Spring 2020

ASSESSING THE ENERGY MANAGEMENT CULTURE OF GLOBAL LEADING MINING COMPANIES: CURBING CARBON EMISSIONS IN A WORLD OF GROWING CLIMATE CHANGE CONCERNS

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by

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A thesis submitted in partial fulfillment of the requirements for the degree of

MS. Mining Engineering

Montana Tech

2020

Abstract

Industries such as the oil, mining and chemical industry have been under a lot of pressure from governments and certain organizations worldwide to reduce their carbon footprint. The United Nations (UN), the International Council on Mining and Metals (ICMM) and other organizations, have mapped out policies and recommendations that can be used to achieve this. Mining companies all over the world have adopted sustainability commitments based on recommendations by the United Nations Intergovernmental Panel on Climate Change and have set targets for managing their energy use and GHG emissions. This research assessed the energy management culture of twenty (20) leading mining companies worldwide, using the UN's Sustainable Development Goals (SDGs) 7, Affordable and Clean Energy and 13, Climate Action as a performance metric, and established a trend of adaptation to these sustainability goals. Results showed that the mining industry is so far on an average, committed to achieving 80% of these goals. An investigation into the activities of these mining companies revealed what renewable technologies and energy management structures are currently being used. This research also reviewed how renewable technologies are a product of mining, which goes to prove that mining is essential in the combat of climate change. Future work will focus on assessing the impact of these management goals on the economic model of the companies.

Keywords: Mining, Carbon Footprint, Climate Change, Sustainable Development Goals, Renewables, Energy Management

Dedication

I dedicate this work to my parents Mr. Clement Ateng (in memoriam) and Madam Elizabeth Zelia Abukari and to all my siblings for their continuous love, prayers and support.

Acknowledgements

I am most grateful to God for His graciousness in seeing me through this academic journey, for His divine favor, blessing and strength to successfully complete my graduate studies. My deepest appreciation to the Montana Technological University Mining Engineering Department for funding my master's degree.

I would like to express my sincere appreciation to Dr. Thomas Camm who was my advisor till his sabbatical leave, and still accepted the request to be on my committee while on leave, his support and guidance established me for success for the onset of my studies. To Mr. Chris Roos, who stepped in as my advisor and thesis committee chair, for his advice and guidance, steering me in the right direction to make my research a success, and then to Dr. Kumar Ganesan, my thesis committee member, thank you for your inputs and guidance that made this research a success.

To Ing. Ebenezer Kwame Ako, Mr. Thomas Armooh and Mr. Godfred Avane whose mentorship, guidance and support has contributed immensely to my academic success. My profound thanks also go to the Society of Mining Metallurgy and Exploration (SME), International Society of Explosive Engineers (ISEE) and SRK consulting for their financial assistance that helped me greatly during my studies.

Finally, to Dr. Paul and Donna Conrad, Dr. Akua Oppong- Anane, Barbara and Charlie Gadd Noe, the Morin family, the Eldred family, the Swant family and all members of the Abundant Life Fellowship church in Butte. You all created a family away from home and made my stay here a memorable one. I am forever grateful.

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Glossary of Acronyms

Acronym	Definition
CO_2	Carbon dioxide
GHG	Green House Gas Emissions
NASA	The National Aeronautics and Space Administration
EPA	Environmental Protection Agency
LPG	Liquified Petroleum Gas
LNG	Liquified Natural Gas
CDP	Carbon Disclosure Projects
UN	United Nations
UNDP	United Nations Development Programme
ICMM	International Council on Mining and Metals
ISO	International Organization for Standardization
IPCC	Intergovernmental Panel on Climate Change
SDG	Sustainable Development Goals
kWh	Kilowatts-hour
kg	Kilogram
GRI	Global Reporting Initiative
R&D	Research and Development
CO_2eq	Carbon dioxide equivalent

1. Introduction

According to NASA, Earth's climate has changed throughout time, in fact in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 11,700 years ago marking the beginning of the modern climate era (Holly, Randal, Susan, & Daniel, 2020). This modern era represents the entirety of human civilization, from the stone age through the industrial revolution and into the modern age. While most of the climate changes throughout history are attributed to small variations in Earth's orbit that change the amount of solar energy our planet receives, the heat-trapping properties of "greenhouse gases" was discovered in the mid-19th century. Carbon dioxide and other gases affect the transfer of infrared energy through the atmosphere which is believed to have increased the rate of climate change since the mid-20th century (Holly, Randal, Susan, & Daniel, 2020). Figure 1 below shows results from a study conducted by NASA based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements providing evidence of an increase in atmospheric CO_2.

