronic scrap from 50,000 tonnes per year to 100,000 tonnes per year. The announcement indicated that minimal capital expenditure was required for the expansion since the main aspect of the expansion was the modification of the sampling and receiving process rather than additions of equipment to the smelter flowsheet or changes to technical processes. This project was expected to be completed by January 2010. (Xstrata, 2008) No subsequent announcement has been made indicating that these targets have been achieved, but Xstrata has stated that it processes 110,000 tonnes per year of secondary materials such as e-scrap, copper residues, copper scraps, refinery by-products, catalysts, etc. (Xstrata) (Xstrata Recycling)

The CCR has been in operation since 1931 and processes anodes from Xstrata's Horne and Altonorte smelters and Vale Inco's Sudbury operations. The output from the CCR is pure copper, silver, gold, a PGM concentrate and various specialty chemicals. The PGM concentrate is sold to a third-party for further refining. (Xstrata Copper)

Xstrata Copper has vertically integrated into the business of acquiring secondary copper materials for the Horne smelter through the establishment of Xstrata Recycling. Xstrata Recycling has three facilities for the collection of higher grade, precious metal bearing materials, primarily from the electronics industry. These facilities are located in San Jose, California; East Providence, Rhode Island; and Penang, Malaysia. The facilities in the United States are consolidating sites with complete sampling operations, while the facility in Malaysia was built strictly as a consolidation site for existing customers and for OEMs in the electronics industry. Materials collected at all these facilities are shipped to the Horne smelter for processing. (Xstrata Recycling)

Xstrata will be an important competitor for Teck, if Teck chooses to enter the e-scrap business. Teck's entry into the market would increase the number of smelters processing e-scrap from one to two in North America, and it would increase the overall smelting capacity by 40 – 80% depending on how much e-scrap Xstrata can actually process. This large jump in capacity could significantly increase the rivalry in the industry and push down processing charges to favour the suppliers. At the same time, the volume of e-waste collected for recycling is growing rapidly in North America and it is possible that Teck and Xstrata could be targeting different qualities of e-scrap feed streams. Xstrata is focused on sourcing high copper and precious metal bearing materials including PGMs. Teck should consider focusing on e-scrap with lower copper, gold and silver content and avoid PGMs altogether if there is a payable component in the contract to purchase a particular e-scrap stream. Xstrata also has the advantage of having consolidation and sampling sites in areas of high e-waste generation in the United States, namely California and the North Eastern states. Teck will need to evaluate options for ensuring adequate access to suppliers in regions of high e-waste generation.

4.1.4 Threat of New Entrants

New entrants into the end-processing arena of the e-waste recycling chain can have a significant impact on the competition between the end-processors. Since large-scale operations are needed for economic entry into this segment of the industry, a new entrant significantly increases the capacity of the industry and can alter the supply and demand balance for the processing of e-scrap. Research by Teck personnel suggests that the current supply and demand balance can support a new entrant to the industry, particularly if Teck is targeting the e-scrap fractions that are less favourable for the copper producers and the refiners of precious metals including PGMs. Forecast growth in the generation of e-waste and the recovery of e-waste into the recycling chain is expected to be sufficient to supply the existing competitors, including their planned expansions, as well as the additional capacity from the proposed #4 Slag Fuming Furnace and Settling Furnace at Trail Operations. There has been no indication from other existing integrated copper or zinc smelting operations that they intend to enter the e-scrap processing business. (Goosen, 2010)

There are several barriers to entry that would make it difficult for other companies to enter the business of processing complex e-scrap feed streams. Two key barriers are capital investment requirements and economies of scale. The processing of complex e-scrap streams requires significant investments, often in the hundreds of millions of dollars, to build a sufficiently large furnace, appropriate pollution abatement equipment and related infrastructure to reach an economic scale for operation. Companies that have existing infrastructure to build upon to allow the processing of e-scrap would require less capital investment than a company building a completely new facility, which can provide some existing smelting operations with a competitive advantage. Another critical barrier to entry is the technical knowledge required to successfully operate a complex smelting operation. In depth knowledge of the physical and chemical technologies employed, the operating experience to ensure process reliability and the skilled workforce to implement the day-to-day operational requirements of the plant create a series of activities that would be difficult for a new entrant to imitate. Other technologies do exist for processing copper and precious metal bearing recyclables, such as standard copper smelters or hydrometallurgical processes, but they generally do not have the capability to handle the complex e-scrap feed stream containing items such as lead, cadmium and organics. (Schulep, et al., July 2009) An additional barrier to entry to consider is the government and permitting of smelting processes. Obtaining the necessary permits to build and operate a new smelter can be very difficult, particularly in developed countries. These barriers to entry push a smelting operation out of the reach of the disassemblers, consolidators and intermediate refiners as well as others that may choose to enter the industry.

Teck has the financial strength, including existing infrastructure, and the technical knowledge to construct the furnaces required to successfully process large volumes of e-scrap. Trail Operations has been operating fuming furnaces for over 70 years and an electric settling furnace for more than a decade. Using this experience and the existing skilled workforce, the operation of these new furnaces pose limited technical risk to Teck. Finally, Teck has the permits in place to operate the existing operations, which currently process e-waste, and the support of the British Columbia Ministry of Environment to expand the recycling operations at Trail.

4.1.5 Threat of Substitutes

For the purpose of this analysis, the threat of substitutes is considered to be the alternative activities that could occur to reduce the mass and/or the value of e-waste and e-scrap in the recycling chain. The first possible substitute is the choice to dispose of e-waste in the municipal waste stream rather than ensure it is recovered to the recycling stream. This is not just a threat; it is the current reality. Recovery rates of e-waste into the recycling stream in Europe are just under 50%, while North American recovery rates are only about 20%. Although these rates are low, the expansion of government legislation, the growth in e-waste generated and the current trend upwards in recovery rates indicate that the amount of e-waste entering the recycling stream will continue to grow above current levels. Disposing of e-waste in a landfill or incinerator is still cheaper and often more convenient for a consumer or an institution compared to the financial cost of collection, disassembly, sorting and end-processing. Government legislation is helping to realize the true economic cost of e-waste, which includes the societal and environmental impact of disposal, by implementing extended producer responsibility laws. These laws force the producers to internalize the cost of disposal and to provide a convenient option for collection. Implementation of government legislation is an obvious reason for the increasing recovery rate of e-waste, but increased public awareness about the potential damage to the environment and the loss of secondary resources is also encouraging the public to choose recycling over disposal. Market data suggests the growth in the sale and obsolescence of electrical and electronic products will also increase the volume of e-waste, even if the recovery rate was to remain constant.

A second activity that would reduce the mass of e-scrap available for treatment is the exportation of e-waste that has entered the recycling stream to locations and companies that do not have the technology or the skilled workforce needed to ensure the proper recycling of the e-waste. It can be cheaper for collection companies to package up e-waste into a container and send it to Nigeria or China than to properly disassemble and process it in North America or Europe. Legislation is in place or is proposed in North American and Europe to prevent this, but it is questionable how effective it is. There is no conclusive data available on how much 'recycled' e-waste is properly processed and what is what is not. Weaknesses of the system include insufficient legislation, the existence of various exclusions and exemptions within legislation and a lack of enforcement. There is expanding pressure on electrical and electronics product producers from various stakeholder groups to demonstrate sustainable practices for the recycling of their products. This force is acting to reduce the exportation of e-waste inappropriate locations.

Another action that could reduce the mass and/or value of the e-waste generated is the potential of electrical and electronics producers to reduce or change the materials used in the manufacture of their products. Overall, OEMs are going to attempt to use less materials in their products where possible to reduce the cost of production due to lower material costs. This is particularly true when the price of commodities, such as copper, gold and oil, are high. Government legislation is also impacting the use of certain materials in these products. Laws like the RoHS Directive restrict the use of lead and cadmium in electrical and electronic equipment, which reduces the amount of these metals available for recovery and resale in the recycling process. Consumer preferences will also affect the types of products made available by the OEMs. The obsolescence of CRT technology will reduce the leaded glass stream available from the disassembly of e-waste, while the adoption of flat panel screens will increase the stream of glass from liquid crystal displays (LCDs) , which contains tin and indium.

