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Sustainable Steelmaking: Infrastructure for the Future

Proposed Category: Beyond Today's Infrastructure

1. Abstract

More than 20 years after the Brundtland Report we are still grappling with what it means to be ‘sustainable.’ Historically, many of New Zealand’s industrial operators have remained silent on how sustainable development applies to their business. New Zealand Steel (NZ Steel) is one such company that has only in recent years acknowledged its efforts towards achieving a cleaner and more efficient production process in the context of sustainability.

Well before the debate became mainstream, NZ Steel sought to advance the sustainability of its unique steelmaking process through progressive engineering and good operational practices. Environmentally efficient practices are incorporated across all levels at NZ Steel, from existing operations to large scale capital projects. Some projects implemented have required substantial capital investment, while other smaller initiatives have involved the implementation of management systems to direct activities and behaviour. Compared to older mills like NZ Steel’s Glenbrook Mill, more modern and efficient integrated steel mills may require less investment to improve their sustainability. Directly and indirectly, these initiatives have contributed to NZ Steel remaining internationally competitive and financially viable, whilst maintaining a significant contribution to New Zealand’s economy.

This paper touches on the concept of sustainability within the wider steelmaking industry and elaborates on the successes and struggles that NZ Steel faces in working towards a more sustainable steelmaking business.

2. Introduction

NZ Steel was incorporated in 1965 with the vision of establishing a steel industry that would utilise the ironsand (titanomagnetite) resources of New Zealand’s west coast. While early attempts to smelt the iron from ironsand failed, the development of direct reduction techniques meant that the potential of the resource located at Waikato North Head (WNH) could be realised. After extensive trials iron and steel production commenced at Glenbrook. To this day NZ Steel remains the only manufacturer worldwide to turn ironsand into steel through the process presented in Figure 1.

Substantial expansion of NZ Steel’s operations during the 1980s resulted in a five-fold increase in steelmaking capacity and the commissioning of hot and cold rolling mills in 1987. More than 20 years on, New Zealand’s only fully integrated steel mill produces approximately 600,000 tonnes per annum (tpa) of steel for the domestic and export markets.

NZ Steel is now part of the international business BlueScope Steel and in itself contributes approximately 0.5% to New Zealand's Gross Domestic Product.