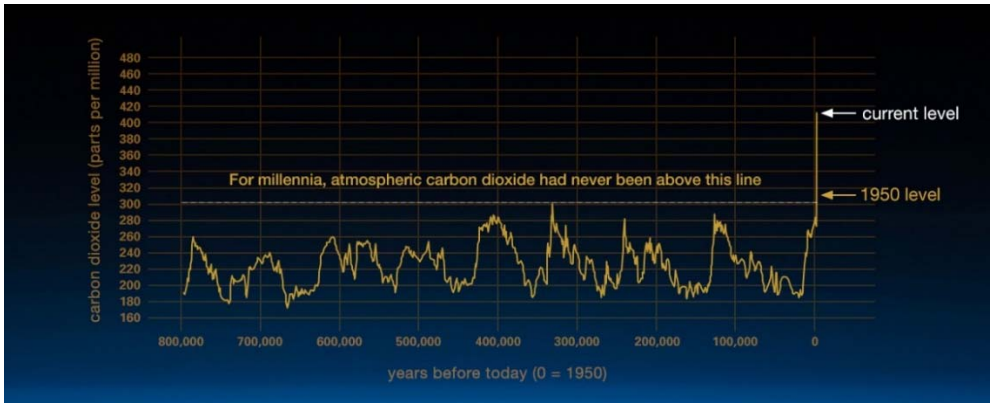

Figure 1: Atmospheric CO_2 increase since the industrial revolution (Holly, Randal, Susan, & Daniel, 2020)

NASA states that there is a scientific consensus that “ninety seven percent of climate scientists agree that climate-warming trends over the past century are extremely likely due to human activities, and most of the leading scientific organizations worldwide have issued public statements endorsing this position” (Holly, Randal, Susan, & Daniel, 2020).

In recent years, there has been a great global concern for the unfavorable changes in climate. Most of this has been attributed to industrial activities and how much carbon emissions are produced through their operations. In some cases, major industries such as the oil, mining and the chemical industry have been under a lot of pressure from governments, activists and certain organizations to make changes to their operations because of this. According to the Union of Concerned Scientists, in a published article; “governments, industry, and individuals all bear some responsibility for climate change. But major fossil fuel companies—including ExxonMobil, Chevron, Shell, BP, ConocoPhillips, Peabody Energy, Consol Energy, and Arch Coal—are substantial contributors to the problem, and therefore must take responsibility for their actions” (Union of Concerned Scientists, 2019). They propose that at a minimum, society should expect fossil fuel companies to:

- **Reject disinformation on climate**, including through their trade associations and other lobbying groups; they should also publicly disassociate themselves from such groups and their activities.
- **Support sensible climate policies** to reduce global warming emissions.
- **Fully disclose the financial and physical risks of climate change** to their business operations.

- **Align their business models with a carbon-constrained world** consistent with keeping warming well below a 2°C increase above pre-industrial levels, as agreed by world leaders.
- **Pay for their share of the costs** of climate-related damages and climate change adaptation. (Union of Concerned Scientists, 2019)

However, contrary to the popular notion, the mining industry has been engaged in a lot of energy management and carbon reduction activities as part of their sustainability commitments towards the combat of climate change. With the adoption of key policies and recommendations by important organizations such as the United Nations (UN), the International Council on Mining & Metals (ICMM), the Intergovernmental Panel on Climate Change (IPCC), International Organization for standards (ISO) and many others. One of the very notable policies drafted are the seventeen United Nations' Sustainability Development Goals (SDGs), two of which are related to climate change and affordable clean energy.

It is also noteworthy that the mining industry plays a huge role in the quest for green energy. Facts show that most of the products needed to build renewable power supply (Solar, wind, hydro and geothermal plants, etc.), all come from the products of mining (Copper, Iron, Steel, Aluminum, etc.)