4.1.6 Impact of Government on Industry Groups

Governments at the regional, national and international level are an important force in the e-waste and e-scrap industry that affects all of the players in the industry. Chapter 3 outlined the current status and likely future direction of legislation and regulations in Canada, the United States, the European Union and in some other parts of the world. The key role government plays is in enacting and enforcing laws that regulate the generation, collection, import and export of e-waste in each jurisdiction. It is likely that increased legislation will contribute to the expansion of e-waste recovered to the recycling chain and the responsible recycling of these materials in an environmentally sound manner. Expanding legislation would be expected to increase the available feed materials for all of the companies along the e-waste recycling chain. This has been the experience in many locations around the world that have implemented e-waste recycling laws. A potential threat associated with increased legislation is that some laws may act to reduce the movement of materials to other jurisdictions. Teck has experienced this particular threat with the existing e-waste business due to restrictions on the transportation of whole e-waste to Trail Operations from Alberta, Saskatchewan, Washington and Oregon. It is impossible to predict exactly how the legislation will evolve, the timelines for implementation and the extent of enforcement, but it is clear that this is not a static environment. All of the groups in the e-waste and e-scrap industry will need to remain current on this changing environment and adapt their strategies to take advantage of the opportunities that may occur.

4.1.7 Impact of Complementors on Industry Groups

Important complementors in the E-waste industry are third-party certification programs since members of the e-waste recycling industry may become preferred vendors once they are certified to a recognized recycling standard. No single standard for the management of e-waste and e-scrap exists globally and many standards are still in development. Some of the certification programs specific to the management of e-waste and e-scrap were described in Chapter 3 including the recycler qualification program in Canada; e-Stewards and R2/RIOS in the United States; and WEEELABEX in the European Union. Other important international third party certification programs that some companies have received, particularly the larger disassemblers, consolidators, intermediate refiners and large smelters, include ISO 9001, ISO 14001 and OHSAS 18001. These are internationally recognized standards for the management of quality, environment and health and safety programs respectively.

OEMs, retailers, consumers, institutions and governments want the assurance that a particular recycler will handle their materials appropriately with regard to worker health and safety, environmental impact, data security and exportation to developing countries. A single negative story in the media can affect an organization's image and can be particularly harmful for those organizations that aggressively promote their commitment to sustainability. Consumers are increasingly aware of the impact of improper waste disposal and want to know their waste is being managed responsibly. It can be difficult and confusing to separate the responsible recycling companies from the disreputable ones. Certification to a recognized standard can become an important factor in the selection of a recycling company and can provide a competitive advantage to those companies that hold certification. Certification provides a mechanism for recycling companies to demonstrate sustainable recycling practices.

Companies in the e-waste and e-scrap recycling industries will want to monitor the progress on the development of these standards and the requirements of regulatory agencies. It is possible that the certification to a particular standard may become a requirement in some jurisdictions or a particular standard may become the widely accepted benchmark in the industry. Companies that are not aware of the changing certification landscape could be left behind.

4.2 Scenario Analysis

Scenario planning is a technique, originally developed by the military and adapted to apply to many situations, that involves developing a sequence of possible events and then testing proposed decisions against those alternative possibilities. In the business world, this technique was pioneered by Pierre Wack at the Royal Dutch/Shell group in the late 1960s. This approach is often used to test the potential impact of unpredictable future conditions, which are typically out of the control of the organization generating the scenarios, on the future success of that organization. Analysis of these scenarios can provide guidance to management in making decisions on the approval of individual projects by demonstrating how an investment would be expected to perform under the various proposed scenarios. It is important to note that these scenarios are not predictions about the future. They are simply a mechanism to talk about the future and provide information that is relevant to making a decision without trying to predict what is inherently unpredictable. (Rosell, 1995) (van der Heijden, 1995)

Detailed scenario planning, including all of the supporting research and monitoring of the external environment, can be very labour intensive. Some companies, such Royal Dutch/Shell, have entire internal groups dedicated to scenario planning. For the purpose of this paper, scenario planning will involve the analysis of two important external factors that are outside of the control of Teck, namely metals prices and government regulation. Both factors could have a material impact on the success of the #4 Slag Fuming Furnace and the Settling Furnace project. Figure 8 gives a simple matrix describing the four possible scenarios to be analyzed.

Scenario I – Increased government regulation and low metals prices – This scenario should result in increased availability of e-waste and e-scrap as government implements or expands recycling programs. Landfill or incinerator disposal bans and restrictions on the export of e-waste will also add to the recovery of e-waste to the recycling chain. This will result in less competition for e-scrap feed materials between the end-processors, which would favour the smelters and may improve the choice of materials available or the terms of purchase for the materials. Low metals prices could affect the output of smelters processing primary materials since low metal prices could cause closures of high cost smelters and refiners. The closure of other smelters would decrease the competition for the primary feeds used by e-scrap smelters, which would decrease competition for secondary materials, assuming few mine closures occur as a result of the low prices. If the supply and demand balance for primary raw materials favours the miners, closure is less likely for the mines than the smelters during a period of low prices. Lower metals prices may be indicative of a poor economy and consumers may reduce their purchases of new electronics in times of economic uncertainty, which could mitigate some of the impact of increased government regulation. The fees paid to recyclers for the collection and disassembly of e-waste should be relatively independent of metals prices. These fees are usually determined based on the mass of e-waste collected or processed rather than the value of the contained metals.

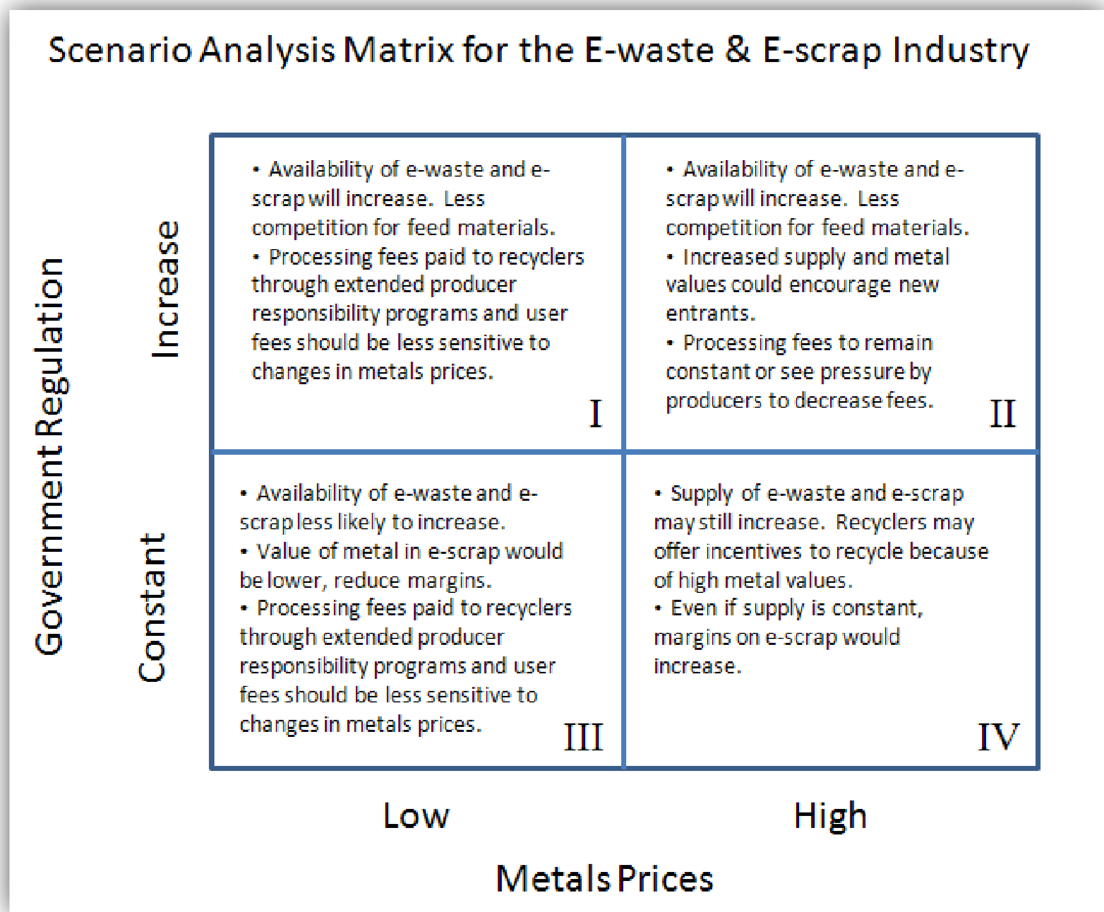

Figure 8. Scenario Analysis for the E-waste and E-scrap Industry.