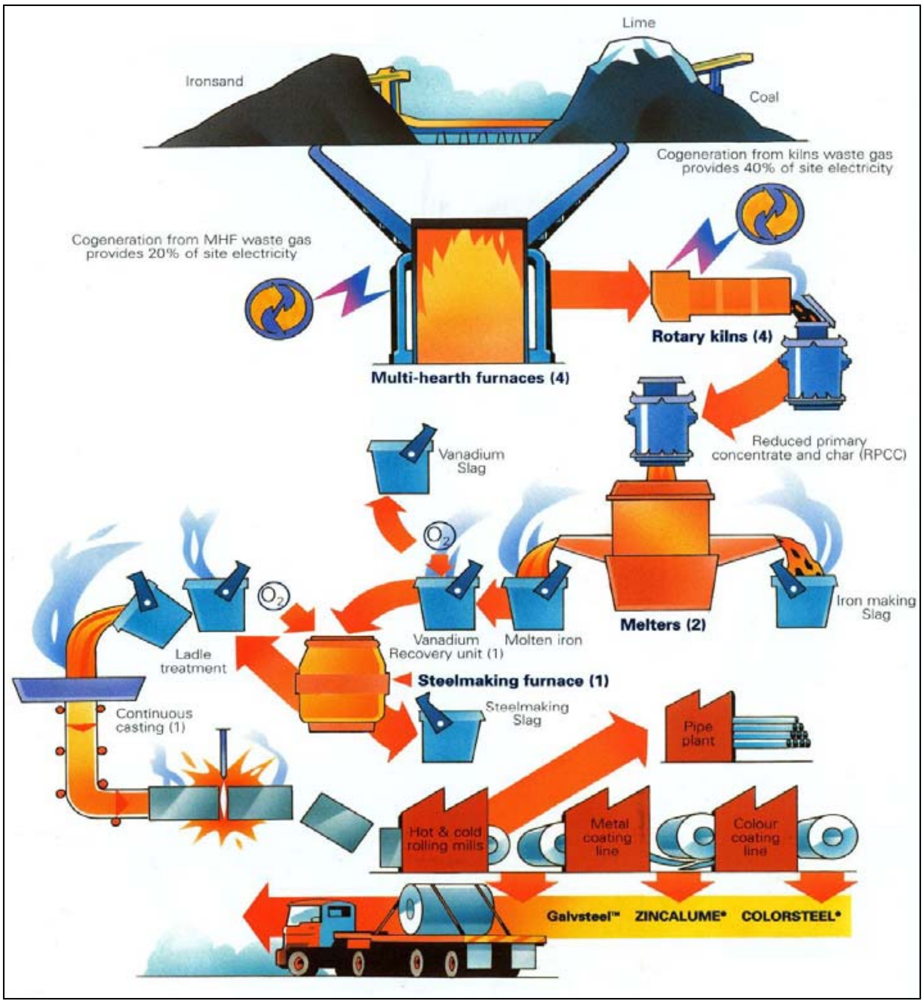

Figure 1: NZ Steel's iron and steel making process.

3. Sustainability in the Steelmaking Industry

Sustainable development is a concept first defined within the United Nations World Commission on Environment and Development's 1987 'Brundtland Report' as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". The concept is governed by three major elements: Economic development, Environmental protection and conservation, and Social well-being (Green, 2008); which should be appropriately balanced.

In New Zealand businesses have generally been slow in implementing these elements to meet with the established notion of sustainable development - despite recent increases in pressure from media and government (Collins, Lawrence, Pavlovich, and Ryan, 2007). NZ Steel, however, has adopted what are now considered 'sustainable practices' consistently throughout its history and as a manufacturer is better placed than most businesses to drive sustainability through implementation of efficient manufacturing techniques and developing efficient products and/or services (Organisation for Economic Co-Operation and Development [OECD], 2009).

Worldwide, steelmaking is recognised as an energy intensive industry with potential for significant pollution (Rubel, Wortler, Schuler, and Micha, 2009). NZ Steel's facility is not exclusive in this sense, however, its performance in terms of energy intensity, greenhouse gas emissions and waste generation is not directly comparable to overseas facilities due to its the unique steelmaking process. For instance, around 70% of steel produced internationally originates from iron ore either via a blast furnace or direct reduction process with the balance produced from scrap steel using predominantly electric arc furnace technology. However, NZ Steel does not utilise these common technologies, and instead operates a primary steel production facility specifically designed to utilise locally sourced ironsand and coal. The use of ironsand as a raw material for steel manufacture is unique to this site and introduces specific issues with respect to waste and energy intensity, which are discussed later in this paper. Production volumes from the Glenbrook Mill are relatively small; 600,000 tpa compared with a typical average output of 3-6 million tpa for facilities overseas. Further, as newer facilities are constructed advancements in technology are able to be incorporated which ensure higher production efficiencies. NZ Steel's primary and rolling mill operations were installed in the mid-1980's and coating processes over 30 years ago, and are in this respect at a disadvantage.

This paper outlines the key initiatives NZ Steel has implemented to foster sustainability and touches on the struggles the company has endured in seeking to reduce its environmental footprint.

4. NZ Steel's Approach to Sustainability

Early-on NZ Steel adopted a range of infrastructure and management approaches to foster sustainability and continual improvement, including:

- A commitment to the design and installation of controls that meet or exceed environmental regulatory requirements;
- An integrated management system based on ISO14001 Environmental Management Systems, ISO9001 Quality Management Systems and best practice safety and risk management systems to reduce hazards, minimise costs and conserve resources;
- A systemised business improvement process focussed on reducing waste (cost and resources);
- Supply chain management protocols to ensure supply efficiencies and waste reduction;
- A commitment to innovative product design features to support community needs to conserve resources and minimise hazards.