1.1. Objectives

This thesis seeks to conduct an assessment on twenty (20) selected mining companies, representative of all continents, except Antarctica, by reviewing their sustainability reports, financial reports and 10-Ks and press releases to;

1. Establish their energy management culture, which is the systems, policies and best practices they have put in place to ensure a reduction in their GHG emissions.
2. Establish their adaptation to the use of renewable and green energy technologies and the reasons or motivations behind their choices.
3. Establish and make recommendations based on their performance against the UN's SDG7, Affordable Clean Energy and SDG13, Climate Action.
4. Answer the question; Is the Mining industry concerned about the effects of climate change?

Another aspect of this research seeks to highlight the important role mining plays in the area of renewable technologies as a means of combating the issue of climate change.

2. Literature Review

2.1. Introduction

At the 21st Conference of the Parties (COP) in Paris, on December 12, 2015, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort (UNFCCC, 2020). Affordable, scalable solutions are now available to enable countries to leapfrog to cleaner, more resilient economies. The pace of change is quickening as more people are turning to renewable energy and a range of other measures that will reduce emissions and increase adaptation efforts (United Nations, 2019).

There has been a lot of commitment from the mining industry following proceedings of conferences such as the ones held by the UN. Several mining companies across the world have taken a stance of acknowledging and addressing the effects of climate change both on their operations and environment. According to Barrick Gold,

> Climate change and the transition to a low carbon future bring physical, regulatory and reputational risks for us and for the mining industry in general. We understand the important link between energy use and climate change. By effectively managing our energy use, we can reduce our greenhouse gas (GHG) emissions, achieve more efficient production, reduce our draw from local energy grids and save a significant proportion of

> our direct mining costs. Managing our energy use is therefore a business imperative. (Barrick Gold, 2020)

With policies, recommendations and goals drafted by organizations such as the UN, ICMM, IPCC, ISO, etc., and adopted by some mining companies, it will be useful to assess and study the energy management culture of some of these companies to inform decision making and to give other mining companies which have not made these commitments yet, a fair idea of what can be done. It will also provide answers to the question of what the mining industry is doing about their greenhouse gas emissions and whether they are adhering to the policies and goals drafted by the authorities to combat climate change.

2.2. Climate Change and Carbon Emissions

According to National Geographic, climate change is a long-term shift in global or regional climate patterns. Often climate change refers specifically to the rise in global temperatures from the mid-20th century to present. Climate is sometimes mistaken for weather; however, climate is measured over a long period of time, whereas weather can change from day to day, or from year to year. The climate of an area includes seasonal temperature and precipitation and regional wind patterns. Climate change is also related to other damaging weather events such as more frequent and more intense hurricanes, floods, downpours, and winter storms. (National Geographic, 2019)

As discussed previously, the current climate change is largely a result of human activity since the industrial revolution and includes things such as burning fossil fuels. Burning natural gas, oil, and coal releases greenhouse gases into earth's atmosphere where these gases trap heat from the sun's rays and cause Earth's average temperature to rise. The current rise in Earth's temperature is referred to as global warming. While the warming of the planet is a significant

component of climate change, it also impacts local and regional precipitation and wind patterns. Throughout earth's history, climate has continually changed and when this change is driven by natural process, it tends to be a slow process over hundreds and thousands of years. The human influence of climate change is occurring at a much faster rate (National Geographic, 2019). Human activities such as the heavy use of fossil fuels, deforestation and land-use change, contribute immensely to the hike in greenhouse gas emission levels in the atmosphere.

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. Human activities are altering the carbon cycle, both by adding more CO_2 to the atmosphere, by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere, and by influencing the ability of soils to store carbon. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution. The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO_2. (IPCC, 2007)

The industrial sector that includes mining, manufacturing, and construction produced as much as 21 percent of carbon dioxide emissions in 2014. The use and combustion of fossil fuels in various steps of manufacturing and industrial processes is responsible for these emissions. For example, creating cement from limestone requires the combustion of significant fossil fuels to generate heat for the kiln (Cunanan, 2018). The emissions from these fossil fuels also adds up to CO_2 emissions that limestone itself generates.