Scenario II – Increased government regulation and high metals prices – This scenario will should also result in the increased availability of e-waste and e-scrap as described in Scenario I. In general, this would reduce competition for e-scrap feed materials, but the large volume and high metal value may encourage new entrants that could alter the supply and demand balance. The fees paid to recyclers for collection and processing would be expected to remain the same as opposed to being a function of metals prices. In areas where the producers, such as the OEMs and retailers, are responsible for funding the recycling programs for their products, the producers may put pressure on the recyclers to reduces their fees, if they believe that the companies in the recycling chain are making large profits from the handing of e-waste. The producers would make their case by using the argument that the contained value per tonne of e-waste has increased, so the recycling fee should be decreased.

Scenario III – Constant government regulation and low metals prices – The growth in the availability of e-waste and e-scrap would be minimal in this scenario. The generation of e-waste would still be expected to grow due to increasing purchases of electrical and electronic equipment, but the recovery rate would be assumed to be fairly constant with minor growth due to increased consumer awareness. High growth in the availability of e-waste depends on both an increased generation rate and an increased recovery rate. Significant growth in the recovery rate will require additional legislation, not just increased consumer education. The value of the metal contained in the e-waste and e-scrap would decrease with lower metals prices, which could squeeze the margins for both the pre-processors and end-processors. The inherent value of the e-scrap would be less for the pre-processors, while the 'free metal' contained in the e-scrap would have less value to the smelters. Free metal is defined as the recoverable metal content in a feed stream that does not have a payable component in the purchase contract. For example, a purchase contract for e-scrap may only require payment for 95% of the contained copper content in a shipment, while the remainder of the recoverable copper is considered to be 'free'. Constant government regulation would ensure the maintenance of e-waste recycling programs and the supply of e-waste to the recycling chain. The collectors and pre-processors should still realize fairly constant processing fees, as these fees are set based on mass not contained metal value. Low growth in e-waste deporting to the recycling chain along with low metal prices would act as a deterrent for new entrants to the industry.

Scenario IV – Constant government regulation and high metals prices – Slow growth of e-waste and e-scrap recovered to the recycling chain would be expected in this scenario since additional legislation is a key driver for increased recovery rates. The high metals prices could encourage some collectors and pre-processors to offer incentives to consumers to recycle their end-of-life materials with them due to the inherent value of the metals in e-waste, which could promote increased recovery rates above the similar low metals prices scenario. In addition, increased consumer awareness of e-waste recycling programs could raise collection rates in jurisdictions with existing legislation. These factors could somewhat mitigate the impact of stagnant government regulation. Slower growth in e-waste entering the recycling chain would be less likely to encourage new entrants to the industry. For the pre-processors of e-waste and the e-scrap processing smelters, the high value of the metals contained in these streams will act to increase the margins realized by these companies.

The next step in the scenario analysis process is to evaluate how implementation of the #4 Slag Fuming Furnace and the Settling Furnace project may be impacted under each of these four scenarios. Under Scenario I, increased government regulation and low metals prices, there would be little question of sufficient availability of e-scrap for processing in the new furnaces due to high growth in the amount of e-waste entering the recycling chain. The strong supply of e-scrap in this scenario is favourable for the project since a lack of feed material is a key concern given the high capital required for this project and the high cost of not maximizing the throughput of these furnaces. Competition for these materials would favour the end-processors over the disassemblers and consolidators assuming the end-processors are the bottleneck in the process of recycling of e-waste. High barriers to entry into the end-processing section of the industry should limit new entrants unless profits in the industry were very high. Margins realized by Teck under this scenario would be estimated to remain fairly constant per tonne of e-scrap processed. Low metals prices would work to push overall industry margins lower, but if the supply and demand balance favours the end-processors, purchasing contract terms may be more advantageous for the smelters.

Scenario II, increased government regulation and higher metals prices, should be very favourable for the #4 SFF and SF project. As in Scenario I, the availability of e-scrap to process in the furnaces should be higher and the competition for these feed materials should be decreased compared to the current environment. Under the scenario conditions, the risk of not filling the feed circuit to the proposed furnaces would be low. The high metals prices and reduced competition for feed should have an additive effect resulting in higher margins per tonne of e-scrap processed. The higher margins and resultant increase in profits could cause producers to attempt to reduce the fees per tonne of e-waste collected, which in turn would result in the dismantlers and consolidators being more aggressive on the contract terms for the purchase of e-scrap. The realization of high profits by the end-processors and others in the industry could cause new entrants to invest in the industry. Despite these potentially mitigating factors, this scenario would lead to the best economic outcome for the #4 SFF and SF project.

The scenario that would result in the weakest economic outcome for the #4 SFF and SF project would be Scenario III, constant government regulation and low metals prices. The slow growth of e-waste entering the recycling chain could make it difficult for Trail Operations to secure the desired amount of e-scrap for the furnaces. Under this scenario, alternate secondary feed materials to the #4 SFF and SF from other industries might need to be sourced to maximize the profit from this investment. Constant regulation in an environment of low prices would at least maintain the existing supply of e-scrap. The fee-based structure for funding the recycling industry is independent of metals prices and a reduction in supply would not be expected in a low metals prices environment. This is unlike what often occurs in the primary mining industry where low metal prices often lead to the closure of high cost mines. Margins on the e-scrap and other feed materials would also be lower in a low metals price environment due to the decreased value of the 'free metal' in the feed.

Scenario IV, constant government regulation and high metals prices, would tighten the supply of available e-scrap for the #4 SFF and SF project. The growth of available e-scrap would be slow without the influence of increasing regulation, yet the economics of operating a complex smelting facility typically require that the operation run at full capacity, so competition for the e-scrap would increase. The high metals prices may increase the availability of other secondary feed materials somewhat since sellers of these materials often prefer to sell these materials in a higher price environment. Higher metals prices will also improve the margin to Teck per tonne of feed processed due to the higher value of the contained 'free metal'.

Each of these scenarios provide a framework for analyzing the potential impact of key factors on the economic feasibility of the #4 SFF and SF project. None of these scenarios are predictions about the future, but they do provide a spectrum of conditions for consideration when making decisions about this project. Scenario I should ensure supply of sufficient feed to the furnaces, but the margins could be smaller than desired. Optimizing contracts for the purchase of feeds and the sale of black copper for Teck will act to improve margins. Scenario II would be almost ideal for this project with high availability of materials and high margins for Teck and its competitors. This would provide Teck with a good position for establishing supply agreements and contract terms to position itself favourably should the industry environment become less positive. Scenario III would be the most challenging. Teck would need to aggressively source e-scrap and other secondary materials to provide enough feed to the furnaces. Establishment of longer-term supply contracts could mitigate the risk of low feed supply. Smaller margins due to low metals prices could be alleviated through contract term negotiations, while maximizing throughput would spread the fixed cost of operation over more feed tonnes. Scenario IV would also see high competition for e-scrap. Longer-term supply contracts would be beneficial in this situation, but access to secondary feeds that fit with the metallurgy of Trail Operations is another option for maximizing #4 SFF and SF throughput. High metals prices would ensure good margins on the materials treated. Application of these scenarios to a more rigorous economic analysis outside the scope of this paper would further inform the decision making process.

These scenarios should also be used to evaluate the base case of incremental expansion of the existing e-waste processing business at Trail Operations. The impact of metals prices on the e-waste recycling industry would be minimal since the fee-for-service structure of the e-waste recycling industry is essentially independent of metals prices. This is an advantage over the e-scrap recycling segment of the industry, which is much more price sensitive due to the high concentration of metals in the e-scrap feed streams. This leaves two scenarios for the evaluation of e-waste recycling, increased or constant government regulation. As regulation increases, Teck can expect its allocation of the e-waste collected in BC to expand. The BC regulations are already fairly extensive, but the implementation of landfill disposal bans and the setting of recovery targets would increase recycling rates. Increased regulation in the other Western Canadian provinces would only increase the amount of CRT glass available to Teck. The high cost of transportation of e-waste, particularly when compared with e-scrap, and the regulatory hurdles in the United States limit the upward potential of increases to government legislation. In the case where government regulation is constant, the status quo would be maintained with a small amount of growth in the amount of e-waste processed due to increased generation of e-waste and improved consumer education.

