Developing a toolkit to analyse energy usage and GHG emissions performance and quantifying opportunities to save energy for a large iron ore mining company

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A report submitted to the School of Engineering and Energy, Murdoch University in partial fulfilment of the requirements for the degree of Bachelor of Engineering
I declare that this project is my own account of my research and contains as it’s main content work, which has not previously been submitted for a degree at any tertiary education institution.

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Amy Joyce
EXECUTIVE SUMMARY

Rising energy costs and general industry acceptance of the links between fossil fuel consumption and climate change has resulted in a drive towards energy efficiency improvement in Australian industry (Greene and Pears 2003). In order to facilitate this improvement, the Australian government has collaborated with large energy users to develop the Energy Efficiency Opportunities (EEO) program. Under this program, participants are required to develop a thorough understanding of their energy use identify and assess opportunities for efficiency improvement within their business.

The purpose of this internship was to work within Rio Tinto Iron Ore (RTIO)’s Energy team assessing identified opportunities to a ±30% accuracy as required by EEO regulations and developing tools to better understand energy and emissions performance within the business (ComLaw 2006).

In order to improve the accuracy of identified EEO’s, the information and calculations captured in existing RTIO opportunity scoping documents were critically examined and verifications compiled to raise possible improvements.
A basic model to analyse greenhouse gas (GHG) emissions performance for sites currently in operation was developed. This was able to provide a visual comparison of target performance over time to be compared with several metrics at a higher level to explain identified variations.

RTIO’s energy efficiency progress under the EEO program was benchmarked against its main Pilbara competitors and found to have a comparatively high % savings per total GJ of energy use indicative of RTIO’s success under the program.
Finally, an existing GHG tracking tool for RTIO’s Projects and Development (P&D) division was revised and developed to improve its functionality. This tool allows for GHG emissions over the life of a new development to be estimated with reasonable accuracy. Improvements to this tool included developing a dynamic platform to calculate diesel consumption based on mobile machinery use as given in the mine plan as well as the functionality to compare performance with existing sites.

Maintaining a sound understanding of their energy consumption and GHG performance will continue to be a high priority for the business due to the inherent economic and environmental benefit it creates as well as the need for ongoing compliance with EEO legislation.
ACKNOWLEDGEMENTS

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<tr>
<td>BHP</td>
<td>BHP Billiton</td>
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<td>DRET</td>
<td>Department of Resources, Energy and Tourism</td>
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<td>EEO</td>
<td>Energy Efficiency Opportunities</td>
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<td>EI</td>
<td>Emissions Intensity</td>
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<td>EPCM</td>
<td>Engineering, Procurement, Construction, Management</td>
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<td>FMG</td>
<td>Fortescue Metals Group Ltd</td>
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<td>GJ</td>
<td>Gigajoule</td>
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<td>IGVA</td>
<td>Industry Gross Value Added</td>
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<td>KT</td>
<td>Kilotonne</td>
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<td>KWH</td>
<td>Kilo-watt Hour</td>
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<td>LOI</td>
<td>Loss on Ignition</td>
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<td>LOM</td>
<td>Life of Mine</td>
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<td>MWh</td>
<td>Megawatt Hour</td>
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<td>NGA</td>
<td>National Greenhouse Accounts Factors</td>
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<td>PJ</td>
<td>Petajoule</td>
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<tr>
<td>RTIO</td>
<td>Rio Tinto Iron Ore</td>
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<tr>
<td>S&amp;E</td>
<td>Social and Environment</td>
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<tr>
<td>The Act</td>
<td>Refers to the <em>Energy Efficiency Opportunities Act 2006</em></td>
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<tr>
<td>TMM</td>
<td>Total Material Moved</td>
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1.0 INTRODUCTION

The Australian mining industry is under increasing pressure to improve the energy efficiency of its operations. This is due to a variety of factors, including industry competition, increasing energy costs, climate change and concern about the reliability of energy supply (Greene and Pears 2003). Whilst energy supply from fossil fuels has offered significant opportunities to industrialised nations during the 20th century, mankind is now faced with the environmental and economic challenges arising from their exploitation (Armaroli and Balzani 2006). Increased environmental awareness in the public arena has meant that large corporations, such as Rio Tinto Iron Ore (RTIO), are under considerable obligation to demonstrate sustainable operating practices as this directly influences access to funding and project approval (Environment Australia 2002). In terms of energy, it is increasingly being recognized amongst industry that demonstrating action on climate change can help improve bottom line competitiveness whilst directly benefiting the company’s brand and reputation (Smith and Hargroves 2007).

From an economic perspective, energy use in the mining industry often accounts for between 15 and 20% of total operating expenditure (Environment Australia 2002) with cost improvements of 10-30% possible following the integration of energy efficiency measures (Murphy and Grimmond 2007). In addition, improving energy and greenhouse gas (GHG) performance reduces the risk of having to make rapid (and often vastly expensive) investment decisions in order to satisfy changing external requirements (Environment Australia 2002). These requirements are often legislative in nature and may carry heavy financial implications for non-compliance.

As a large energy user, RTIO is under legislative obligation to participate in the federal government’s Energy Efficiency Opportunities (EEO) program. Under this program, the business is required to identify and assess opportunities to save energy within its operations and produce annual progress reports for submission to both the public and government (Department of Resources, Energy and Tourism 2010).
In addition, RTIO is required to maintain a comprehensive understanding of their energy use and demonstrate a commitment to improving their overall energy efficiency (ComLaw 2006). The creation and development of tools to measure energy and GHG performance are significantly important in the realisation of these objectives.

1.1 Purpose and Objectives

The overarching purpose of the internship placement accounted for by this report is to comply with Murdoch University’s requirements for graduation from a Bachelor of Engineering degree. The placement allows students the opportunity to apply the knowledge base that they have developed throughout their degree in a practical setting, whilst developing soft skills and forming valuable industry relationships. Throughout, students are required to demonstrate a range of engineering competencies laid out by Engineers Australia. For the purpose of this placement, these include:

- Engineering Operations
- Materials/Components/Systems
- Research/Development/Commercialisation
- Self-Management in the Engineering Workplace
- Engineering Project Management
- Investigating and Reporting

A work plan was set up by RTIO to provide a framework for fulfilling these competencies through the undertaking of a variety of projects scoped towards reviewing EEO scoping documents and developing tools to measure energy and GHG performance.

- Revision of EEO scoping documents to refine accuracy
- Creation of a basic GHG performance tracking model
- Revision of GHG tracking spreadsheet for new projects and developments
1.2 Project Background

Whilst there has been a long term overall decline in the energy intensity of the Australian economy (defined by the United States Department of Energy (2012) as the energy consumption per unit of gross domestic product), this has not been the case for the mining industry. The energy intensity of mining operations has been steadily trending upwards and is projected to continue increasing at a rate of approximately 6% per year (Bureau of Resources and Energy Economics 2012). This is driven principally by a reduction in the grade and quality of mining ore. According to CRC ORE (2011), between 1980 and 2010 the average grade of mined Australian ore bodies has reduced by 50% and this has resulted in a 70% rise in energy consumption. As ore quality decreases, it is often necessary to mine deeper resulting in additional drilling and blasting. Deeper mining may result in the need for operations to commence below the water Table. This presents an additional energy use due to the pumping and subsequent water disposal resulting from mine dewatering that is required (United States Department of Energy 2007).

In order to minimise energy intensity, measures to increase energy efficiency can be implemented. Energy efficiency improves when a given level of service is provided with a reduced energy input or when services are enhanced for a given amount of energy input (US Department of Energy 2012). Measures to increase energy efficiency, and research to understand how this can be done, are of particular importance to Australia as the nation's energy efficiency gap (that is, the difference between energy efficiency actual performance and best practice) is among the largest of all developed countries (Davey, Orme and Hay 2013).

The approach of businesses towards energy efficiency is driven principally by economics, policy, and the increasingly valued perception of sustainable development.


1.21 Economics

Mining is among the most energy intensive activities in Australian industry (Figure 1). As such, the procurement of energy accounts for a significant proportion of the total operating expenditure of iron ore mining. It is estimated that this expenditure can often range from 15-20% of the total business operating cost (Environment Australia 2002). At present, it is estimated that the iron ore mining industry in WA consumes in excess of 3 million litres of diesel each day and projections indicate that this will continue to increase drastically as the iron ore output of the Pilbara moves to double by 2020 (Shastri, et al. 2012). Like the production rates of ore, the economic burden of energy cost is not static, and recent increases in the price of energy have intensified economic pressure and raised awareness of consumption within industry (Greene and Pears 2003). In addition to this, the general industry acceptance that greenhouse gas emissions corresponding to energy use are responsible for climate change (Rio Tinto 2012) generates a further economic risk. This is due to uncertainty over future government measures to attach a price to carbon emissions as well as the possibility of physical damage and production restrictions generated by the increasing incidence of severe weather events associated with climate change (Rolph and Prior 2006).