2.3. Energy Usage in the Mining Industry

Energy usage is simply defined as the amount of energy used in a process or system. The mining industry is one of the most energy-intensive industries globally. From breaking up the

rock, hauling, comminution, processing to the product's final stages, mining makes use of various forms of energy. Table I below shows various activities and processes within mining that uses different forms of energy.

Table I. Energy Usage in the Mines

Electricity	Fuel	Gas
Crushing	Transportation (Buses and light vehicles)	Processing
Ore Conveying	Excavation and Hauling	Workshops & Kitchen/Lunchrooms
Grinding	Drilling	
Processing	Ground Support	
Ventilation	Generators sets	
Drilling	All diesel-powered equipment	
Excavation and Hauling		
Ground Support		
Utilities		
Workshops & Offices		

Generally, electricity accounts for a greater percentage of the total energy consumption on our mines, with fuel and gas accounting for less than half. In underground mining, electricity is used extensively in operating machinery, for ventilation, lighting, transportation (hoisting), drilling, bolting and so on. In surface mining, electricity is also used drilling, loading, trolley assist on some trucks, conveyor belts, crushers, mills, pumps, compressors, workshops, offices, canteens and housing. Fuel is generally used by all types of machinery for transportation, excavation, hauling and drilling in both surface and underground mining. It is also used in generator sets as an alternative source for the generation of electricity for onsite use. Gas (LPG, LNG, Acetylene, etc.) is generally used in workshops for welding and cutting, in the furnace for ore processing and in canteens and housing for domestic use.

To evaluate the impact of various energy sources on greenhouse gas emissions, we must understand both the units of consumption as well as the units of carbon dioxide production. Electricity as an energy source is measured in kWh and produces a little over one pound of

carbon dioxide (CO_2) per kWh. Fuel, which mostly consists of diesel or petrol is measured in liters and produces about 2.68kg of CO_2/liter of diesel and approximately 2.31kg of CO_2/liter of petrol. LPG, which is also measured in liters, produces about 1.51kg/liter.

Even though mining plays a critical role in the energy transition by providing raw materials like copper, silver, aluminum (bauxite), nickel, zinc, neodymium, indium, etc., needed to sustain these budding industries, the mining industry remains vulnerable to both societal pressure and policy changes. In view of this, mining companies have a lot of work to do if they are to meet the goals of the reducing GHG emissions. An article by Jessie Lund and Thomas Kirk of the Rocky Mountain Institute documents the following statistics related to the mining industries responsibilities:

> "A recent report by CDP shows that in 2015, half of worldwide industrial greenhouse gas emissions could be traced back to just 50 companies (called carbon majors) working in heavy fossil fuel industries. Mining companies, particularly those involved in coal extraction, ranked high on the list, taking two of the top five spots and 20 spots overall. In fact, even three International Council on Mining and Metals (ICMM) member companies — the "crème de la crème" when it comes to sustainability efforts in the industry — made the list. Therefore, meeting the goal of the Paris Agreement will require these companies to significantly reduce the amount of CO_2 they release" (Jessie & Thomas, 2018).

2.4. Mining and Energy Management

Energy management is the process of controlling, tracking and monitoring the use of energy within a system with the aim of reducing consumption or improving efficiency. This enables a reduction in the cost of energy, reduced carbon emissions and reduced energy related

risks. Energy management consists of energy audits, monitoring and targeting, measurement and verification, implementation of identified energy saving opportunities and continuous improvement.

Energy represents a tremendous improvement opportunity for mining companies since significant savings are derived from more proactive energy management. Energy is one of the biggest expenses for mining companies, constituting approximately 30% of total cash operating costs. Deloitte argues that mining companies can reduce their energy consumption by 15-20% at existing mines and up to 50% in new mines through an effective energy management program that incorporates energy management into the mine design process (Deloitte, 2019).

Mining companies have a host of options to choose from when planning for operational emissions reductions, including leveraging new technologies and innovations to add renewables to their electricity supply, improving mining processes, switching from fossil fuels to renewable fuels, reducing waste, and optimizing transportation. Mining companies need to evaluate these options internally and choose the most beneficial and cost-effective approach for their unique circumstances, but every plan must have an appropriate target as well as public disclosure of progress (Jessie & Thomas, 2018).