In conclusion, the scenario analysis indicates that the strategy of entering the e-scrap processing business via the installation of the #4 SFF and SF is reasonable under each of the scenarios considered. Overall, the e-scrap market brings the potential for both greater risks and rewards to Teck, but Teck can take actions to improve its position in the industry under the less favourable conditions. A more rigorous economic evaluation outside the scope of this paper could provide numerical support for the upside and downside potential of each scenario. Entering the e-scrap segment of the e-waste recycling industry is more sensitive to both government regulation and metals prices than the base case of incremental expansion of the existing e-waste business. There are limited consequences to Teck's e-waste processing business under conditions of variable metals prices or government regulation.

5 Analysis of Additional Considerations

5.1 Administrative System Analysis

Entering the e-scrap processing business on a large scale is a significant business decision requiring a substantial financial investment for the installation of the #4 Slag Fuming Furnace and the Settling Furnace. Resources have been assigned to review technical issues, provide capital estimates, assess project risks and prepare economic analyses of multiple scenarios. Another important area that needs to be considered and will require the assignment of additional resources is the development of the administrative systems needed to enter and operate within the industry. Establishment of these systems will not materially affect the economics of the project, but will increase the probability of being successful. Assuming the project is approved, a detailed administrative system review, including the required timing for development and implementation, should begin shortly after project approval.

Teck is not well known within the e-waste and e-scrap recycling industry except in the Western Canadian market. Even in that market, Teck is known for the processing of CRT glass and moderate amounts of whole e-waste, not large volumes of e-scrap. Teck needs to explore options for marketing Trail Operations' expanding capacity, unique capabilities and overall vision regarding the processing of e-scrap. This can also be used to promote the sustainable practices of Teck to various stakeholder groups. Trail Operations has to look at establishing and maintaining relationships with potential suppliers of e-scrap and other recyclable feeds as well as relationships with customers who might purchase the black copper product from the settling furnace. Trail Operations has well established networks in the primary concentrate market with mines, traders and various customer groups, but these are not the same organizations involved in the recycling industry. Teck also needs to gain a better understanding of the industry and the players in it. Porter's Five Forces analysis of the industry is an evaluation at a given point in time. The recycling of e-waste and e-scrap is a rapidly changing industry, and Teck must maintain the market intelligence needed to be current with the changing forces acting within the industry.

Contract management and accounting systems will need to be modified to accommodate the incoming e-scrap feeds. Ensuring appropriate contracts are put in place with competitive terms that are suitable for the industry will require more research. Contract terms for secondary materials may not fit into the existing template used for the purchase of primary materials and may require modifications of Trail Operations' contract management system. Trail Operations has several large, existing supply contracts for feed materials from a limited number of companies due to the economies of scale required in the mining industry. The more fragmented nature of the recycling industry and the greater range in the quality of secondary feed materials may require an increased number of suppliers to meet the volume of secondary materials desired and increase the number of contracts to be managed. Modifications to the contract management system may also be needed for the sale of black copper. Financial and metallurgical accounting systems will need to be adjusted to allow for accurate and timely exchange of funds with suppliers and customers and to provide financial reporting on the performance of the recycling business. Additionally, Trail will need to upgrade systems used for tracking all incoming and outgoing materials to allow for metallurgical accounting of materials. Procedures should to be written to document the workflow of these contract and accounting processes.

Transportation and logistics is another area to be considered. E-scrap is generated globally and the contained value of metal in e-scrap allows for the economic transport of e-scrap to many locations around the world. Despite this, Trail Operations' inland location is a disadvantage that increases the overall cost of procuring both recyclable and primary materials. An evaluation of how to best optimize the transportation and logistics of e-scrap is needed to identify opportunities to minimize transportation costs. It may be possible to leverage the existing transportation and logistics network used by Trail Operations to reduce the overall cost of shipping feed materials into Trail and sending products out to customers.

Another topic to consider is the management of regulatory requirements, particularly with respect to hazardous waste permits and customs documents. Familiarity with the regulatory environment in both the exporting and importing countries is necessary to correctly classify various e-scrap and secondary streams according to applicable regulations and to apply for the required permits. Documentation must then be maintained in accordance with those regulations. An evaluation of import and export customs requirements is also needed to ensure correct compliance with the relevant laws in each jurisdiction. Third-party certification programs, like ISO 14001 or the EPSC Recycler Qualification Program, are not regulatory requirements, but require similar systems. Teck should assess to what extent it will participate in these certification programs and allocate the resources as required. Trail Operations is already certified to the ISO 14001:2004 and ISO 9001:2008 standard, but has not been certified to the new EPSC Recycler Qualification Program or other e-waste recycling standard. This issue if further complicated by the numerous standards advocated by different jurisdictions for the management of e-waste rather than the adoption of an international standard for e-waste such as the ISO series of standards.

Trail Operations utilizes economic and metallurgical models to optimize the blend of feed materials consumed at Trail. These models are complex and are used to predict the impact of changes to feed materials and process parameters on the economic performance and overall metallurgy of the site. These models will need to be updated and validated to incorporate the impact of these process changes throughout the Operations.

Receiving, sampling and assaying is a critical element in Teck's success in the e-scrap processing industry. Although this goes beyond administrative systems to the technical development and implementation of robust, reliable and trusted receiving, sampling and assaying processes, the administration of these systems should not be forgotten. The analytical services lab at Trail Operations is an excellent facility and already holds ISO 9001 and ISO 14001 certification. Although this is already a well-established framework, resources will be needed to develop, document and implement new analytical procedures. The receiving and sampling department at Trail Operations has extensive experience with the scientific sampling of high value materials. This knowledge will need to be applied to the development of new receiving and sampling processes for e-scrap. Whether or not these processes need to be certified to the ISO 9001 and ISO 14000 standards will need to be determined. If these receiving and sampling processes are located at a distance to Trail Operations, a system for managing and monitoring these processes is needed to ensure these distant facilities maintain the high level of quality and environmental responsibility that Trail Operations is known for.

5.2 Stakeholder Analysis

Stakeholder analysis has become increasingly important in the mining and resource industry in the last few decades. Social pressure from various stakeholder groups have been able to influence the actions of these companies through all stages of mining and smelting projects regardless of it being a new development project or a modification to an existing operation. Approval of the #4 Slag Fuming Furnace and the Settling Furnace project will have an impact on numerous stakeholder groups. The purpose of this section is to identify who are the key stakeholder groups and to predict the issues that will be important to each group. The key stakeholder groups include Trail and area residents, Trail Operations employees, Teck Resources, Teck shareholders, government and non-governmental organizations (NGOs).

Trail and area residents will be directly impacted by the installation and operation of the #4 SFF and SF project. This stakeholder group also includes local businesses and landowners. During the construction phase of the project, residents may be concerned about issues such as noise from demolition and construction activities; increased dusting and emissions from the disturbance of soil; the number of construction jobs that will be created in the community; and increased truck traffic through town. Once the facilities are operational, concerns of local residents may include the potential for increased water discharge from the plant; increased sulphur dioxide, greenhouse gas and metals emissions to the air; elevated noise levels in the community; and the potential for additional permanent jobs at Trail Operations. Communication plans to engage this group have been developed for the pre-approval phase of the project and are currently being implemented. Public engagement meetings were held in December 2010 and follow-up discussion groups, one-on-one interviews and additional meetings are continuing in 2011. The purpose of the initial meeting was to inform the public about the project, the potential benefits to the community, what is being done to address possible concerns from the area residents and to invite public participation in discussing the issues important to the community. Feedback from this first public engagement meeting, where approximately 80 people attended, was that 96% of attendees who handed in a feedback form felt positive about the project. (Adair, 2011)

Trail Operations employees are residents of the area, but this group also has a direct connection to in the #4 SFF and SF project and they have a different level of knowledge about Trail Operations than the general public. A series of four employee information sessions were hosted on-site in November and December 2010 to accommodate all of the various shifts at Trail Operations. These sessions allowed for interactive discussions between employees and the project team about the project and how it could impact the community and Trail Operations employees. Many of the issues that would have been raised at the community level were present within the employee group and there was interest in how these new facilities would be specifically incorporated into Trail Operations.