![Figure 1 – Industry Energy Intensity Comparision 2009/2010 (Australian Bureau of Statistics 2011)](image-url)
Owing to the economic significance of energy within the iron ore mining sector, the implementation of EEO’s often falls within the realm of standard business improvement. It is well established within existing business frameworks that it is good practice to implement measures that have attractive payback periods in order to reduce operating costs. This is often the case with energy related projects, as substantial increases in efficiency can often be achieved with relatively minor capital expenditure (Environment Australia 2002).

1.22 Policy

Governments have a key role in setting the standard for environmental performance and ensuring that it is met by industry (Environment Australia 2002). Given the widely accepted links between energy use and global environmental change, the government’s role to promote the adoption of energy-efficient technologies through policy is significantly important (Howarth, Haddad and Paton 2000). Responding to the legislative pressures imposed by policy is a key driver for energy efficiency improvements within industry (Greene and Pears 2003).

Over the past four decades, a suite of policy has been introduced and this has been largely underpinned by fluctuations in energy supply (see Appendix 8.2: Energy Policy in Australia) (Greene and Pears 2003). The effectiveness of these strategies has historically been marred by their tendency to be focused on delivering technological solutions alone, rather than facilitating change through a combination of technology, human behavior adaptation and modifications to corporate governance (Greene and Pears 2003). In addition, past policy has generally not been effective in addressing the behavioural and market failures relating to EEO’s. These market barriers are used to explain the fact that whilst the implementation of EEO’s are often cost-effective and thus in the interests of the businesses they serve, they are frequently not applied, contributing to the energy efficiency gap (Davey, Orme and Hay 2013). A key market barrier to EEO’s in the Australian mining industry is the public good nature of information (Davey, Orme and Hay 2013). Essentially, as information related to EEO’s released in the public sphere is often costly to produce, non-remunerable and benefits all consumers thus limiting competitive advantage, there is perceived little incentive for private organisations to generate and supply it (Productivity Commission 2005).
Without access to relevant and reliable information pertaining to energy efficiency, such as case studies, businesses may lack the evidence to make sound business decisions on appropriate technology selection, instead preferring to select technologies that have known and well-established outcomes (Davey, Orme and Hay 2013).

The introduction of the *Energy Efficiency Opportunities Act 2006* aimed to address these shortcomings via the implementation of the EEO program. Under the program, large energy users triggering a participation threshold of 0.5PJ are required to identify and assess cost effective energy saving and efficiency opportunities with a payback of up to 4 years (ComLaw 2006). Participants are also required to meet a series of key elements that form the basis of an assessment that is both comprehensive and rigorous (Davey, Orme and Hay 2013). These include:

- Leadership
- People
- Information, Data and Analysis
- Opportunity, Identification and Evaluation
- Decision Making
- Communicating Outcomes (Department of Resources, Energy and Tourism 2008)

The program operates on five year cycles, whereby participating businesses are required to produce an assessment plan at the beginning of the cycle followed by annual assessments to the federal Department of Resources, Energy and Tourism (DRET) (ComLaw 2006). These assessments include a component that is made publically available.

The first cycle of the EEO program, concluded in 2011, was highly effective and resulted in a total energy savings of 88.8PJ and an annual financial savings of $808 million (ACIL Tasman 2013). A key factor to the success of the program was the wealth of public good information that became available as a result (Davey, Orme and Hay 2013).

RTIO is currently participating in their second cycle of the program.
1.23 Sustainable Development

Increased stakeholder pressure and concern for the environment has placed sustainable development at the core of business decision making (International Institute for Sustainable Development 1992). Energy efficiency is a key component of this, as it is widely accepted that the fossil fuels required for energy generation are finite, and that conventional carbon-rich sources of energy production are linked to climate change (Hoffman 2006).

As public and stakeholder pressure for corporations to demonstrate that they can operate in a sustainable manner is increasing (Environment Australia 2002), leading edge organisations are realizing that “business as usual” and ad-hoc sustainability initiatives are no longer sufficient (Ceres 2010). In terms of mining, this is because without public and stakeholder support, organisations can be very restricted in gaining approval for new ventures and have access to funds severely limited (Environment Australia 2002).

Whilst the social and environmental value afforded to sustainable development as a whole drives the selection of appropriate energy-efficient technologies, mounting concerns over the future of reliable and financially viable energy supply also affect these outcomes (Greene and Pears 2003). In addition to technology selection, business values and energy market factors (such as supply and cost) also affect the behaviour of stakeholders. The chosen technologies and the behaviour of the stakeholders interacting with them determine the characteristics of the final product.

For example, a mining company that prioritises sustainable development and is exposed to rising diesel costs will likely select energy efficient mobile machinery. The economic driver of rising costs working together with the increased value on responsible environmental behaviour will see that the machinery operators interacting with the technologies receive training pertaining to reducing energy consumption through efficient operator practices. This in turn will allow the miner to produce ore at a reduced cost. The role of energy and sustainable development in the technical decision making process can be seen in Figure 2 below.
1.3 Rio Tinto Iron Ore Background

Rio Tinto Iron Ore (RTIO) is an economically and strategically important part of the broader Rio Tinto Group’s asset portfolio. Iron Ore, a key ingredient in the production of steel, is not only vital to maintaining the modern material luxuries of developed economies, but is also crucial to the growth of developing regions such as Asia and India (Qureshi and Guanghua 2008).

Given the company’s global nature – with operations spanning Australia, Canada, Guinea and India, RTIO is well placed to take advantage of the current market demand, and does so by maintaining its position as the second largest supplier of the world’s iron ore trade (Rio Tinto 2013).

Of this supply, most of the ore currently originates from the company’s Western Australian Pilbara operations (see Figure 3). Here, RTIO operates a total of 14 mines, three port facilities at Cape Lambert and Dampier, 1,500km of rail and related infrastructure (including a utilities division supplying the mines with generated electricity) (Rio Tinto 2013).
This internship project took place within RTIO’s corporate Energy team, located on St Georges Terrace, Perth. Here, activities can be primarily grouped into two business departments – Operations and Projects and Development. The Operations team work to implement energy efficiency into the business’ existing assets and maintain a thorough understanding of consumption within these areas. Existing assets include:

- Brockman 2 / Nammuldi
- Brockman 4
- Channer
- Eastern Range
- Greater Paraburdoo
- Hope Downs 1
- Hope Downs 4
- Mesa A
- Mesa J/K
- Tom Price
1.31 Mining Process

Whilst in terms of process, iron ore mining is relatively simple; all stages are substantially energy intensive. Mobile machinery is used to drill and blast in the mining pit and the ore is subsequently loaded into trucks and hauled to the fixed plant for processing. Processing not only increases the quality of the ore and reduces impurities, but also separates the ore into two distinct exportable product groups - lump (+6.3 mm to -31.5 mm) and fines (-6.3 mm) (Geoscience Australia 2012). Conveyor belts then transport the ore to stackers which are used to stockpile lump and fines into corresponding piles. A reclaimer is engaged to load trains, which transport to ports at Dampier and Cape Lambert. Here, the ore is stockpiled for ship loading. The location of the port in which the ore is shipped depends on the ore product (a result of where the ore was mined). Ore product and shipping information is given in Appendix 8.1: Ore Product and Shipping information. The elements of the iron ore mining process are given in Figure 4.
1.32 Business Strategy

Rio Tinto recognizes that GHG emissions resulting from human activities are contributing to climate change (Rio Tinto 2009) and that a reduction in emissions is important to both minimize adverse environmental impacts and to manage the large costs associated with energy (Rio Tinto 2012).

Rio Tinto’s approach to energy efficiency and climate change begins with their global code of business conduct, a document titled *The Way We Work* (see Figure 5). The document is inspired by Rio Tinto’s core values – Respect, Teamwork, Honesty and Integrity, and outlines the business’ approach to sustainable development. This is recognized within the document as development through “economic prosperity, social wellbeing, environmental stewardship and strong governance and integrity systems” (Rio Tinto 2009). The theme of sustainability is carried downstream through RTIO’s group policies, standards, guidance notes and voluntary commitments. In terms of energy, the key objectives are to deliver economic value, minimise environmental harm, improve energy efficiency and reduce greenhouse gas intensity.
In order to affect the objectives laid out in the sustainability strategy, RTIO facilitates an energy and climate program. The focus of this program is scoped around four key areas (Rio Tinto 2012):

- Engaging with governments and other stakeholders to design effective mitigation and adaptation approaches
- Measuring and reporting energy use and emissions
- Reducing the energy intensity and emissions of operations and optimizing energy use
- Securing a reliable supply and, where possible, reducing the carbon intensity of energy supply

RTIO recognise that setting targets and regularly reporting against them is a business priority and is effective in assisting to manage performance. For 2013, the business emissions intensity target is given as 9.45 tCO$_2$e/kt shipped (Rio Tinto 2012). Performance against this target is reported publically in the annual RTIO Sustainable Development report.
2.0 LITERATURE REVIEW

Literature reviews formed a critical part of the internship process and were instrumental in forming the geopolitical, legislative and technical context of which the projects were steeped in.