The following timeline (Figure 2) presents some of the key milestones and achievements during NZ Steel's history that have assisted the company to achieve a more sustainable future.

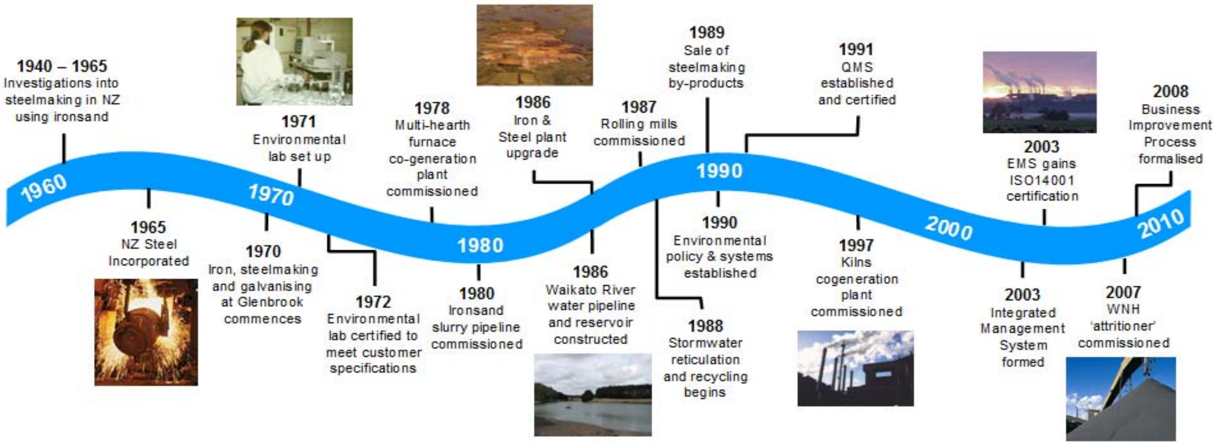

Figure 2: Key Milestones and Achievements

5. Investment in Process Infrastructure

NZ Steel is committed to increasing the efficiency of its production processes through the execution of infrastructure development projects and the continuous improvement of business systems. The location of NZ Steel's industrial site at Glenbrook can be seen as a sustainable strategic decision as steelmaking facilities worldwide are often located long distances from the source of their primary feed - iron ore and coal. The Glenbook Mill is located 18 km from the ironsand resource at WNH, 90 km from Huntly coal mines and 170 km from the limestone supply in the Waikato. Major utilities and transport networks, including sea ports for import of consumables and export of products, are in relative close proximity to the site. New Zealand's major labour pool, support services and domestic market are also located largely within a 100 km radius of the site.

Where environmental compliance is not the driving issue capital projects undertaken have been adopted for their financial or technological benefits, many projects also have reasonable environmental and social benefits. The following subsections review key improvement projects adopted for the purpose of conserving resources or minimising environmental effects and comment on NZ Steel's approach with respect to the World Steel Organisation's sustainability indicators (World Steel Organisation, 2010a)for energy and resource efficiency, material efficiency and environmental management.

Sustainability in Steelmaking Facility Design

The wider steel industry has worked hard to improve its environmental performance in recent years. Like most industrial plants, steelmaking activities result in discharges to the atmosphere (OECD, 2009). Particulate emissions are the main contaminant emitted from both point and fugitive sources at the Glenbrook Mill, as control devices burn off the majority of volatile gases and solvents. NZ Steel recognises that improving its environmental footprint starts with making sure emissions are as clean as possible before they leave the process. Therefore, significant investment has been made in incorporating features into the design of the steelmaking facility to reduce particulate emissions. Stack emissions from the Glenbrook Mill emit between 2,000-1 million m^3 per hour of waste gases. Large extraction fans and ducting pull the dust laden gas from the processes and direct them to either a wet scrubbing system or a dry baghouse for treatment before discharge to atmosphere via stacks and vents.