Teck Resources, as the parent company for Teck Metals and Trail Operations specifically, has a direct interest in this project. From a financial perspective, Teck wants to ensure the project will provide a reasonable return on investment. All business opportunities must be rigorously evaluated against corporate criteria for financial viability and the #4 SFF and SF project is no different. As a company, Teck is committed to sustainable business practices and the existing e-waste processing capabilities at Trail are already widely promoted in Teck's sustainability literature. The expansion of Trail Operations' capacity to process the growing quantity of e-waste in a socially and environmentally sustainable manner is one way Teck can demonstrate its continuing commitment to sustainable development. (Teck Resources, 2010) (Teck Resources) Teck shareholders would have similar issues to Teck Resources. Their concerns would be primarily focused on the financial return that could be realized from the implementation of this project.

Governments on local, provincial and national levels all have an interest in the #4 SFF and SF project. Local governments would want to understand how the project would affect the local economy, the community environment and the well-being of its citizens. A presentation outlining the project and the community engagement process was made to the Trail City Council on December 13, 2010. The British Columbia and Canadian governments must be engaged as part of the permitting and approval process. The provincial and federal governments also stand to gain from increased tax revenues, job creation and good-news stories about the environmentally sound projects being implemented by corporations. Local, state and federal governments in the United States also need to be considered as stakeholders given the proximity of Trail Operations to the United States border.

The interests of NGOs with respect to the #4 SFF and SF project vary depending on the purpose of the organization. Local economic development groups such as the Lower Columbia Community Development Team (LCCDT) or the Columbia Basin Trust work to improve the social and economic strength of the region. These groups are generally supportive of projects that will provide economic development in the region, particularly projects with a positive environmental impact. (LCCDT) (Columbia Basin Trust) Local environmental groups, such as the Columbia River Integrated Environmental Monitoring Program or the West Kootenay EcoSociety want to ensure there is minimal impact on the Columbia River and the local environment due to increased industrial activity. Geographically broader environmental groups and non-profit organizations, some of which are focused on the responsible recycling of e-waste, want to ensure e-waste is recycled according to widely accepted recycling practices and to minimize or completely ban the export of e-waste to countries that do not have the infrastructure to properly process the e-waste. These organizations, such as the Basel Action Network or the Electronics Recycling Association of Canada, would encourage the development of facilities to responsibly process the growing supply of e-waste and e-scrap. (Basel Action Network) (Electronics Recycling Association)

5.3 Strategic Fit with Current Organization

The construction of the #4 Slag Fuming Furnace and the Settling furnace to allow a large scale move into the processing of secondary materials, such as e-scrap, is a strategic shift in the direction of Trail Operations. A question that needs to be answered is whether or not this shift is a strategic fit with Trail Operations and with Teck Resources as a whole? The availability of feed materials to Trail Operations is moving to favour the miners in the supply and demand balance for primary feed materials. A movement into secondary materials would contribute to the long-term viability of Trail by diversifying its business to create additional profit centres and to generate as much value as possible from existing assets. Trail Operations has been a custom smelter processing a variety of primary materials for decades. It has built into its existing facilities the capability of processing a wide range of materials of varying composition. The technical skill and experience of Trail Operations' employees, which exists in a culture that promotes innovation and problem solving, along with the existing processing capabilities at Trail would indicate a positive fit for this new strategic direction at Trail. Trail Operations also has experience with the processing of secondary materials, such as used lead acid batteries and e-waste. The management of these materials and the associated business systems has served as a good trial to demonstrate how well secondary materials treatment would fit with Trail on a larger scale. This strategic shift towards increased processing of e-scrap and other secondary feed materials is not only a good fit for Trail, it is important for the long-term success of the organization.

Teck Resources is first and foremost a mining company, and Trail Operations is the only smelting and refining operation in the company. So, how is the #4 Slag Fuming Furnace and the Settling Furnace project a strategic fit with Teck Resources? The fit is through Teck's commitment to sustainability. "At Teck, the pursuit of sustainability is one of our core values that drives our approach to business." (Teck Resources) In 2010, Teck was named to the Dow Jones Sustainability Index (DJSI) World Index, which indicates Teck is considered to be in the top 10% of the mining industry with respect to sustainability. Two of the key voluntary initiatives mentioned by Teck in the 2009 Sustainability Report were the electronics recycling program at Trail and the International Zinc Association's fertilizer and zinc supplement program. (Teck Resources, 2010, p. 19) Numerous case studies on both of these topics are also described on the Teck web site. As Porter and Kramer point out in their article on the link between competitive advantage and corporate social responsibility (CSR), "CSR can be much more than just a cost, constraint, or charitable deed. Approached strategically, it generates opportunity, innovation, and competitive advantage for corporations – while solving pressing social problems." (Porter & Kramer, 2006, p. 1) The expansion of e-scrap processing will allow Teck to be part of the global solution in the management of the rapidly expanding generation of e-waste. The project will provide economic growth to Trail and other local communities, and it will create value for the company and its shareholders. Trail Operations' strategic shift towards increased recycling and processing of e-scrap and other secondary materials further establishes Teck's commitment to sustainability.

6 Analysis of Trail Operations' Competitive Advantage

An enduring competitive advantage is one of the primary strategic goals of management. A competitive advantage is important for business success since it can be defined as the ability to achieve above average profitability on a consistent basis. Identifying a competitive advantage for a firm requires knowledge and understanding of the opportunities and threats that exist in the external environment that the firm is competing in. The Five Forces analysis in Chapter 5 provided insight into that external environment that Teck would face in the e-waste and e-scrap industry.

Jay Barney suggests that this understanding of the external environment is only part of what is needed for a complete understanding of the competitive advantage of a firm. An analysis of a firm's internal strengths and weaknesses, also referred to as resources and capabilities, is essential to fully understand the source of a firm's competitive advantage. For these internal resources to contribute to the competitive advantage of a firm, the combination of strengths and weaknesses must be valuable, rare and difficult to imitate plus the firm must have the organizational systems to capitalize on these resources. (Barney, 1995) An understanding of Trail Operations' strengths and weaknesses will assist in determining whether or not Trail Operations can develop and maintain a competitive advantage in the e-waste and e-scrap processing industry.

6.1 Trail Operations' Strengths

Trail Operations has numerous strengths that would contribute to the company's ability to successfully compete in the e-waste and e-scrap processing industry.

- *Financial Resources* – Teck has the financial resources to invest in the construction of additional smelting facilities at Trail Operations. Although this is a significant investment for Trail, it is not large by comparison to the financial resources required for many of the mining projects that Teck has invested in. Access to this resource is not an advantage against incumbent firms, but it is a significant barrier to entry for other potential entrants. Even with access to this resource, Trail Operations must still demonstrate that the construction of the #4 Slag Fuming Furnace and the Settling Furnace will provide a solid return on investment for the company.

- *Unique Smelting Technology* – Trail Operations is applying unique smelting technology compared to the other large e-scrap processors as the only e-scrap processor using fuming furnace technology as the primary processing step. Other smelters using Isasmelt and other technologies have had their throughput limited due to excessive furnace brick corrosion and wear. Trail has been operating fuming furnaces for over 70 years and has extensive experience with this technology. Furnace brick corrosion and wear has not been a problem in Trail Operations' fuming furnaces. The feed system for the fuming furnace would also allow more variation in the physical characteristics of the feed materials compared to those furnaces using submerged lance technology. The settling furnace is an electric furnace, similar to the electric furnace portion of the Kivcet furnace, which has been operating at Trail since 1997.
- *Integrated Processing Facilities* – Trail Operations would become the only single smelting complex processing e-scrap based on zinc and lead metallurgy rather than copper or copper and lead metallurgy. In addition, the integrated nature of the existing infrastructure at Trail enables the facility to recover a wide range of metals into saleable products. These capabilities will allow Trail to target different qualities of feed materials due the differences in process chemistry relative to likely competitors. Trail can treat mixed metallic e-scrap streams containing plastics and is not restricted to only treating high-grade e-scrap or copper wire. These lower grade materials are often being turned away by other smelters, which are operating at capacity and are able to selectively choose their feed materials. The differences in metallurgy at Trail also provide the opportunity to treat other metal bearing streams from outside the e-scrap industry that competitors would not be able to process.
- *Management of Hazardous Metals* – Lead, cadmium, mercury, etc. are hazardous metals and Trail Operations has many years of experience with the handling and recovery of these metals. Trail has broad experience working with hazardous metals and has already established procedures and systems to manage worker safety and environmental impact.
- *Knowledgeable Human Resources* – The skilled people working at Trail Operations are an important strength. The years of experience at implementing and operating

complex metallurgical processes are incorporated into the processes, documents, systems and organizational culture that exists at Trail. Trail Operations has a long history of innovation and problem solving that has allowed this facility to evolve with changing technologies and business environments to remain a profitable operation for over a century.