2.5. Mining Sustainability Commitments on Energy and Carbon Emissions Management

Across the globe, many governing organizations like the International Council on Mining and Metals (ICMM), International Organization for Standards (ISO) and United Nations (UN), have created policies and standards to which mining companies have committed to reducing their

carbon footprint. These commitments are focused on practicing effective energy management within their operations.

According to a report by the ICMM on building resilience to the effects of climate change in the mining and metals industry, extreme weather and climate change have affected mining operations in recent years. Flooding, drought, increased storm intensity, greater variability of water supply and an increasing number of high-temperature days have led to reduction in or shut-down of production, increases in capital expenditure, health and safety impacts and made vulnerable communities more prone to social unrest. Considering this, and the social aspects of carbon emissions, the industry has experienced a gradual shift from the heavy use of fossil fuels to a rapid growth in the use of green or renewable energy. The report by the ICMM states that company members have recognized the need for an urgent global response to the threat of climate change across all areas of society and the economy and they are committed to being part of the solution. These members have committed to mitigating CO_2 emissions at site level and across the supply chain, building resilience to adequately respond to climate related risks and continuing to contribute to the sustainable production of commodities essential to the energy and mobility transitions. This step change has also seen associated calls for companies to disclose climate-related risks and opportunities (ICMM, 2019).

2.5.1. The ISO 50001

The ISO 50001 which is the international standard for energy management systems was created by the ISO to help organizations perpetually reduce their energy use. The standard is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to

integrate energy management into their overall efforts to improve quality and environmental management.

ISO 50001:2018 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy,
- Fix targets and objectives to meet the policy,
- Use data to better understand and make decisions about energy use,
- Measure the results,
- Review how well the policy works, and
- Continually improve energy management.

Like other ISO management system standards, certification to ISO 50001 is possible but not obligatory. Some organizations decide to implement the standard solely for the benefits it provides while others decide to get certified to show external parties, they have implemented an energy management system (ISO, 2019).

With these commitments made, most mining companies across the globe have embarked on several green projects including, solar and wind power, fuel and power consumption reduction initiatives, forestation projects, energy efficient processing (comminution) and so on. They make efforts to track, improve, verify and monitor the use of energy to reduce their carbon footprint. This is reported as part of their sustainability goals on quarterly, midyear or yearly basis.

2.5.2. The Paris Agreement

The Paris Agreement is a milestone environmental pact that was signed and adopted by nearly every nation in 2015 to address climate change and its negative impacts. The deal aims to

substantially reduce global greenhouse gas emissions to limit the global temperature increase in this century to 2 degrees Celsius above preindustrial levels, while pursuing means to limit the increase to 1.5 degrees Celsius. All major emitting countries made the commitment to cut their climate-altering pollution and to strengthen those commitments over time (UNFCCC, 2015).

2.5.3. The UN's SDGs

Adopted by 193 heads of state and governments at a special UN Sustainable Development Summit in September 2015 the SDGs are a set of 17 individual goals and 169 separate targets that seek to address a wide variety of development issues (ICMM, 2019). The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice. The 17 Goals are all interconnected, and in order to leave no one behind, it is important that we achieve them all by 2030 (UN, 2019).

Figure 2: Sustainable Development Goals (ICMM, 2019)

2.5.4. ICMM on Energy Performance and Carbon Management

Mining is a significant emitter of greenhouse gasses and the ICMM has encouraged companies to work towards mitigating climate change through the adoption of GHG reduction and energy performance policies. While climate change is a global concern and does not respect national borders, the greenhouse gas emissions that are primarily responsible for this change continue to rise. The ICMM recognizes this problem and states that "Global emissions of carbon have increased by almost 50 per cent since 1990 and grew more quickly between 2000 and 2010 than in each of the three previous decades. Climate change can disrupt national economies and affect lives, with the poorest and most vulnerable people being affected the most" (ICMM, 2020). They further require all ICMM members to implement best-practice framework for sustainable development in the mining and metals industry as shown in Figure 3. The ICMM's formal position statement shown below, commits their member companies to "being part of the solution." (ICMM, 2020).