More than 3 million m^3 of waste gas is cleaned each hour the Glenbrook Mill runs at full capacity. The biggest percentage of capital investment in environmental control at NZ Steel is spent on infrastructure to control the large volume of air emissions and on improvements to the quality of emissions discharged into the atmosphere. NZ Steel also maintains a comprehensive network of air monitoring stations to assess air quality beyond the site boundary and respond appropriately if adverse trends occur.

Water is a key ingredient in the steelmaking process at Glenbrook with up to 1 million tonnes of water each day circulating for steelmaking and finishing processes. Significant infrastructure has been developed at the site for the efficient management of water resources at the Glenbrook Mill. Fresh water is sourced from the Waikato River, transported through a 15 km underground pipeline and stored in the site's 150,000 m^3 capacity reservoir. The river intake was constructed in the early 1980s to meet increased demand and reduce reliance on underground aquifers. While the water supply pipeline and reservoir alone represent significant capital investment there are also five water treatment plants, a stormwater collection and treatment network for the 190 ha site and a complex water recirculation and recirculation network. Wastewater is treated to remove suspended solids, neutralise pH and reduce temperature and metallic contaminants before being discharged to the Waiuku Estuary. With this treatment an estimated 99% of process and stormwater is returned for process reuse. This infrastructure has assisted the Glenbrook Mill in making efficient use of water. While the site upgrades of the 1980s necessitated consent to abstract 40,000 m^3 per day the current freshwater demand is around 20,000 m^3 per day.

Prior to the 1980s facility upgrades trucks were used to transport ironsand the 18 km from WNH to Glenbrook. With vociferous comment from the affected community an options study was undertaken to assess alternatives to the anticipated 6-fold increase in road traffic. What resulted was the construction of a pipeline to pump slurried ironsand to the Mill. Later the pipeline was recognised by the NZ Institute of Professional Engineers as an outstanding and innovative engineering achievement. Further process efficiency was adopted in the construction of the rolling mills in 1987 which included an acid regeneration plant (ARP) to regenerate the hydrochloric acid (HCl) used in pickling steel. The ARP enables HCl to be returned to the pickling bath rather than being used only once, dissimilar to many other steel mills that have to constantly 'top-up' their HCl levels with 'new' HCl. A useful by-product is also produced; this is a red iron oxide (FeO) that can be used in water treatment processes and in the production of magnets. Significant environmental and financial savings are made by recycling the HCl and the need to dispose of or treat a large quantity of waste acid and FeO is avoided. Due to the low purchase cost of HCl and high capital investment it is unlikely that newer steelmaking facilities would install a regeneration facility (J. Mulholland, personal communication, September 16, 2010).

In addition to the existing infrastructure at NZ Steel, a range of projects to further increase the efficient use of resources and energy are proposed or in the feasibility stage. These projects include a major upgrade and optimisation of the steel plant, the construction of plants to further utilise vanadium and extract titanium from the steelmaking process. As is common in business, the implementation of these projects hinge on the profitability of the wider BlueScope business and the distribution of costs across their many facilities due to the significant capital investment required upfront.

Energy and Resource Efficiency

The Glenbrook steelmaking process uses significant amounts of energy (electricity, natural gas and 800,000 tpa coal as raw material feed) which compares with other steelmaking facilities. At full capacity the Glenbrook Mill consumes up to 930 gigawatt hours (GWH) of electricity per year; around the same consumption as Hamilton and Cambridge combined. However, approximately 60% is supplied from two cogeneration facilities utilising hot waste gases from the multi-hearth furnaces and kilns. New Zealand as a whole benefits from cogeneration at Glenbrook through reduced carbon emissions from national thermal power stations and associated savings of coal and gas. Unlike the majority of cogeneration facilities additional materials are not brought in to run the facility; should NZ Steel's cogeneration plants be decommissioned, the same volume of waste gases from the ironmaking facility would still be emitted (P. van Brakel, personal communication, September 15, 2010)