- *Western North American Location* – Although Trail Operations' inland western North American location is not an advantage for low value, high mass, whole e-waste, it is an advantage relative to other smelters competing for e-scrap. Currently, e-scrap is shipped from California to Xstrata in Quebec, Canada and from Australia to Umicore in Belgium. Trail Operations would be the closest location for processing any e-scrap generated in western North America.

6.2 Trail Operation's Weaknesses

Trail Operations is not without its weaknesses that could influence its success in the e-waste and e-scrap processing industry. A good understanding of these weaknesses allows Teck to chart a course that minimizes the impact of these weaknesses or to implement changes to mitigate them.

- *New Entrant* – Teck is a new entrant to the market for processing e-scrap and the scale of entry needs to be large to reach efficient economies of scale, but Trail Operations requires sufficient raw material to make the investment in additional smelting capacity economic. It could be difficult to secure the volumes of e-scrap desired since Trail does not have an extensive, established network within the e-waste recycling industry. In addition, Teck has limited knowledge of the recycling industry as a whole, which is likely to be significantly different from the mining and smelting industry. To mitigate the weakness of being new to the industry and to secure the feed required to fill the new furnaces, Teck needs to market Trail Operations to the e-waste and e-scrap industry to develop the relationships with suppliers required to secure the necessary feed. Another approach could involve the establishment of partnerships with firms in the recycling industry. This could assist Teck with gaining more knowledge about the recycling industry and provide connections to companies that are experienced in the world of recycling.

- *No Precious Metal Refining Capacity* – The #4 Slag Fuming Furnace and the Settling Furnace project does not include the processing capacity to refine the black copper from the smelting furnace into refined copper, gold, silver and PGMs. Trail Operations will want to target feed materials that will minimize the payable amounts for these elements in the material purchase contracts since no value is created for Teck by only recovering the metals to black copper.

- *High Labour and Construction Costs* – The high cost of labour and facility construction could limit Trail Operations ability to vertically integrate into the consolidation and sampling functions of the e-waste recycling chain. Trail Operations will likely need to look to contracting arrangements or partnerships to secure the services it requires. The challenge will be in managing these upstream services to the standards demanded by Teck and its customers.

- *Lack of Required Organizational Structure* – Teck needs to ensure the business systems are in place to support business expansion. At Trail Operations, the existing Business Development group has successfully established the e-waste processing business and the existing Raw Materials group has sourced primary materials for decades. However, the Business Development group has no experience with the large volume of materials that need to be managed for the new smelting facility and the Raw Materials group is not familiar with the recycling industry. Other players in the industry have separate departments, business units or whole subsidiaries for managing their recycling businesses. Teck would be naïve to assume the new e-scrap business can just be squeezed into existing business systems. To address this weakness, Teck has to evaluate and implement the organizational structure needed to support this business expansion.

6.3 Strategic Implications of Strengths and Weaknesses

Michael Porter has stated that a company can only outperform its competitors if it can establish and preserve a difference between them. Additionally, competitive strategy requires firms to choose different sets of activities to deliver a unique mix of value. (Porter, 1996) Porter has identified three generic strategies using different sets of activities that allow firms to maintain a competitive advantage: overall cost leadership, differentiation and focus. (Porter, 1980) An overall cost leadership strategy focuses on cost control, construction of efficient-scale facilities and cost minimization in R&D, sales and advertising. Differentiation is a strategy that involves creating a product or service that is perceived throughout the industry as being unique and will allow the firm to charge a premium for the product or service. A focus strategy targets a particular supplier group or segment of a product line or a geographic market. To be successful in any one of these strategies Porter points out it is necessary to have total commitment to the strategy and the strategy must be best suited to the firm's strengths and least replicable by the firm's competitors. Without commitment to any particular strategy, a firm risks being 'stuck in the middle', whereby it either bids away profits by competing on price or it does not have a unique enough service to demand a premium or it does not have a service that meets the targeted segment of the market.

Based on the strengths and weaknesses of Trail Operations outlined above, Teck should consider adopting a focus strategy. Trail Operations' unique smelting technology and metallurgy will allow Teck to target feed materials that would be considered to be a poor fit with the technology and metallurgy of its competitors. For example, feed materials high in lead and zinc are a good fit for Trail Operations, while there is less desire for the high copper feeds that are favoured by copper smelters. The ability of Trail Operations to manage a wide range of metals and to convert them into saleable products, will enable Teck to treat the mixed metal wastes that other, less flexible facilities cannot process. Trail Operations would also prefer to process lower-grade mixed metal feeds since Teck wants to minimize what it pays for contained gold, silver and PGMs in e-scrap, because it would not return value to the company. A smelter that has a precious metals refinery that can recover these high value materials would seek out high-grade feed materials. The fuming furnace design also allows for the addition of irregularly sized feed to the furnaces at Trail, while smelters using submerged lance technology, like the Isasmelt furnace, require a finer, more physically consistent feed. Overall, these differences in technology and metallurgy will allow Teck to focus in on a segment of the feed streams from the e-waste recycling chain that uniquely fit with Trail Operations' capabilities.

Maintaining a competitive advantage requires that the internal resources of a firm be valuable, rare and difficult to imitate. Trail Operations' strengths must be compared against these criteria to determine if they do in fact provide Teck with a competitive advantage. Financial resources are certainly valuable, but are not necessarily rare or difficult to imitate. These resources provide a barrier to entry into the industry rather than a source of competitive advantage. Management of hazardous metals and a western North American location are also valuable and are more rare and difficult to imitate than financial resources, but there are several companies that could reasonably achieve these capabilities. Unique smelting technology, integrated processing facilities and knowledgeable human resources are valuable, rare and difficult to imitate. Trail Operations also has the organizational systems to capitalize on these resources as the successful installation and operation of the Kivcet furnace demonstrates. Trail Operations has developed these capabilities over many years and are the result of the Operations' history. Typically, when valuable and rare resources exist due to unique historical circumstances, competitors who might consider imitating these resources are at a significant cost disadvantage. (Barney, 1995) It is these three strengths that are the source of Trail Operations' competitive advantage. Decisions made to leverage these resources will assist in securing Teck's niche within the e-waste and e-scrap processing industry.

7 Recommendations

The recommendations put forward in this study are based on the assumption that the technical feasibility study and economic evaluation support the approval of the #4 Slag Fuming Furnace and Settling Furnace. If this assumption holds true, there are several actions that should be taken to position Teck in the e-scrap market and increase the probability of a successful entry into the e-scrap processing industry.

One of the first actions required is to continue with the stakeholder engagement process to communicate the new strategy for Trail Operations to expand into the processing of secondary materials. This message needs to be communicated to several stakeholder groups with specific information that is relevant to each group. For the Trail area residents, Trail Operations employees and local stakeholder groups like city governments and NGOs, they need to know that this project is important for ensuring the long-term viability of Trail Operations as well as the potential direct impact to each group during construction and operation of the new facilities. Trail Operations already has a good working relationship with the local stakeholder groups and it is imperative that the company maintains this social license to operate. Corporate stakeholders and shareholders need to know how this project will maximize the value of Trail Operations' assets and improve the profitability of the facility while improving the image of Teck as a sustainable corporation.

A complementary activity to the communication of the new strategy to stakeholder groups is to develop a marketing plan to promote Teck's entry into the e-scrap processing industry to potential suppliers and others in the e-waste and e-scrap industry. The focus should initially be on North American suppliers, but should also expand to the European Union and perhaps Asia. Teck is not well known in the industry and potential suppliers will not be aware of Trail Operations' unique processing capabilities and preferred feed materials. The marketing plan must go beyond promotional materials, attending conferences and joining trade associations to building valuable business relationships through contacts at companies who could become important suppliers or partners. These relationships will be built through face-to-face meetings, invitations to visit Trail Operations and open discussions to find a fit between potential feed materials and the capabilities of the Operation. Business relationships with established players in the e-waste and e-scrap recycling industry will also assist Teck in gaining a better overall understanding of the industry. A concerted effort in this area will help mitigate Teck's weakness of being a new entrant to the e-scrap processing industry.