It was evident from the reviewed literature that energy and climate change remains a hot topic at both a national and global level. This is supported by the vast number of studies and research material available within this space. Documents such as Garnaut’s *Climate Change Review* (Garnaut 2008), Rolph and Prior’s *Climate Change and the ASX100* (2006) and *The Future of Energy Supply : Challenges and Opportunities* by Armaroli and Balzani (2006) systematically identify trends pertaining to energy and GHG emissions and the risks, opportunities and future directions for industry. The publications clearly demonstrate the need for industry to reduce their energy consumption.

Understanding the legislative drivers and government policy influencing energy efficiency was critically important in considering the motivating factors that underpinned the adoption of EEO’s within industry. Key documents used to develop this understanding were Howarth, Haddad and Patton’s *The Economics of Energy Efficiency : Insights from Voluntary Participation Programs* (2000), *Policy Options for Energy Efficiency in Australia* (Green & Pears, 2003) and *Implementation Regulation Impact Statement on Extending the Energy Efficiency Opportunities Program to New Developments and Expansion Projects* (Davey, Orme & Hay, 2013).

The reviewed literature can be broadly separated into three categories:

- Energy Efficiency Opportunities Policy
- Opportunities to Improve Energy Efficiency (Case Studies), and
- Industry Analysis

Just as it was important to understand the concepts and content examined during the literature review process, it was also important to understand what was missing from the research. This will be discussed in section 2.4 Knowledge Gaps.
2.1 Energy Efficiency Opportunities Policy

Government policy and legislative requirements are key drivers for energy efficiency improvements within the iron ore mining sector. The key resources utilised for this project are as follows:

- **EEO Assessment Handbook** (DRET 2010) – A guideline on planning and identifying opportunities to improve energy efficiency.

- **The Economics of Energy Efficiency: Insights from Voluntary Participation Programs** (Howarth, Haddad & Patton 2000) – This document explores the economic effects of international voluntary participation programs related to energy efficiency improvement. Howarth, Haddad & Patton found that these programs were effective in driving efficiency.

- **The Energy Efficiency Opportunities Act 2006** (Australian Government 2006) – The primary legislation which outlines the conditions for mandatory participation in the EEO program and subsequent requirements.

- **Energy Efficiency – Policy Measures to Reduce Greenhouse Gas Emissions.** (Insight Economics 2006) - Explores the policy measures potentially used to reduce GHG emissions.

- **EEO Energy Mass Balance: Mining** (DRET 2010) – A document that provides guidance for the development of an EMB specific to the mining industry.

- **EEO Industry Guidelines** (DRET 2008) – Provides background information on EEO and outlines the key elements participating businesses are required to demonstrate throughout the EEO process.

- **Implementation Regulation Impact Statement on Extending the Energy Efficiency Opportunities Program to New Developments and Expansion Projects** (Davey, Orme & Hay, 2013) – This report explains the market barriers to energy efficiency in Australian industry citing the public good nature of information as of significant importance. Also explores the future developments for the EEO program as it is applied to new projects and developments.

- **Policy Options for Energy Efficiency in Australia** (Green & Pears 2003) – Explains in detail past policy measures to drive energy efficiency and their effect.

- **Significant Opportunities Register: Mining** (DRET 2010) – A register of significant opportunities identified by mining industry participants.
2.2 Opportunities to Improve Energy Efficiency (Case Studies)

Existing case studies were an invaluable tool in evaluating the opportunities to save energy identified by RTIO. These case studies allowed for a better technical understanding of existing EEO’s and provided useful information for consideration in the accuracy refining process. For the purpose of this internship, conveyor belts, variable speed drives and mobile machinery have been selected as it is within these areas that some of the most significant reductions in operating cost and energy usage can occur, making them highly material in nature. Key documents have been separated into their relevant sub-sections and include:

2.21 Conveyor Belts

- *Low Rolling Resistance for Conveyor Belts*. Goodyear (2000) – Discusses super low loss belting and the effect that this can have on power consumption.
  - *Energy Saving Conveyor Belt Idlers*. Tapp (2002) – Discusses the design of conveyor belt idlers that may yield improvements in energy efficiency.

2.22 Variable Speed Drives; and

- *Applications of Variable Speed Drive (VSD) in electrical motors energy savings*. Saidur, Mekhilef, Ali, Safari, Mohammed (2011) – Identifies the energy savings opportunities presented by applying variable speed drives to existing electric motors
  - *Save Energy With Variable Speed Drives*. Tolvanen (2008) – Offers a broad introduction to the energy saving benefits of VSD’s and how these can be achieved.
  - *The Right Drive to Maximise Efficiency and Production for Large Overland Conveyors*. Hampton (2013) – Discusses VSD’s as they apply to conveyor belts and the energy savings that occur as a result of their installation.
2.23 Mobile Machinery


- Reducing Energy Consumption and Carbon Footprint Through Improved Production Practices. Awuah-Offei, Summers and Hirschi (2010) – This technical report discusses the measures that can be taken to reduce energy consumption in truck and shovel overburden removal. In order of significance, the following opportunities are discussed: 1) shorten haul roads, 2) increase shovel capacity, 3) increase shovel optimization through optimal truck matching.

2.3 Industry Analysis

Whilst the scope of the works undertaken were specific to RTIO’s operations, it was valuable to develop context by drawing comparisons between alternate large iron ore miners in the region. In order to do this, production, energy and emissions information was sourced from several key documents:

- 2012 BHP Billiton Sustainability Report. BHP (2010 - 2012)
- Rio Tinto Iron Ore Sustainability Report. RTIO (2010 - 2012)
- Fortescue Metals Group Public Environment Report. FMG (2010 - 2012)

These reports provided information on GHG emissions as well as production performance. Annual reports provided information on annual tonnes shipped.

- BHP Billiton Annual Report. BHP (2010 - 2012)
2.4 Knowledge Gaps

Despite the economic, environmental and social significance of the iron ore mining industry in Western Australia, little research is available comparing or benchmarking industry performance in terms of energy intensity. Whilst energy intensity information can (and has, for the purpose of this internship project) be calculated by compiling data sourced from multiple publically available business reports, it is not easily available. This may be due to a variety of reasons, including the inherent economic and political sensitivity of the information, the reputational risk that is generated from transparency and the limited incentive that may occur as a result of providing this information.

Whilst it is generally acknowledged that the energy consumption of an operation is strongly influenced by the grade and quality of the ore it is mining (CRC ORE 2011) there appears to be little research available relating energy intensity to ore geology.
3.0 MEASURING THE PERFORMANCE OF EXISTING OPERATIONS AND SCOPING EEO OPPORTUNITIES

3.1 Project Introduction

3.11 Project Background

RTIO operations use a significant amount of energy. In 2012, the 39PJ consumed by RTIO accounted for 4% of the state’s total energy use (Bureau of Resources and Energy Economics 2012). To put this into perspective, this is roughly equivalent to the energy required to provide electricity to all Western Australian households for one year (see Figure 6 below).

![Pie chart showing energy consumption in Western Australia by category.](Image)

Figure 6 - Energy Consumption in Western Australia by Percentage (Australian Bureau of Statistics 2012, RTIO 2012)

Owing to the scale of RTIO’s consumption, the business triggers the 0.5PJ mandatory participation threshold mandated by the Energy Efficiency Opportunities Act 2006. As such, RTIO is required to identify and assess opportunities to increase energy efficiency within the business and report on these findings both publically and to government.

These opportunities are identified via on-site workshops with accountable staff and scoped out at a concept level using simple calculations pertaining to cost and energy savings.
Concept level calculations are typically recorded at an accuracy of ± 80%. In order to comply with the reporting requirements of The Act, opportunities must be evaluated to an accuracy equivalent to ±30% or less.

In order to do this, RTIO site energy advisors produce a scoping document for each EEO. These documents capture important technical information pertaining to each opportunity as well as preliminary calculations detailing their projected energy and cost savings.

In addition to evaluating opportunities, RTIO is legally required to integrate and demonstrate a set of key elements within its business practice (Department of Resources, Energy and Tourism 2008). These include:

- Leadership
- People
- Information, data and analysis
- Opportunity identification and evaluation
- Decision making, and;
- Communicating outcomes

As part of these elements, Rio Tinto is required to develop a thorough understanding of their energy use via sound record keeping and data analysis. This understanding is gained by the development of tools to better comprehend trends in energy use.