In terms of carbon discharges, steelmaking will always generate carbon dioxide (CO_2). As a primary steelmaker NZ Steel emits about 1.7 million tpa of CO_2, while the amount generated by the ironsand mining activities is comparatively negligible. The proportion of CO_2 generated through steelmaking is approximately 89% from coal, 7% from natural gas and 4% from other materials such as limestone, electrodes and diesel. NZ Steel is addressing CO_2 emissions with cogeneration going some way to reduce levels of CO_2 emitted by the company. In the early 1990s, NZ Steel entered into a voluntary agreement with the New Zealand Government to reduce CO_2 emissions and help New Zealand meet its international obligations. The CO_2 targets of this agreement were met by the year 2000 and up to 0.25 million tpa of CO_2 can be claimed as a countrywide saving through initiatives such as cogeneration. Any further CO_2 efficiency, however, may only be made through alternative technologies to reduce coal consumption in the ironmaking process.

Improving Material Efficiency

For the purposes of assessing sustainability waste is defined by the World Steel Organisation as 'those materials that ultimately end up in a landfill (onsite or offsite) or are incinerated (with or without heat recovery), exclusive of recycled material, utilities waste (e.g. fly ash), stored material (slags) and byproducts (World Steel Organisation, 2010b). NZ Steel has implemented innovative ways to reduce waste and minimise the volume of waste it generates including:

- Internal steel scrap recycling and sale of non-ferrous scrap uprisings from maintenance activities. This level of scrap recovery is typical of steelmaking internationally as the value of even residual metals within scrap is high;
- The reduction and recycling of a range of materials including product packaging; used materials (bricks, oils etc.); office equipment and materials; recovery of hazardous components in batteries, electrical equipment and lighting has occurred at NZ Steel for the last 10-15 years. Recycling is an activity only recently adopted by many New Zealand businesses and in some cases only due to recent legislative disincentives to landfilling;
- Sale of by-products for raw material feed into other processes, such as vanadium slag, iron oxide, zinc ashes and dusts;

- Utilising iron and steelmaking slags to provide a range of products for use in drainage, road construction and water treatment. The unique combination of ironmaking raw materials renders slag products with high-strength properties for roading, capacity to extract various contaminants in water treatment processes and also replace natural quarried aggregates;
- Minimising wastes at source, e.g. clay fines transported with ironsand feed.

These initiatives have led to a reduction of waste going to landfill of at least 70%, and an overall material efficiency of around 87%. Comparing NZ Steel's material efficiency to the metric provided in the World Steel Organisation's sustainability indicators has its difficulties which stem back to earlier comments made around the uniqueness of the Glenbrook Mill. Specifically, the landfill volume calculated for NZ Steel includes a contribution of residual materials from the ironsand resource (clay fines) that is atypical of other steelmakers, and flocculated material from a raw water treatment plant, whereas most steelmakers would be reliant on a municipal water supply. In addition, further recovery of residual materials into the process, typically approached through use of Sinter Plants, is often uneconomic simply because of the comparatively small volumes of material, long payback on infrastructure capital and low landfill disposal costs.

NZ Steel has experienced that to establish and maintain the infrastructure to segregate, collect and package residual materials is not always a straightforward activity. Key problems have included finding a consistant resource to collect and recycle or recover materials; evaluating true costs; and embedding the correct behaviour in employees (around 1150 people) and contracting staff (normally 200 and up to 400 people during maintenance activities). The task of changing behaviour has recently been moderated with increasing emphasis in the community on reducing waste and the need to recycle. NZ Steel has also recently instituted mechanisms in supply contracts and business initiatives to assist in the diversion of waste to landfill. As costs for landfill development and disposal increase the commitment at NZ Steel to reducing waste to landfill is likely to be further enhanced.