In preparing this marketing plan, Teck needs to be clear on the segment of the market that it is targeting for securing feed materials. It is recommended that Teck adopt a focus strategy for the selection of feed materials to Trail Operations whereby the raw materials are a good fit with the capabilities of Trail and are a less favourable fit for other e-scrap processors. The rare and difficult to imitate strengths of Trail Operations that will allow the company to gain a competitive advantage in the e-scrap processing industry are its unique smelting technology, integrated processing facilities and knowledgeable human resources. The feed streams that fit with these capabilities, which are also a less favourable fit with other competitors, include low-grade e-scrap; high zinc and lead bearing materials; and irregularly sized materials.

Through the adoption of a focus strategy, Trail Operations needs to define the criteria and the standards for selecting incoming raw materials to Trail. Trail Operations should not limit itself to sourcing feed strictly from the e-scrap industry if there are available materials that fit this feed criteria from outside the e-scrap industry. Scanning the environment for suitable feed materials from other industries should be included in the responsibilities of a person charged with securing feed for the #4 Slag Fuming Furnace.

Additional marketing work is needed for the sale of black copper, but sales of black copper should not pose the same challenge as securing incoming raw materials as there are many companies who could process this material. In addition, there seems to be more refining capacity for black copper than smelting capacity for e-scrap.

Teck must evaluate the optimal business structure needed to support the entry into the e-scrap processing industry and the most advantageous degree of vertical integration. Existing e-scrap processors from the smelting industry have taken different approaches in their business structures. Aurubis, Xstrata and Dowa all have subsidiaries located upstream of the smelter in the recycling chain to secure feed materials for the smelting operation. Some of these subsidiaries go all the way up the recycling chain to the collection step, while others are simply consolidators for e-scrap. This structure may be a function of being in the recycling industry for a relatively long period of time in the cases of Aurubis and Xstrata, while vertical integration is a common strategy for many Japanese companies. Umicore has an entire recycling business group at the corporate level since the sourcing and processing of secondary feed materials is a major corporate focus. This business group was formed as part of a conscious shift in the strategy at Umicore from a smelting company to a materials technology company in the last decade. Umicore is generally not vertically integrated, but it has shredding and sorting plants. It has recently entered into a partnership in India to provide expertise in establishing improved e-waste recovery processes. LS Nikko has taken the approach of forming a partnership with ERI and direct investment in the recycler to assist with their expansion. As a new entrant to the industry, Teck should consider establishing one or more partnerships in the industry rather than attempt to vertically integrate into the industry. This will allow Teck to gain market intelligence on the e-waste and general recycling industries from experienced firms; to access resources off-site of Trail Operations to act as consolidating and sampling locations; and to find mutually beneficial arrangements that will secure a regular supply of a large quantity of feed to Trail Operations.

In addition to evaluating the optimal business structure, Teck needs to ensure the business systems are in place to support business expansion. This would include activities related to contract management of incoming raw materials and product sales; accounting system modifications; administration of regulatory issues; optimization of transportation and logistics; and co-ordination of relevant certification programs. Teck cannot assume the new e-scrap business can be forced into existing business systems and must evaluate and implement the organizational structure needed to support this business expansion

Teck should assign a resource to monitor and report on the market trends and legislation associated with the management of e-waste. Forecast sales data and obsolescence rates for consumer electronics indicate that e-waste generated will continue to expand. The current legislative trend is to expand the jurisdictions with e-waste recycling laws, broaden the number of items that are included in the scope of recyclable items and increase the recovery targets for e-waste recovered from the municipal waste stream to the recycling chain. This would suggest that the amount of material available to the e-waste recycling chain should continue to grow quite rapidly. E-waste generation rates and government regulation are two of the largest factors affecting the supply of e-scrap, but this analysis is only accurate at a point in time. Regular monitoring of the environment is necessary to inform decisions about changes in the industry environment.

In summary, the key recommendations from this study are as follows:

- Continue to inform key stakeholder groups regarding Teck's decisions concerning the new strategy to expand the processing of secondary materials at Trail Operations. This will assist in maintaining Teck's social license to operate.

- Develop a marketing plan to promote Teck's entry into the e-waste and e-scrap processing industry and to increase industry knowledge of Trail Operations unique processing capabilities and preferred feed materials. Assign the necessary resources to establish a network of business relationships within the industry.
- Trail Operations should target e-scrap feeds such as low-grade e-scrap, high zinc and lead bearing streams and irregularly sized materials as feed to the #4 Slag Fuming Furnace. A feed specification should be established to assist with the evaluation of potential secondary raw materials from e-scrap feed streams and recyclables from other industries.
- Teck needs to evaluate the optimal business structure for entry into the e-scrap processing industry. It is recommended that Teck investigate options for strategic partnerships with firms already in the recycling industry rather than using a vertical integration approach. This should help Trail Operations access e-scrap from areas of high generation in North America such as California and the North Eastern US.
- Trail Operations must ensure the business systems are in place to support business expansion. This applies to areas such as contract management, accounting systems, transportation, regulations and certifications.
- Teck should assign a resource to monitor the industry environment given the new and dynamic nature of the industry. This would involve monitoring of e-waste generation and recovery forecasts, changes to international waste legislation, evaluation of competitors and estimates of the supply and demand balance for e-scrap.
- Trail Operations should consider assigning an individual to co-ordinate these business activities as part of the implementation team for the #4 Slag Fuming Furnace and the Settling Furnace Project.

8 Conclusion

Teck's Trail Operations is at a point in time where a critical decision must be made. The challenging industry environment for primary zinc and lead smelters is expected to worsen in the coming years, particularly in the zinc industry, as a structural shift is projected to move the supply and demand balance in favour of the miners. Teck must determine what actions it needs to take to maximize the value of its existing assets and to ensure the long-term viability of Trail Operations. The construction and operation of the #4 Slag Fuming Furnace and the Setting Furnace has the potential to be a cornerstone of a revised business model that increases the amount of secondary materials processed at Trail Operations.

In considering the decision of whether or not to move forward with the new furnaces, Teck must assess this project against other alternatives. One such alternative is to maintain the current course of optimizing the mix of primary and secondary feed materials processed with the existing assets at the smelter to maximize the profitability of Trail Operations. This option would include the incremental expansion of e-waste processing as feed availability allows. The risk with this strategy is the squeezing of margins at Trail Operations as the purchase of primary feed materials favours the miners and the stockpiles of low cost, historical materials are depleted. This would force the Operation into a survival position whereby all costs would be cut to minimize financial losses while other options for the site are evaluated. This is not too unlike the position Trail Operations found itself in during the early 1990s with the failure of the QSL furnace and the subsequent decision to build the Kivcet furnace. It was a tough time for all stakeholders that had a vested interest in Trail Operations.

Another alternative to installing the new fuming and settling furnaces would be the closure of the Trail Operations site. This would be a very difficult and costly course of action. Trail Operations is viewed as a continuing operation, and as such there are no closure plans or reliable estimates of what that might cost. The closure of Trail Operations would involve severance payments associated with the layoff of 1,500 employees, many of them unionized, and with years of experience. This cost alone approaches the cost of the new furnaces. Site closure would also indirectly impact many more people and cause a severe downturn in the regional economy. In addition, Trail Operations would need a significant investment of financial resources for demolition and site remediation. The assets at Trail would also have minimal salvage value. Many of the assets cannot be moved and they are much more valuable as an integrated whole than as individual parts. Finally, there would be an on-going post closure cost incurred by Teck for the long-term monitoring and management of the site.

Installation of the #4 Slag Fuming Furnace and the Settling Furnace would enable Teck to participate in the dynamic and growing e-waste and e-scrap industry. The amount of e-waste generated globally is expanding as more and more consumers add to the number of electronic devices used in their day-to-day lives and increase the rate of obsolescence of these devices. The regulatory environment for e-waste disposal and recycling is also changing rapidly. New laws are being passed in multiple jurisdictions that push more e-waste into the recycling chain rather than to landfill or to export markets. For those jurisdictions with existing legislation, the breadth of the scope of items that must be recycled and the recovery targets to the recycling chain are continuing the increase. Trail Operations' key competitors for the processing of e-scrap are the 'big six' integrated smelters located in North America, the European Union and Asia. Announcements of expansions at several of these companies indicate that these smelters are already running at capacity and that they believe there is an opportunity to be capitalized upon.