3.12 Project Objectives

The primary objectives of the internship placement from an operations perspective are as follows:

- Increase the accuracy of existing scoping documents
- Prepare a model to quantitatively demonstrate the energy performance of RTIO’s operations, railways, ports and utilities.
3.2 Project 1 - Increasing the Accuracy of Scoping Documents

3.21 Project Methodology

3.211 APPROACH

This task was approached systematically in a variety of stages based on the following key objectives:

- Gaining an understanding of the technical aspects of the identified opportunity
- Centralising the scoping document template and revising formatting
- Standardise the constants for energy price and content
- Verify that the Figures provided for energy use and savings were accurate and if necessary, source alternative data
- Investigate alternative ways to calculate energy savings and subsequent cost savings
- Prepare suggestions and verifications
- Communicate suggestions and verifications
- Amend scoping documents

3.212 SCOPE

The project was initially scoped to include both the Tom Price and Marandoo mine sites. This expanded over the course of the internship to include a preliminary investigation into the Yandicoogina, Brockman 2, Brockman 4 and Paraburdoo operations.

In line with the requirements of The Act, greenhouse gas emissions were not accounted for within these documents.
3.213 ASSUMPTIONS

This task assumed that data provided by on-site energy monitoring systems (such as Modular Mining) was reasonably accurate.

A number of quantitative assumptions were also made pertaining to energy factors and prices. These were sourced from the National Greenhouse Accounts Factors (NGA) (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education 2013) report as well as internal staff from relevant divisions. Whilst cost details are omitted in the interests of business confidentiality, energy conversion factors are as follows:

- **Energy content of diesel (GJ/kl)**: 38.6
- **Energy content of electricity (GJ/kWh)**: 0.0036

3.214 LIMITATIONS

The primary limitation of this task was the time able to be spent on site communicating with site personnel, obtaining verifications and sharing resources. Site time was limited to one visit (Tom Price and Marandoo).

3.22 Works Completed

The works completed can be separated into the key objectives laid out by the approach:

- **Gaining an understanding of the technical aspects of the identified opportunity**

Many of the concepts and equipment presented in the scoping sheets had not been encountered before and thus it was essential to gain a basic understanding of the materials, components and systems referred to in the documents. Researched technologies included regenerable and non-regenerable variable speed drives, conveyor belting and idlers, electrical contactors for autonomous lighting sensors and haul truck tray design. Knowledge in these areas was gained by reviewing relevant literature online and utilising the network of staff available within the RTIO.
energy team. A brief technical description and account of energy savings for some commonly occurring EEO’s can be seen in Table 1.

**Table 1 - Technical Description and Energy Savings of Some Commonly Occuring EEO’s**

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>Technical Description and Energy Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conveyor Belts</strong></td>
<td>The energy efficiency of conveyor belts can be optimised with the implementation of super low loss belting and efficient idler practices</td>
</tr>
<tr>
<td><strong>Conveyor Super Low Loss Belting</strong></td>
<td>Super low loss belting reduces the indentation resistance of the belt (Goodyear 2000). For steel cord and thick fabric belts the indentation resistance is proportional to the load to the exponent of 4/3 (Tapp 2002). This visco-elastic resistance is the major form of energy loss within the belt (around 61%) and occurs due to compression of the belt as it passes over the idlers (Antoniak 2001). Super low loss belting is able to reduce visco-elastic resistance by a third and may result in energy savings of up to 12% (Bridgestone 2013).</td>
</tr>
<tr>
<td><strong>Conveyor Idlers</strong></td>
<td>An idler is a roll or series of rolls that supports and protects a conveyor belt (Domnick 2002). Reducing the idler roll diameter reduces the indentation rolling resistance (Tapp 2002). In addition to the energy efficiency properties of an idler, factors that contribute to idler life must be taken into account whilst selecting appropriate technology. These include bearing style, seal effectiveness, lubrication, roll construction, idler frame, maintenance and environment (Domnick 2002). Increasing idler spacing will often reduce operator cost and can result in power savings (Nel 2011).</td>
</tr>
<tr>
<td><strong>Haul Trucks</strong></td>
<td>Haul trucks account for a significant proportion of on-site energy use. As such, measures to improve their efficiency are often highly productive.</td>
</tr>
<tr>
<td><strong>Payload Management</strong></td>
<td>Increasing the payload of mobile machinery means that more material can be transported. Often this does not substantially increase fuel costs, thus leading to substantial improvements in energy efficiency (Department of Resources, Energy and Tourism 2010). Increasing the payload of a vehicle can be achieved in several ways with significant opportunities including:</td>
</tr>
<tr>
<td></td>
<td>- Installation of light-weight trays</td>
</tr>
<tr>
<td></td>
<td>These trays are lighter than the previous trays and so more ore can be hauled for the same fuel consumption – thus increasing fuel efficiency (Barrick (Australia Pacific Holdings) Pty Ltd 2011). It is estimated that light</td>
</tr>
<tr>
<td>Optimising Haul Route</td>
<td>Variable Speed Drives</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td><strong>Weight trays</strong> may allow 5% more ore to be carried with each cycle (Rio Tinto 2011).</td>
<td>VSD’s reduce the output of an application component by controlling the waveform of the current and voltage supplying the motor, ensuring that it operates no faster than is required (Tolvanen 2008). In terms of operation and maintenance, VSD’s generate harmonics which can be detrimental to the equipment connected to the electrical system and as such these must be filtered and/or managed accordingly (Hampton 2013). Energy efficiency can be obtained by employing regenerative VSD’s, which harness braking energy traditionally lost to heat in the form of electrical energy and return it to the supply grid (Dunn 2010). The reduction of maintenance and downtime may be quite substantial and contributing factors include:</td>
</tr>
<tr>
<td><strong>Reduction of carryback</strong> Carryback refers to sticky clay deposits that occur in haul trucks after dumping thus limiting truck capacity. Carryback can be reduced by diverting hot engine exhaust under the tray to evaporate water content, causing the clay to dry out sufficiently for the total carryback to be output during dumping. Average carryback usually corresponds to 1% of total load (Rio Tinto 2011).</td>
<td><strong>The elimination of control valves</strong>  <strong>Current-limit feature</strong> (prevents motor burnouts caused by multiple restarts)  <strong>Protection of the motor insulation</strong> (shields it from voltage problems) In addition, the useless life of equipment may be extended due to the motor operating at reduced speeds. (Ontario Hydro 1997)</td>
</tr>
<tr>
<td><strong>Fuel</strong> is consumed predominantly during acceleration (Larsson and Ericsson 2009). By eliminating unnecessary stopping, a significant reduction in energy use can be achieved (Department of Resources, Energy and Tourism 2010). Alternatively, “hierarchy rules” may be introduced on site in place of “WA road rules” allowing large fuel consumers right of way to reduce stopping. FMG began implementing this in 2012, with expected energy savings of almost 30,000GJ (Fortescue Metals Group 2012).</td>
<td></td>
</tr>
</tbody>
</table>
• **Centralising the scoping document template and revising formatting**

Each mine site typically has its own energy representative responsible for preparing the concept level scoping documents. As such, substantial variation existed in terms of style and formatting between mine sites. The first step of this project was to convert documents to a central format and ensure spelling and formatting was clear and accurate. This was important in terms of convenience and future ease of reference.

• **Standardise the constants for energy price and content.**

Having standardised values for the energy content of electricity and diesel as well as pricing allowed for all scoping documents to be comparable across the business. This was also the first step towards improving the accuracy of the documents. For instance, in the Tom Price LED lighting towers document, the energy content of diesel was given at 35GJ/kl. At an annual fuel consumption of 6060.6L, this worked out to an energy consumption of 212GJ/year. By applying the more accurate value of 38.6GJ/kl (reference NGA factors), an annual energy consumption of 234GJ was obtained. This Figure is 10.35% higher than the original calculation and thus indicates a substantial improvement in accuracy.

• **Verify that the Figures provided for energy use and savings were accurate and if necessary, source alternative data**

Many of the Figures quoted during the early stages of project identification relied on guess work and anecdotal information provided by relevant site-based employees.
In most cases, these were simply “ball-park” Figures and accuracy could be greatly improved by reviewing information provided by internal and external resources (seen in Table 2 below)

<table>
<thead>
<tr>
<th>Internal Resources</th>
<th>External Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modular Mining (site based data system)</td>
<td>Supplier quotations</td>
</tr>
<tr>
<td>IODMS (document control system)</td>
<td>Supplier presentations</td>
</tr>
<tr>
<td>Project Centre (document control system)</td>
<td>External case studies</td>
</tr>
<tr>
<td>Site and corporate personnel</td>
<td>Academic research</td>
</tr>
<tr>
<td>Site EEO information packs</td>
<td>Technical papers</td>
</tr>
</tbody>
</table>

Table 2 - Internal and External Resources for Data Scoping

For example, in a document related to increasing the payload of haul trucks, the average burn rate of a Komatsu 830E haul truck was listed as 200L per hour. According to Modular Mining, this Figure was actually around 60% lower. By applying the lower burn rate to the associated calculations, a more accurate Figure was sourced, minimising the risk of the overestimation of energy and cost savings. This is important, as overestimating these savings could potentially lead to poor business decisions by management.