> When the UN's Sustainable Development Goals (SDGs) officially came into force in January 2016, the nations of the world committed to mobilise efforts to end poverty, fight inequalities and tackle climate change. Business has a significant part to play, alongside governments and civil society, in creating pathways for a greener, safer and sustainable future for us all. Metals and minerals are essential to almost all aspects of everyday life; they enable farming, healthcare, communications, construction, transport and energy and water supply. And they will arguably become more important as they help to deliver the infrastructure required for a low-carbon future. This is one of a series of case studies gathered from our members to highlight how companies are working to enhance their

contribution to society and help industry to manage potential adverse impacts their activities may have on the realisation of some of the SDGs. (ICMM, 2020)

Figure 3: ICMM's 10 Principles for Sustainable Development in Mining (ICMM, 2020)

The UN's SDG13 calls for rapid action to decarbonize the global economy in line with the 2015 Paris Agreement on climate change which calls on governments to limit global warming to well below 2 degrees Celsius with an ambition to keep it below 1.5 degrees Celsius to avert the worst effects of climate change. Mining companies can contribute to addressing climate change by reducing their carbon footprint and by engaging in dialogue with stakeholders to enhance adaptive capacities and integrate climate change measures into policies and strategies. Coal-fired power generation is a major emitter of carbon dioxide and is a focus of international attention in tackling climate change. Large-scale commercially viable technological solutions such as carbon capture and storage will be needed if thermal coal is to have a significant role in the low-carbon future that governments agreed to in Paris. Mining also has a role in adapting to climate change by ensuring its surrounding communities (and its own operations) are resilient to the physical impacts of more extreme weather events (ICMM, 2019).

3. Research Methodology

The goal of this research was to better understand the energy management culture of selected mining companies, including their best practices, the motivation behind it, the technologies employed and its effects to the reduction of carbon emissions in the mining industry. A review was conducted of sustainability reports and financial reports for 20 international companies from 2017 to 2019, the US Securities and Exchange Commission's 10-K forms and press releases. The research method employed was both quantitative and qualitative. Energy management activities and targets were measured and ranked against the UN's SDGs, with the aim of determining how efficient the mining companies have performed against these goals. Identified patterns will reveal decisions that are currently being made, reasons for such decisions and any room for improvement in the energy management activities of these mining companies in order to achieve these goals.

It is imperative to this research study that the selected companies are a representation of the global community, given that climate change is of global concern. Hence companies with presence in almost all continents, except Antarctica, were selected for this study. The diversity of minerals mined, and methods being used by these companies also comes as a vital component of this study since the energy demand depends heavily on the types of operations being run. These companies are active members of the ICMM and committed to sustainable mining as well as transparent reporting of their activities.

Data gathered for this study were the types of renewable energy technologies used by these companies, alongside their carbon emission rates, which will be analyzed using simple data analytic tools and graphs. Policies and activities of the mining companies provided in their

reports and made accessible on their websites were graded on a scale of 0 to 3, using the SDG7 and SDG13 as a performance metric, with 0 being unachieved goals and 3 being fully achieved goals. Finally, this research concluded with a review of the of mining in the materialization of renewable technology

3.1. Sustainability Reporting

Boston College's Center for Corporate Citizenship defines sustainability reporting as "the disclosure and communication of environmental, social, and governance (ESG) goals, as well as a company's progress towards them" (Boston College, 2019). Sustainability reporting enables organizations to consider their impacts of wide range of sustainability issues, enabling them to be more transparent about the risks and opportunities they face. These reports are released by companies and organizations of all types, sizes and sectors, from every corner of the world (GRI, 2019).The format and material included in sustainability reports can vary by company and jurisdiction, however GRI (2019) identifies the following references for reporting guidelines:

- GRI (GRI's Sustainability Reporting Standards)
- The Organization for Economic Co-operation and Development (OECD Guidelines for Multinational Enterprises)
- The United Nations Global Compact (the Communication on Progress)
- The International Organization for Standardization (ISO 26000, International Standard for Social Responsibility)