Sustainability is one of the core values of Teck guiding the actions of its employees. Expanding into the processing of e-scrap and other secondary materials at Trail Operations is a good fit with this core value. Teck should aim to achieve a global leadership position in the e-scrap processing market within the next five years. Trail Operations must focus on the sourcing of feed materials from around the globe that are uniquely suited for treatment at Trail Operations and will increase the profitability of the facility. This would include lower-grade e-scrap feeds, without payable terms for gold, silver and PGMs; e-waste and other secondary feeds that are a particularly good fit with the metallurgy of a zinc – lead smelting complex; and irregularly sized feeds that cannot be treated in many competitors' facilities. By selecting feed materials that are uniquely suited to Trail Operations, Teck will be able to leverage its unique smelting technology, integrated processing facilities and knowledgeable human resources to secure a competitive advantage over existing firms.

Recycling will be a key component in the future of metals production. Increased global demand for metals will outstrip the capacity of the primary resource industry to provide feed materials. Additionally, the expectation of the global society is for increased recovery of metals from secondary sources to reduce the environmental footprint of metals production. Entry of Teck's Trail Operations into the processing of e-scrap and other secondary materials will enable the company to participate in the mining of the future, not just the past.

Appendix

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Thanks,

Catherine Adair
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Thanks.

Tammy

Tammy Salway, P.Eng.
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Phone: 250.364.4708
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eMail: Tammy.Salway@teck.com
www.teck.com

Permission for use of Figures 2 and 3

From: Ford Christa TRAIL
Sent: March 28, 2011 4:30 PM
To: Salway Tammy TRAIL
Subject: RE: Request permission to use 'Whole E-waste Process' diagram and 'E-waste Processed' chart in MBA project

Permission granted.

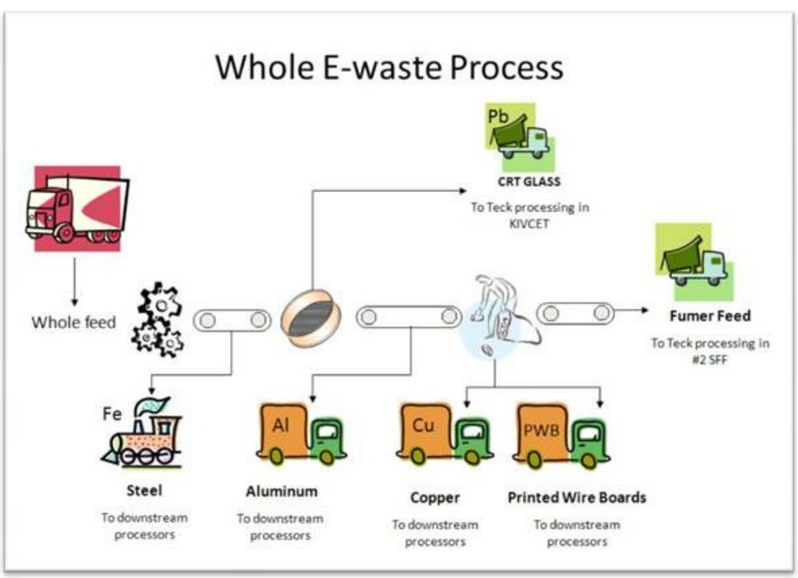
From: Salway Tammy TRAIL
Sent: March 28, 2011 1:13 PM
To: Ford Christa TRAIL
Subject: Request permission to use 'Whole E-waste Process' diagram and 'E-waste Processed' chart in MBA project

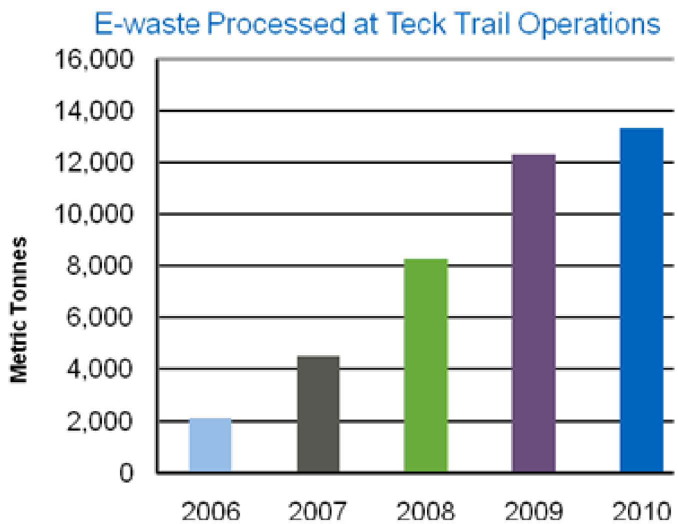
Christa,

I would like to use your diagram and chart, which are included below, in my MBA project that will be published in the SFU Library. I need a response from you indicating your approval of this usage of your figure and chart, if you are willing to approve it. Let me know if you have questions.

Thanks.

Tammy





Tammy Salway, P.Eng.
Raw Materials Engineer
Teck Metals Ltd.
Phone: 250.364.4708
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Permission for use of Figure 7.

From: Electronics TakeBack Coalition [mailto:info@etakeback.org]
Sent: March 29, 2011 10:29 AM
To: Salway Tammy TRAIL
Subject: RE: Request to use figure from your website in an educational project

Tammy –
We will allow use of that image if you credit us as the source, "used with permission of the Electronics TakeBack Coalition."
Barbara Kyle
ETBC

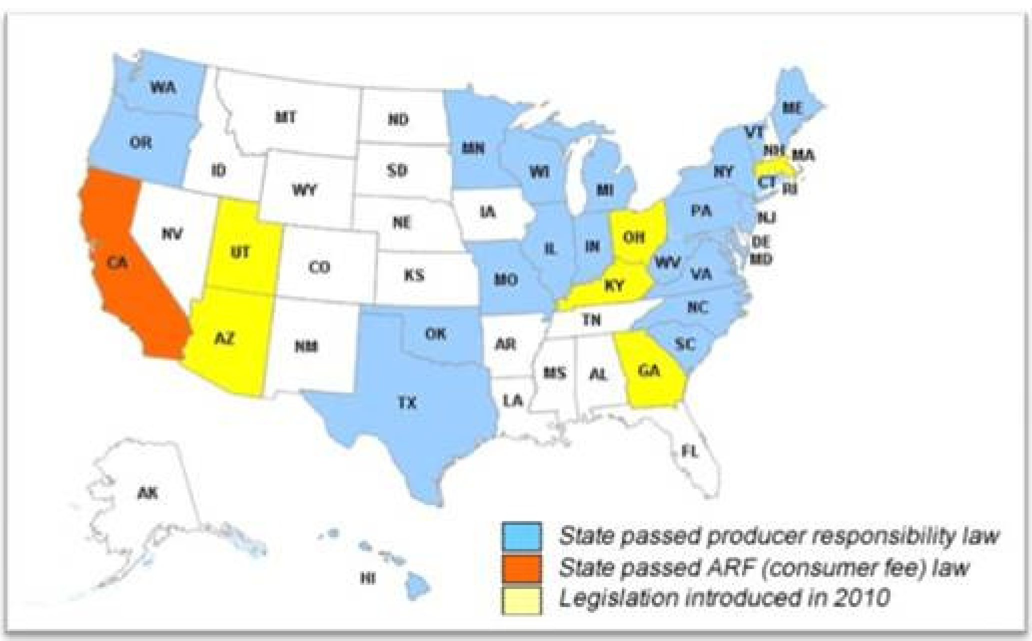
From: Salway Tammy TRAIL [mailto:Tammy.Salway@teck.com]
Sent: Monday, March 28, 2011 1:28 PM
To: info@etakeback.org; webmaster@electronicstakeback.com
Subject: Request to use figure from your website in an educational project

Hello.

I would like to inquire about using your image/figure included below as part of my Executive Master in Business Administration final project at Simon Fraser University. The project will be copyrighted in my name and a copy will be available at the University where it may be accessed by the public but it will not be available for distribution.

Sincerely,

Tammy Salway



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