- **Investigate alternative ways to calculate energy savings and subsequent cost savings**

The potential energy savings for EEO’s are most commonly estimated using basic physical principles and engineering models (Sorrell 2007). In some cases, similar opportunities had already been investigated thus providing a source for existing models and estimations. At a RTIO level, these were sourced by utilising centralised records and recording software (namely Project Centre).

Case Studies were obtained from the DRET website and via information available publically online. By looking at similar case studies, alternative calculation methodology was able to be produced.
The installation of LED lighting towers, for example, is an opportunity that can be seen implemented both internally across RTIO’s operations and externally among other industry EEO participants. In this case, it is easy to develop a best practice approach to developing the associated energy and energy cost savings calculations. This is given by Figure 7 below.

```
| Burn rate | 10.0 | L/hour |
| Operating hours / day | 11.0 | |
| Annual operating days | 365.0 | Hours |
| Annual fuel consumed by metal halide lighting tower | 40,150.0 | L |
| Annual fuel consumed by LED lighting tower | - | L |
| Resultant reduction | 40,150.0 | L |
| Energy savings | 1,549.79 | GJ |
| Diesel cost p/L | 1.25 | $'s |
| Energy cost savings | $50,187.50 |
```

*Where, for the purpose of this figure, 1.25 represents the theoretical cost of diesel. This figure may not represent the actual cost of diesel for RTIO.*

**Figure 7 - Best Practice LED Lighting Calculation**

- Prepare suggestions and verifications

Based on the findings from the above steps, a document was prepared for each mine site providing alternate (more accurate) Figures, raising verifications, and detailing additional calculation options that would potentially result in improved compliance with the ±30% requirement prescribed by The Act. The number of opportunities examined and the subsequent verifications raised can be seen in Figure 8 below.
Communicate suggestions and verifications

The aforementioned suggestions and verifications were communicated to corporate management. In the case of Tom Price and Marandoo, these were also discussed with site personnel throughout the course of meetings conducted during a site visit. This enabled for ground trothing of Figures and discussion of possible amendments.

Amend scoping documents

Once the verifications were raised, communicated, and feedback received, the final step was to amend the scoping documents with the updated information. This allowed the documents to be closed out to an accuracy achieving or approaching ±30%.

By reducing the error of scoping documents, financially attractive opportunities could be identified via the calculation of payback periods. As economic viability remains a critical priority for industry, payback periods are used extensively to evaluate the feasibility of assessments (Harris and Anderson 2000).
Figure 9 below shows the payback period of several key identified opportunities. In terms of business improvement, opportunities with a payback period of less than 4 years are generally considered attractive (Department of Resources, Energy and Tourism 2008).

![Figure 9 - Payback Periods of Key Opportunities](image-url)

### 3.23 Further Developments

Verifications will continue to be raised with site representatives to close out the scoping sheets to an acceptable level of accuracy. Operations will continue to be supported by the RTIO corporate energy team to implement attractive improvements approved by management. This ongoing support is important, as without effective management processes in place, improvements will either not material or not be sustained (Environment Australia 2002).
In addition to this, care must be taken to ensure that financially viable projects sit within the mainstream business objectives. While an opportunity that sits outside the mainstream business approach may be considered attractive in terms of payback, these can often produce adverse impacts from both a motivational and a long term economic perspective (Environment Australia 2002).

3.3 Project 2 - GHG Performance Model

3.3.1 Project Methodology

3.3.1.1 APPROACH

This task was approached methodically by undertaking a series of steps:

- Collate data (from S&E Survey)
- Organise and analyse data
- Design interface
- Integrate data into interface

3.3.1.2 SCOPE

The GHG performance model encompasses data spanning the period 01.01.2012 – 30.06.2013. This scale was selected on the basis of practicality due to the vast quantities of information that required sorting and analyzing and the substantial time commitment that this subsequently generated.

ASSUMPTIONS

The core assumption of this task was that the data provided by the RTIO S&E survey was reasonably accurate. The model also assumes that the baseline developed by calculating the 2012 average results is reflective of a typical year’s energy and GHG performance (this was later verified by comparing these results with those of 2011).
3.313 LIMITATIONS

This project is limited by the baseline comparison values selected (2012 average) and the relatively short time frame of analysis selected.

3.32 Works Completed

- **Collate data**

Data was collated from the RTIO S&E survey, as well as RTIO monthly internal Production Reports.

- **Organise and analyse data**

Information was then organized to form a variety of metrics including CO₂ emissions per amount of ore railed, electricity usage per amount of ore railed, diesel usage per total material moved, amount of ore processed per amount of ore shipped and strip ratio (TMM / ore shipped). A baseline for these metrics was developed by using 2012 yearly average data. From here, variance from these baseline values was determined.

- **Design interface**

The role of the interface was to provide a visual platform to observe trends in GHG emissions performance. In order to do so, the overall target performance at each level needed to be represented as well as it’s variation from the baseline. The interface was designed using the performance hierarchy given in Figure 10.
The first level of the model depicts the overall GHG performance for a given month and compares this with the target for that period (Figure 11). This data is important to the business as overall annual compliance with externally reported tCO2e/ore shipped targets are communicated publically in the RTIO annual sustainable development report.

<table>
<thead>
<tr>
<th>tCO2e/Ore Shipped (kt)</th>
<th>Target</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.22</td>
<td>9.74</td>
<td>-15.06%</td>
</tr>
</tbody>
</table>

Note: in the interest of maintaining business confidentiality, performance Figures have been chosen arbitrarily.

The model then breaks down target performance into three categories – Mine, Ports and Rail. For each category, the model compares the emissions value with a baseline Figure (sourced from the 2012 average). From this, a variation from the baseline can be calculated (Figure 12).

Mine

<table>
<thead>
<tr>
<th>tCO2e/Ore Railed (kt)</th>
<th>Variation from Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.23</td>
<td>-4.99%</td>
</tr>
</tbody>
</table>

Ports

<table>
<thead>
<tr>
<th>tCO2e / Ore Shipped (kt)</th>
<th>Variation from Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.02</td>
<td>4.53%</td>
</tr>
</tbody>
</table>

Rail

<table>
<thead>
<tr>
<th>tCO2e / Ore Railed (kt)</th>
<th>Variation from Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.04</td>
<td>-2.37%</td>
</tr>
</tbody>
</table>

Note: in the interest of maintaining business confidentiality, performance Figures have been chosen arbitrarily.
For June, 2012, we can see that whilst Ports performed 4.53% worse than average, both rail and mine were more efficient. It can be assumed from this information that improvements to the overall target performance were due to higher efficiencies in both the mine and rail divisions.

Further analysis is broken down to a site level. Site level analysis allows energy performance to be related to trends in production. For instance, in Figure 13 below, we can see that Site X was responsible for raling 12.33% of the total RTIO ore for the month of June 2012. This production was 7.09% more than the 2012 baseline. During this period, the emissions intensity decreased by 14.91% and performed 10.86% under target.

<table>
<thead>
<tr>
<th>Mine X</th>
<th>Variation from Baseline</th>
<th>Target</th>
<th>Variation from Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of kt's Railed</td>
<td>12.66%</td>
<td>7.09%</td>
<td>N/A</td>
</tr>
<tr>
<td>tCO2e/Railed(kt)</td>
<td>5.98</td>
<td>-14.91%</td>
<td>6.71</td>
</tr>
</tbody>
</table>

**Figure 13 - GHG Target Performance Model Level 3**

The final stage of analysis was at a metric level (Figure 14). As the two primary sources of energy use on-site are electricity and diesel, the efficiency of this use is examined by comparing to the 2012 baseline. Another useful metric examined at this level is strip ratio, which is given by the TMM per ore railed. Strip Ratio is an indicator of the level of activity of energy intensive mobile machinery on site and thus an increase in strip ratio will usually indicate more intensive operations.
## Mine X

<table>
<thead>
<tr>
<th>Electricity Efficiency</th>
<th>Diesel Efficiency</th>
<th>Strip Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWh / Ore Railed (kt)</td>
<td>L / TMM (kt)</td>
<td>TMM(kt) / Ore Railed(kt)</td>
</tr>
<tr>
<td>1.43</td>
<td>442.84</td>
<td>4.54</td>
</tr>
<tr>
<td><strong>2.96%</strong></td>
<td><strong>-16.31%</strong></td>
<td><strong>0.73%</strong></td>
</tr>
</tbody>
</table>

### Figure 14 – GHG Target Performance Model Level 4

A visually effective way to identify trends in target performance is illustrated by the use of relevant graphs. A commonly used tool communicated to internal stakeholders is the emissions intensity target performance over time (given in Figure 15). This simple graph displays the variation of performance from the target over time, allowing stakeholders to track the effect of efficiency measures and GHG emissions reduction within the business.