By-products are generated indirectly through the process of steelmaking and associated rolling and coating operations. For all steelmaking facilities the largest by-product by volume is slag, a non-metallic residue skimmed from the smelting process, typically stored in large stockpiles. At NZ Steel these slags are cooled, broken up and left to weather before being crushed to a size that meets the demand of the aggregate market. Since the mid 1980s NZ Steel has worked to develop slag for use in road surfacing, soil conditioning, clay stabilisation and sports field drainage, as well as a grit for sandblasting and filtering media for wastewater treatment. All slag products are rigorously tested before being released on the market to confirm that no adverse environmental effects will occur and to ensure suitability for the application. Sale volumes of these innovative by-products has been restricted to some extent due to regulatory barriers and the product bulk density, which raises the cost of transport compared to natural aggregates. However, many of the applications actually reduce adverse effects on the environment. For example the use of ironmaking slags reduces the need to quarry natural aggregate and also the need to landfill the slag.

The recycled content of NZ Steel's finished products is on average 12%, which is comparable with steel products produced using virgin raw materials feed. This is achieved by re-melting ferrous scrap generated in steelmaking and finishing processes, scrap from redundant machinery or demolition materials. Millscale - a ferrous oxide waste – is formed during rolling of hot steel slabs and at NZ Steel has become critical to additions in ironmaking for the recovery of vanadium slag. NZ Steel generates around 13,000 tpa of millscale however this is insufficient to satisfy the 18,000 tpa demand at NZ Steel. As such, 5,000 tpa of millscale has been secured from Pacific Steel resulting in a diversion of by-products from two steelmaking processes and reducing NZ Steel's reliance on gaseous oxygen (generated though a heavily carbon-emitting process).

The raw material feed mined at WNH contains variable amounts of alluvial silt. Cyclones and magnetic separators were originally installed to remove the silts, however, in 2007 an 'attritioner' was installed to further reduce the silt volumes transported in the ironsand slurry that are subsequently landfilled. This project reduced landfilling, water treatment chemicals, as well as the number of process disruptions and therefore the level of product dumping from the ironmaking process.. Another project currently in the feasibility phase, looks to further utilise the balance of alluvial silts transported to Glenbrook, by combining them with a worm castings and organic residual materials from other manufacturing processes. This could potentially avoid the landfilling of the entire 25,000 tpa of alluvial silts.

Even with all of these recovery, recycling and diversion strategies in place NZ Steel generates around 156,000 tpa of solid waste requiring disposal to landfill. However, unlike many other steel mills it disposes of inert wastes to dedicated landfills adjacent to the industrial site rather than placing it in long term stockpiles, or transporting some distance to municipal landfills. The landfill is designed on sound engineering principles to avoid adverse effects on the environment and the surrounding community. In addition, any hazardous wastes are collected and treated for disposal at a Class A municipal landfill and although the volume is much less than the inert wastes, here represents an opportunity to further reduce costs and environmental effects.

NZ Steel landfills represent a significant investment in waste management, as such potential options for further diversion of material from landfill continue to be identified and assessed. However, the comparative cost of disposal is low and the struggle has often been to get buy-in to projects that reduce waste at source or divert waste from landfill, as the financial payback and economies of scale cannot be achieved.

Investment in Environmental Management Systems

The NZ Government was the major investor in NZ Steel's early development and later during its 1980's expansion. At this early stage NZ Steel was required to identify potential environmental effects and seek to minimise any adverse effects largely as a result of the transparency required through government ownership. Legislative controls for air emissions, water abstraction and wastewater discharges have been relatively strict throughout NZ Steel's history. Partly in response to this, in 1990 NZ Steel established a Health, Safety, Environment and Community (HSEC) policy to provide a high-level commitment to the efficient use of resources, reduction and prevention of pollution and promotion of product stewardship. This precipitated the establishment of an environmental management system (EMS) to provide a structured process for the control and minimisation of environmental effects. In 2003 NZ Steel gained certification to the international standard ISO14001 with certification maintained across the entire NZ Steel business. This result compares very favourably against the 32 other companies of the World Steel Organisation (World Steel Organisation, 2010c).