### Figure 15 - Emissions Intensity Target Performance
Figure 16 displays the percentage of GHG emissions attributed to each mining division against the production rate for that month. This allows for a more detailed visual analysis as emission trends can be related back to production and inferences subsequently made regarding variations.

Relating emissions trends to production is important as these factors often exhibit a strong correlation. For example, in January and February of 2013 the kt of SOP (a function of ore shipped) was relatively low. During this period, GHG emissions at the mine site were comparatively higher than previous months. Given that the values for rail are as expected, this is indicative of a disruption at the port. Port disruptions are more likely to occur during this period as the region is experiencing its peak cyclone season (Bureau of Meteorology 2013). These severe weather events are relatively common in this region, with Dampier experiencing an average of 1.4 cyclones each year (Wells and Walker 2003). In the event of a cyclone, port activities may be disrupted due to shutdowns resulting from occupational health and safety concerns and damage to infrastructure. During disruptions production becomes low (a function of the difficulty in loading ships and/or their ability to leave the port) and percentage mining emissions tend to escalate.
This is because during this time, mine sites tend to experience high rates of TMM and thus diesel consumption. Given that diesel consumption is a function of site GHG emissions, the percentage share of these tends to escalate.

3.33 Further Developments

Whilst the project was successful in providing the basis for quantitative analysis of 2012/2013 data, further work is needed in the following areas in order to maximize its usefulness within the business:

- Continue to develop useful metrics to demonstrate energy performance
- Expand the data set to include broader information and year to date performance
- Refine the calculations to capture the impact that variations from the baseline have on overall target performance
  - This was attempted during the course of the internship, although further work is needed to validate the accuracy of calculations and to continue applying them down to the metric level.
3.4 Industry Analysis

By benchmarking RTIO’s energy performance against that of other large iron ore miners operating within the Pilbara, sufficient context can be developed to understand the overall effectiveness of the business’ energy and climate change program.

One metric that can be used to measure a corporation’s energy efficiency is energy intensity. Energy intensity refers to the quantity of energy required per unit output or activity (US Department of Energy 2012). In terms of iron ore mining, this equates to the amount of energy required to produce a certain quantity of ore for shipping. This encompasses the total energy expended to extract the ore from the ground, haul it to the plant for processing, process it, rail it to shipyards and finally load it onto ships. An industry comparison between the “three big” iron ore miners in Western Australia can be seen in Figure17 below.

![Figure 17 – WA Iron Ore Mining Industry Analysis of Energy Intensity](image)

It can be seen from this graph that BHP and RTIO are reasonably comparable in terms of energy efficiency performance and this may be due, in part, to the substantial economies of scale that are enjoyed by both miners. The type of the ore mined is also an important factor in determining the energy intensity of the operation. Pilbara ore typically falls within three categories, Bedded Iron Deposit (BID), Detrital Iron Deposit (DID) and Channel Iron Deposit (CID) (Australian Premium Iron Joint Venture 2013).
Banded Iron Formation (BIF) ore is found within the BID and this is the source of iron for the majority of Rio Tinto, BHP and FMG’s current operations. BIF comprises the Marra Mamba, Brockman and Premium Ore bodies seen in Figure 18 below. Whilst in the Pilbara, this ore is generally of high quality, its extraction is volume and waste intensive. Consequently, BIF requires a significant energy input to transport large quantities of material to both the waste dump and the plant for processing (Capital Corporation 2013). In addition, as ore is depleted, it becomes necessary for operations to mine at deeper depths. This substantially increases energy intensity due to an increased requirement for drilling and blasting. As depth increases, mining operations have the potential to go below the water Table. In order to access the ore, pumps are employed to dewater the pit. This also increases the energy intensity of the operation significantly as energy is required to operate the pumps and to dispose of the mine water. At present BIF is a significant source of iron for both RTIO and BHP and the primary source of iron ore export for FMG.

Unlike FMG, both RTIO and BHP have access to large deposits of CID. This ore, whilst a lower quality in terms of iron content, is often close to the surface requiring little if any drilling and blasting. Because of the abundance of water within CID iron (observed by the high LOI value in Figure 18), the concentration percentage of iron is raised significantly upon processing. This property, along with the low level of contaminants found in the ore, make it highly attractive to market.

CID ore is currently high yield for Rio Tinto at their Mesa A, Mesa J/K and Yandicoogina mine sites. BHP’s Yandicoogina operation is responsible for a large proportion of the business’ total export (BHP Billiton 2002).
In terms of participation in the EEO program, RTIO is remarkably more active than its iron ore competitors in the Pilbara. As of 2012, Rio Tinto had implemented 30 projects in its first cycle, with a combined total estimated energy savings of 111,200GJ. This was far greater than those opportunities implemented for both BHP and FMG for the same period (see Figure 19 and 20 below).

![Figure 18 - Mineral Composition of Pilbara Ore (O’Brien 2009)](image)

![Figure 19 - Industry Comparison of the Number Of EEO’s](image)
In order to produce a reasonably fair comparison EEO performance must be scaled to reflect the size of the operation. For example, RTIO has reported far greater energy savings from projects that have been implemented or have commenced implementation than its competitors, but the miner also consumes a great deal more energy (Appendix 8.3: Energy Consumption and Production Data). Scaling performance to reflect a % Savings/GJ metric takes into account the energy use variations of the businesses (see Figure 21 below).
Benchmarking, although a useful tool in assisting RTIO in understanding where it sits within the context of other Pilbara operations, is not effective to be used as a primary tool to drive improvement and care should be taken to avoid this. This is due to the inherent complacency that can be bred by observing above average or leading performance – there is little incentive for further improvement and thus continued growth may be inhibited. Conversely, while benchmarking may illustrate below-average performance, it does not offer any information as to how the business can improve (Dokus Eylul University 2013). As such, a more effective improvement practice is to consistently measure and improve upon the business’ internal performance results.

3.41 Further Developments

In order to expand the context and to measure performance against other large iron ore miners it would be useful to gather and compare international iron ore mining energy intensity data.
4.0 ESTIMATING THE PERFORMANCE OF FUTURE PROJECTS

4.1 Project Introduction

4.11 Project Background
Rio Tinto Iron Ore is undergoing significant expansion within the Pilbara region, with projects such as Koodaideri and Yandicoogina Sustaining promising huge potential increases in capacity (and thus demand for energy resources). Whilst in the past, it has not been a requirement as given by The Act, the business commits resources to considering and implementing energy efficiency measures into the studies phase of development. This is not only beneficial from an economic perspective (according to Worrell et al (2001) it is often cheaper to implement EEO into design and construction than it is to retrofit) but demonstrating excellence beyond compliance is also highly valuable in terms of improving stakeholder relationships (Hoffman 2006).

4.12 Project Objectives
The principle objective for the works undertaken with Projects and Development was to revise an existing document tracking the expected GHG performance new developments over the life of mine (LOM).

4.2 Project 3 - Revise GHG tracking document

4.21 Project Methodology

4.211 APPROACH
The approach to this project was decided upon throughout the course of meetings with key stakeholders. This included the RTIO energy corporate group and primarily the Projects and Development division energy representative.
Given that the purpose of this document was to provide information for the expected greenhouse gas performance of new developments, several objectives were identified, and include:

- Updating baseline data from 2009 to 2012
- Updating fuel factors for rail transport
- Designing interface to calculate diesel use from trucks and shovel information given in the mine plan
- Updating equipment burn rates
- Design interface to compare expected GHG emissions intensity of new development to existing mine sites
- Design basic energy mass balance (EMB) graphs to visually represent energy use and subsequent emissions

These objectives were worked through methodically in order to complete the task.

4.212 SCOPE

The scope of this project was not to create a new tool for estimating the GHG projections, but to amend an existing tool in order to maximize its function and usability.

4.213 ASSUMPTIONS

It was assumed in this project that the original works including calculations, unless otherwise stated, were correct and functional.

It was also assumed that the information and data provided was the most relevant and correct.

4.214 LIMITATIONS

Sensitive and confidential business information was unable to be included into the tool due to the fact that it was often distributed to EPCM’s. This limited the metrics that could be used to estimate cost information.
4.22 Works Completed

The first step of this task was to update the baseline data from 2009 (as given in the existing document) to 2012. This is to ensure that the emissions intensities compared against are reflective of the current state of the business thus improving the accuracy of subsequent evaluations. It was found during this stage that at an operations level, the average GHG emissions intensity for mines has increased.

Another important component of this task was updating the fuel factors. Fuel factors are numerical values that relate operations to each other based on the energy intensity of the rail journey from the mine to the port. The energy intensity of rail journeys varies given differences in topography, haulage volume and operator practice. Rail factors were sourced from email correspondence with relevant business energy advisors. Rail advisors also provided information on equipment burn rates (the amount of diesel used by the machinery per hour).

This was used to update existing burn rate Tables. The significance of these updates were critical. For example, in the existing document, the burn rate for a given piece of equipment was given at 160L/hour, whilst updated information quoted a much higher burn rate of 181L/hour. Assuming this piece of equipment is utilized 75% of the time (around 6570 hours of operation) this equated to a disparity of 137.97kl, or 5325.64GJ. This equated to an inaccuracy of 11.60%.

Using these updated burn rates, an interface was designed to allow diesel usage to be approximated based on the equipment usage hours given in the life of mine (LOM) plan for the prospective development. As a rule of thumb, shovels and trucks represent 85% of the diesel usage on site, and so this method is a simple way to approximate potential diesel related GHG emissions with reasonable accuracy. The interface was created by programming excel with a suite of complex functions enabling the user to select up to three pieces of machinery and input their planned usage hours from the LOM plan. From here, the document automatically seeks and assigns the corresponding machinery burn rate, and multiplies this by the given hours to produce a diesel value in litres. As this value corresponds to 85% of the total diesel use, multiplying the Figure by 1.15 will give an approximate diesel usage Figure.
Method 3 - Ground Up Estimates
Enter annual TRUCK and SHOVEL operating hours

<table>
<thead>
<tr>
<th>Truck Type</th>
<th>Total</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Komatsu HD785</td>
<td>2,775.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
</tr>
<tr>
<td>Komatsu 730E</td>
<td>2,775.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
</tr>
<tr>
<td>Komatsu 930E</td>
<td>2,775.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,325.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shovel Type</th>
<th>Total</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi EX1900</td>
<td>2,775.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
</tr>
<tr>
<td>Hitachi EX5500</td>
<td>2,775.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
<td>555.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,325.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
<td><strong>1,665.00</strong></td>
</tr>
</tbody>
</table>

Proportion of total diesel used by trucks and shovels: **0.85**

Diesel in Litres

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>406,912,191</td>
<td>748,564</td>
<td>748,564</td>
<td>748,564</td>
<td>748,564</td>
<td>748,564</td>
</tr>
</tbody>
</table>

Figure 22 - Diesel Usage Calculation

Whilst the diesel figures are traditionally sourced using this method, the values for planned electricity consumed over the LOM are typically given by the EPCM. Once these values are input into the spreadsheet, GHG emissions are calculated by applying the conversion factors given in the assumptions. This not only allows the user access to annual GHG emission estimates, but also provides a basis for calculating the overall emissions intensity of the mine (represented by the equation below).

\[
LOM \text{ emissions intensity} = \frac{GHG \text{ emissions (diesel)} + GHG \text{ emissions (electricity)}}{tSOP}
\]

; where \(tSOP\) is the total tonnes of standard ore produced over the LOM.

EI is a better representation of GHG performance than emissions output alone as it factors in the production of the mine, thereby allowing for comparability between sites.

One of the objectives of this project was to include a platform to compare the calculated LOM EI of the prospective development to an existing operation. In order to achieve this, the emissions intensities of all existing operations were calculated from the 2012 data. A selector was imbedded into the output Table allowing the user to manually choose the desired comparison site. From here, excel was programmed to recall the associated EI using the MATCH and INDEX functions, and a function created to determine the variance of the LOM EI from the comparison site EI.
In terms of context, the calculation of this variance allowed the user an insight into how the prospective overall emissions performance of the development measured up against an existing site, although this was a relatively low level analysis and as such it was difficult to gain a perspective of the “big picture”. For this reason, a dynamic graph was created to measure the EI of the development against all currently operating mines (see Figure 23)

![Figure 23 - Comparison of Emissions Intensities Vs Average](image)

Whilst acknowledging that benchmarking is not an ideal tool to drive improvement, Figure 23 is effective in that poor performance can highlight the importance of the integration of energy efficient technologies into the construction phase of development. As such, the tool may be useful in building and driving the business case for these energy improvements.

The final step of this task was to create a series of EMB graphs to profile the development’s energy consumption and emissions generation behavior. This was useful, as it allowed the user to visually identify where energy was being consumed and the effect that this had on associated GHG emissions. Mock up graphs can be seen in Figures 24 through 28 below.
Figure 24 – LOM Energy Mass Balance of Proposed Development

The EMB depicted in Figure 24 displays the percentage of energy use attributed to each area of the mining process over the lifetime of the development. By developing an understanding of where energy use is greatest, RTIO can develop priorities as to where to apply resources as to yield the most significant energy efficiency improvements. Similarly, Figure 25 demonstrates the projected GHG emissions associated with the given energy use.

Figure 25 – LOM Emissions Mass Balance of Proposed Development
Due to inherent inefficiencies in the electricity generation process, RTIO's electricity use is more greenhouse gas intensive than diesel use. Assuming a typical generation efficiency of 33%, for every 3GJ of energy delivered to the system via natural gas, only 1GJ of electricity is produced. The remaining energy is dissipated to atmosphere mainly in the form of heat.

Figure 26 - Electricity Generation Process

When assigning the energy delivered in the form of electricity to the mine and port divisions, RTIO measures the amount of energy that the operation receives (the electricity outputted from the utilities plant in MWh). However, when reporting on the GHG emissions of the business, the total emissions from both the generated electricity and waste are taken into account. This is evident from Figures 27 and 28 where electricity use comprises 3.34% and 6.98% of its total energy use and GHG emissions respectively.
4.33 Further Developments

In order to remain a useful and effective tool, the reference data in this document will need to be continually updated to reflect changes in time. Ideally, a yearly review would ensure the output projects remain relevant within the business context.
5.0 CONCLUSION

The purpose of this internship placement was to gain experience working within RTIO’s energy team, supporting the development of tools to measure the business’ energy and GHG performance and increasing the accuracy of scoping documents as required by the EEO act.

Throughout the placement, scoping documents for Tom Price, Marandoo, Paraburdoo, Yandicoogina and Brockman were critically audited, and a list of verifications and suggestions to improve accuracy developed and presented to management. In order to produce these verifications, technical reports and material specifications were examined and information sourced from engineers and energy professionals within the business. Using engineering calculations facts and Figures were checked and discrepancies noted for review. Site visits at Tom Price and Marandoo allowed for meetings to be scheduled with appropriate engineers and energy representatives. This allowed for raised verifications to be addressed and for resultant changes to be effected, thus improving the accuracy of scoping documents so as to be further in line with the ±30% range required by The Act.

An additional requirement of the EEO program is to develop a sound understanding of energy use through data measurement and analyses. For mines already in operation, a GHG performance model tool was developed to quantitatively examine GHG emissions performance compared to relevant targets and baselines. This tool allowed for variations and trends in target performance to be explained at a metric level. By developing an understanding of which areas are consistently underperforming, RTIO is able to cost effectively apply resources to where most benefits will be obtained.

For future developments, an existing GHG document was revised, adding additional functionality and ensuring that output data was accurate and up to date. A suite of complex excel functions were employed to develop dynamic EMB graphs, a sound interface for planning diesel consumption via mobile machinery burn rate and usage and variation comparisons between new developments and existing mine sites.
Finally, a brief industry analysis was performed to benchmark the performance of Rio Tinto’s energy and climate change program against that of its major Pilbara iron ore competitors – BHP Billiton and Fortescue Metals Group. Based on the information reviewed, RTIO was highly competitive in terms of its energy intensity performance. The business was also far more active in identifying and assessing opportunities under the EEO program than its competitors.

Overall, the activities undertaken were successful in developing Rio Tinto’s understanding of their energy and GHG performance and improving the accuracy of EEO scoping sheets. Fulfilling these objectives played a key role in assisting business compliance with the federal government’s EEO act. In addition, it became evident throughout the course of this internship that key knowledge gaps existed pertaining to the energy intensity of iron ore mining operations in the Pilbara and the effect of ore grade and geology on energy consumption. The research presented in this report was able to contribute towards addressing some of the concepts evident within these knowledge gaps.
6.0 RECOMMENDATIONS FOR FUTURE WORK

Compliance with the EEO program is an ongoing process. As RTIO is currently partaking in their second cycle of the program, they will need to continue to assess the energy and related cost savings of identified opportunities and report on these annually to DRET. In addition, from an economic and compliance perspective, resources should continue to be made available to allow RTIO to uphold a sound understanding of their energy and GHG performance.