Along with EMS certification NZ Steel is certified to the quality management system ISO9001. As the complexity of NZ Steel's management systems grew an Integrated Management System (IMS) was developed to manage the array of BlueScope, international, and regulatory standards. At the hub of the IMS is a cross-reference database where each element of the various standards and other requirements are itemised. This is an innovative approach to maintaining certification to a multitude of standards and thereby minimising resource commitments. In comparison to the 32 other steelmakers who contribute to the World Steel Organisation's 2010 Sustainability Report NZ Steel has been consistently ahead of the bunch with respect to adoption of environmental management systems (World Steel Organisation, 2010c). The EMS has assisted NZ Steel to comply with the current environmental standards and also to move beyond compliance to meet at least some of the expectations of the local community and Iwi.

6. Risk Management and Supply-Chain Value Adding

Identifying and Managing Risk

Heavy industry intrinsically has more hazards than most manufacturing businesses with a high potential for both personal injury and significant adverse effects to the life support mechanisms of natural ecosystems and communities. The identification, assessment and control or these hazards and the risks they pose is critical to NZ Steel's approach to managing its activities and therefore reducing risks to people and the environment. A recent innovation at NZ Steel is the development of an intranet-based database providing a central, readily accessible recording system to support risk management analysis and includes automated notification and review functions. The database (referred to as MARS) records hazard scenarios and associated controls; incidents and details of incident-related investigations and any associated mitigation measures; outcomes of internal audits; and documents the evaluation of proposed changes to process, or business systems. Currently, MARS is being evaluated for application across the entire BlueScope business, in preference to a mix of proprietary products and various other software applications.

A means of systematic risk assessment and identification of controls has typically been adopted in heavy industry since the larger environmental disasters of the late 20th century. NZ Steel's MARS system is a readily accessible tool providing transparency in risk management and decision-making processes.

Formalising a Business Improvement Process

NZ Steel formalised its business improvement process (BIP) in 2008. The BIP process has extensive employee involvement (currently around 72%) and has provided some substantial cost savings in both the manufacturing process and support service areas. The focus of BIP activities is on reducing waste in all activities. Although cost reduction has been an ongoing activity throughout NZ Steel's 40 year history its effectiveness has been greatly improved by formalising the improvement processes and providing recognition. Key components of the BIP process are encouraging all of all employees and work teams to be involved; tracking the performance of BIP activities; and the formal review and recognition by senior management.

Since the major facility upgrades of the mid-1980's capital investment in key sustainability-focussed projects have been in the order of NZ$215 million (based on currency rate at time of commissioning). One example is a the recent optimisation of gas usage in the rolling mills reheat furnace which has provided in the order of $1 million savings per annum.

Supply Chain Management

NZ Steel procures a large volume of goods, from key raw materials used in iron and steelmaking; consumables such as oils, paints, solvents and other hazardous substances used in finishing processes and maintenance, to general office materials and safety equipment. Goods and service supply contracts have traditionally focussed on minimising cost and business disruptions. However, in recent years these formal agreements have increasingly recognised that suppliers have a significant role in adding value to NZ Steel's business. There is recognition of the importance of safe, appropriate disposal of waste materials recovery of product residues. This has now been specifically incorporated in many key contracts. Responsibility is generally put back on the supplier, or contractor, to dispose of waste and recover reusable materials in an appropriate manner. This efficient approach to waste management enables NZ Steel to get on with its core business, while remaining a responsible corporate citizen. Recently this concept was extended to product stewardship where plastic packaging used when transporting NZ Steel's coiled steel to customers has a large recycled content and this in turn is collected from domestic customers for ongoing recycling.