In order to maintain the high standard currently upheld by RTIO in the energy efficiency space, capital and human resources must be applied by management to support the business’ effective energy team from both a corporate and an operational perspective. The energy team plays a critical role in building the business case for EEO’s that will benefit the organisation from both an environmental and economic point of view. As such, this should continue to be recognized and the pursuit of cost-effective EEO’s prioritized by management.

It is evident that clear links exist between the quality of ore and the energy intensity of the operations extracting it, although there appears to be limited research in this space as applied to the Pilbara. Energy efficiency is generated by thorough understanding, and as such there is an opportunity for further research within this space.
7.0 REFLECTIONS

Participation in the ENG450 – Engineering Internship unit affords final year engineering students the invaluable opportunity to work alongside industry professionals applying and developing the skills that they have learnt throughout their degree. General projects and tasks are assigned to fulfill the competencies laid out by Engineers Australia and for the purpose of this placement these include engineering operations, materials/components/systems, research/development/commercialization, self-management in the engineering workplace, engineering project management and investigating and reporting. In addition to developing these competencies, various “soft skills” are invariably developed. These include verbal and non-verbal professional etiquette, effective written communication and personal presentation as required by the corporate standard. These are arguably just as important for the developing engineer as technical competencies and instrumental in preparing the student for entry to the professional workplace.
8.0 BIBLIOGRAPHY


—. Energy and Climate Change. 2012. 


Rolph, B, and E Prior. "Climate Change and the ASX100 – An Assessment of Risks and Opportunities." 2006. 


## 8.0 APPENDICES

### 8.1 Ore Product and Shipping

Table 3 - Site Ore and Production Information

<table>
<thead>
<tr>
<th>Site</th>
<th>Capacity (Mt/a)</th>
<th>Ore type</th>
<th>Blend</th>
<th>Commenced Production</th>
<th>Port</th>
<th>Workforce</th>
<th>Fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brockman 2 / Nammuldi</td>
<td>Brockman 2 - 9 Nammuldi - 7</td>
<td>Brockman Marra Mamba</td>
<td>Pilbara Blend</td>
<td>1992</td>
<td>Dampier</td>
<td>FIFO</td>
<td>Trucks - 22 Loading Units - 6</td>
</tr>
<tr>
<td>Brockman 4</td>
<td></td>
<td>22</td>
<td>Brockman</td>
<td>Pilbara Blend</td>
<td>2010</td>
<td>Dampier</td>
<td>FIFO</td>
</tr>
<tr>
<td>West Angelas</td>
<td></td>
<td>29.5</td>
<td>Marra Mamba</td>
<td>Pilbara Blend</td>
<td>2002</td>
<td>Dampier</td>
<td>FIFO</td>
</tr>
<tr>
<td>Mt Tom Price (including WTS)</td>
<td></td>
<td>30</td>
<td>Brockman Marra Mamba</td>
<td>Pilbara Blend</td>
<td>1966</td>
<td>Dampier</td>
<td>Residential</td>
</tr>
<tr>
<td>Greater Paraburdo o (Paraburdo o, Channer and Eastern Range)</td>
<td></td>
<td>22.5</td>
<td>Brockman</td>
<td>Pilbara Blend</td>
<td>Paraburdoo - 1972 Channer - 1990</td>
<td>Dampier</td>
<td>78% Residential 22% FIFO</td>
</tr>
<tr>
<td>Marandoo</td>
<td></td>
<td>15</td>
<td>Marra Mamba</td>
<td>Pilbara Blend</td>
<td>1994</td>
<td>Dampier</td>
<td>FIFO</td>
</tr>
<tr>
<td>Yandicoogina</td>
<td></td>
<td>53.7</td>
<td>Channel Iron Deposit (Pisolite)</td>
<td>Yandicoogina fines</td>
<td>1998</td>
<td>Cape Lambert</td>
<td>FIFO</td>
</tr>
<tr>
<td>Hope Downs</td>
<td>31</td>
<td>Marra Mamba</td>
<td>Pilbara Blend</td>
<td>2007</td>
<td>Dampier</td>
<td>FIFO</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>----</td>
<td>-------------</td>
<td>---------------</td>
<td>------</td>
<td>----------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>Loading Units</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trucks - 22 Loading Units - 6
Figure 29- Shipping Information
8.2 Energy Policy in Australia

The history of energy policy in Australia is relatively complex, and underpinned largely by fluctuations in energy supply. (Greene and Pears 2003)

The 1973 American Oil Crisis served as a global catalyst for generating discussions within the energy space, with many countries recognizing the need for long-term energy planning. In 1975, the Institute of Engineers, Australia established a Task Force on Energy, subsequently producing a set of key actions for improving energy efficiency in Australia. The National Energy Advisory Committee was formed in 1977 and released their Proposals for Australian Conservation of Energy Program report during the same year. The report put forward several recommendations, including the commissioning of an energy conservation advisory service for industry, training programs in energy conservation, and studies of the effect of increasing crude oil prices. Like much of the policy of the time, the document failed to recognize the need for energy efficiency to be implemented into organizational decision making and corporate governance, and thus even though some of the recommendations put forward in the report were achieved, long term commitments to energy efficiency by industry were not fostered.

Recognising the need for industry to commit to research and develop pertaining to energy efficiency, the Commonwealth Government introduced the National Energy Research, Development and Demonstration Program (NERDDP) in 1978. Under
this program, the government issued grants to projects related to energy consumption. Funding under this scheme was relatively minor (averaging $2 million dollars per year) thus rendering the scheme ineffective, on the whole, for motivating industry to pursue implementation of large-scale energy improvements.

Discussions became subdued during the 1980’s due predominantly to the 1986 collapse in crude oil price. Prior to this, the key driver for implementing policy had been the importance of energy conservation to protect finite resources and to stave off gradually increasing energy prices. Essentially, as prices fell, so did the interest in energy conservation. In 1987, the concept of sustainable development, and subsequently the notion of the sustainable use of energy was introduced in the Brundtland report *Our Common Future*. The importance of energy efficiency for economic sustainability was also emphasized in the 1988 Department of Primary Industries and Energy 2000 report. Whilst underlining the importance of energy efficiency, the report did not recommend any policy measures that could be implemented to drive this.

The 1990’s brought a suite of new policy with the introduction of the Commonwealth Government’s National Greenhouse Response Strategy (NGRS) endorsed by the Council of Australian Governments in 1992. On-trend with previous policy measures, this strategy was essentially technical in nature, paying little attention to human-behaviors and industry cultures in energy consumption (Greene and Pears 2003). In 1995 the National Greenhouse Challenge Program was initiated with the intention of encouraging industry to voluntarily produce formal action plans to reduce GHG emissions. In 1998 the first mandatory energy reporting requirements were introduced by the Commonwealth Government’s Energy Efficiency Policy. The signing of the Kyoto Protocol in 1998
National Greenhouse Response Strategy (NGRS) endorsed by the Council of Australian Governments

Commonwealth Greenhouse Challenge Program introduced

Commonwealth Government introduces Policy on Energy Efficiency

National Greenhouse Strategy adopted

Australia signs Kyoto protocol
8.3 Energy Production and Consumption Data

Table 4 - % Energy Improvement per GJ Consumed Business Comparison

<table>
<thead>
<tr>
<th></th>
<th>Under Investigation</th>
<th>To Be Implemented</th>
<th>Implementation Commenced</th>
<th>Implemented</th>
<th>Not to be Implemented</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.001</td>
<td>0.009</td>
<td>0.003</td>
<td>0.011</td>
</tr>
<tr>
<td>BHP</td>
<td>0.010</td>
<td>-</td>
<td>-</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>FMG</td>
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<td>0.003</td>
<td>0.005</td>
<td>0.001</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Energy data was sourced from public EEO reports and production data from annual reports.

Table 5 - Ore Shipped Business Comparison (Tonnes of Ore)

<table>
<thead>
<tr>
<th></th>
<th>Rio Tinto</th>
<th>BHP</th>
<th>FMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
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<td>113,868,000.00</td>
<td>40,093,093.00</td>
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<tr>
<td>2011</td>
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<td>40,900,000.00</td>
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<tr>
<td>2012</td>
<td>233,000,000.00</td>
<td>148,055,000.00</td>
<td>57,500,000.00</td>
</tr>
</tbody>
</table>

Table 6 - Energy Consumption Business Comparison (GJ)

<table>
<thead>
<tr>
<th></th>
<th>Rio Tinto</th>
<th>BHP</th>
<th>FMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>32,581,100.00</td>
<td>15,032,000.00</td>
<td>6,436,573.00</td>
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<tr>
<td>2011</td>
<td>31,814,600.00</td>
<td>15,734,000.00</td>
<td>7,248,487.00</td>
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<tr>
<td>2012</td>
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