7. Product Stewardship

Product stewardship is the concept of centering environmental protection on the product itself and calling upon those involved in the lifespan of the product to take responsibility to reduce the product's environmental impact. Steel is easily and infinitely recyclable without loss of properties (Rubel *et al.*, 2009). More steel is recycled annually by weight than all other materials combined. Steel products are therefore considered as a sustainable building material, with a long lifespan. NZ Steel takes product stewardship seriously and aims to further extend the lifespan of steel through the production of long-lasting, durable products.

NZ Steel aims to further product stewardship in the re-evaluation of its 1998 lifecycle inventory (LCI) and by producing a full lifecycle analysis (LCA). The LCA will be used to provide an indication of how NZ Steel's steelmaking processes have improved since the 1990s and where potentially other improvements can be made. Downstream consumers, such as roofing roll formers, can also use the LCI to assess their own products. The final LCA is to be presented to consumers to enable them to make informed choices when selecting a steel product. A key example of a recent product innovation using NZ Steel products is the move into steel frame housing (AXXIS$_{TM}$). Steel framing reduces building waste through precision manufacturing and the ability to recycle any offcuts. Buildings can be designed for easy deconstruction, where steel framing can be readily reused or recycled.

Product stewardship in New Zealand using formalised objective analysis is a relatively new approach for business: legislated through the Waste Minimisation Act (2008) and Environmental Choice standards.

Discussion

In a market where profit margins are tight, companies such as NZ Steel must remain innovative and competitive in order to stay viable. Continual increases in productivity and reduction or elimination of expenses contribute to the bottom line of all businesses. So implementation of sustainable practices can have a significant payback and contribute to a sound financial bottom line.

The level of investment NZ Steel has made in infrastructure to support a sustainable approach has been stimulated by the stringent environmental policies set down both by its investors - formerly NZ Government and BHP, now BlueScope Steel – as well as regulatory controls. Other key stakeholders, such as Iwi and the surrounding rural community, have also strongly influenced NZ Steel's often pro-active investment decision making. This paper has outlined the innovations made by NZ Steel to deliver process efficiencies, reduced emissions and waste, while also achieving cost savings.

Further opportunities will exist for NZ Steel to enhance the sustainable foundation of its operations. Rubel *et al.* (2009) defines six levers for enhancing environmental performance in steelmaking. As such the authors have identified what these may be for NZ Steel and believe this will greatly assist the company to forge ahead with sustainability, in anticipation of the society's future needs:

- Enhancements to operations and installed base to continually anticipate changing regulatory controls and better scientific understanding of the operational hazards;
- Undertake full lifecycle analysis for market evaluation and to identify further process efficiencies;
- Optimise energy efficiency to reduce resource cost and carbon dioxide emissions;
- Adjust business accounting systems to more correctly account for environmental benefits and adverse effect, more accurately value natural resources and provide true cost of waste generation (Ambec and Lanoie, 2008);
- Refocus decision making processes to equitably balance the three aspects of sustainable development (economic, environmental, social) and positively engage staff in contributing to environmental improvements; and
- Collaborative industrial development to encourage closed-loop circuits.

NZ Steel has recognised, as others have (Rubel *et al.*, 2009), that better environmental performance through the use of these levers can lead to:

- An increase in revenue and reduction in costs;
- Improved product sales through better access to preferred markets and by differentiating products;
- Cost reduction through risk management;
- Improved relations with external stakeholders; and
- A reduction in the cost of materials, energy, services, labour and cost of capital.

The increasing importance of sustainability will shape the way the steel industry operates in the future. In parallel to that the sustainability of NZ Steel's processes and products will influence the purchase decisions of potential steel users. As demonstrated in this paper, in creating an infrastructure and business culture based on sustainable principles NZ Steel is better placed to anticipate future demands and support global efforts to reduce the environmental footprint of human activity.

8. Conclusion

This journey has illustrated that through pro-active business management a major industrial facility can reduce its environmental footprint, while also improving its financial viability. It has become important for NZ Steel to highlight its sustainability journey in order to satisfy the increasing demands from the market about understanding the lifecycle of steel products. This relative transparency and support for community demands and needs has, even from its conception, been typical of the NZ Steel business.

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