3.1.1. Sustainability Reporting in the Mining Sector

Sustainability reporting (SR) has become a well-entrenched practice in the mining sector. Failure to adequately live up to societal expectations is now considered a significant threat to the viability of the industry. There is general agreement that broad endorsement of standards for nonfinancial disclosure supports mining companies to improve their image, while conflicts persist (Böhling, Murguía, & Godfrid, 2017). Causing significant damage to the natural environment and threats to human wellbeing, mining is perhaps the least obvious case for sustainability. Yet as Böhling, Murguía and Godfrid stated, "due to increased societal pressure, mining companies have been actively innovating in the field of CSR [Corporate Social Responsibility] to address the various sustainability challenges of their operations more proactively" (Böhling, Murguía, & Godfrid, 2017).

3.1.2. Mining and Sustainability Development Goals (SDGs)

Unlike many other sectors there is no primary points of connection between mining and one single SDG. Instead, operations have the extraordinary potential to contribute to several different goals at any one time. This is due to the multifaceted impacts (both positive and negative) that companies and operations can have on communities, ecosystems and economies. As a result, when these impacts are coupled with the fundamental importance of metals and minerals to modern life, the influence of mining on all of the SDGs becomes apparent (ICMM, 2019).

The mining industry impacts positively and negatively across the SDGs, and the nature and size of the impact depends on mining practices. Mining can foster economic development by providing opportunities for decent employment, manufacturing, increased fiscal revenues, and infrastructure linkages. Many of the minerals produced by mining are also essential for many

technologies (notably electronics), infrastructure creation, energy and agriculture production. Historically, however, mining has contributed to many of the challenges that the SDGs are trying to address – environmental degradation, displacement of populations, worsening economic and social inequality, armed conflicts, gender-based violence, corruption, increased risk for many health problems, and the violation of human rights (Kumar, 2017). Because mining activities typically cause impacts on land, water, the climate and the flora, fauna and people that depend on these resources, one area most paid attention to by mining companies under the SDGs, is environmental sustainability.

Under environmental sustainability, SDG6 (Clean Water and Sanitation), SDG15 (Life on Land), SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action) are all addressed by incorporating them into the practices and operations of the mining companies. For the purpose of this research, the focus will be on the SDG 7 (Affordable and Clean Energy) and SDG13 (Climate Action). As shown in the diagrams below, these goals have been broken down into sub goals (colored boundaries) detailed to the mining industry for companies to achieve the major goals. The sub goals are made up of policies, recommendations and best practices that should be incorporated into the business models of the mining companies.

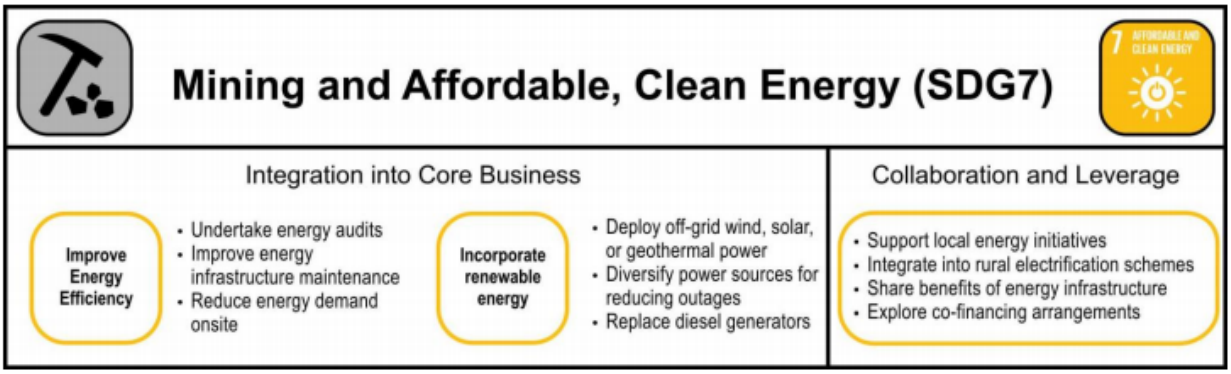

Figure 4: SDG7 Mining and Affordable, Clean Energy (UNDP, 2016)

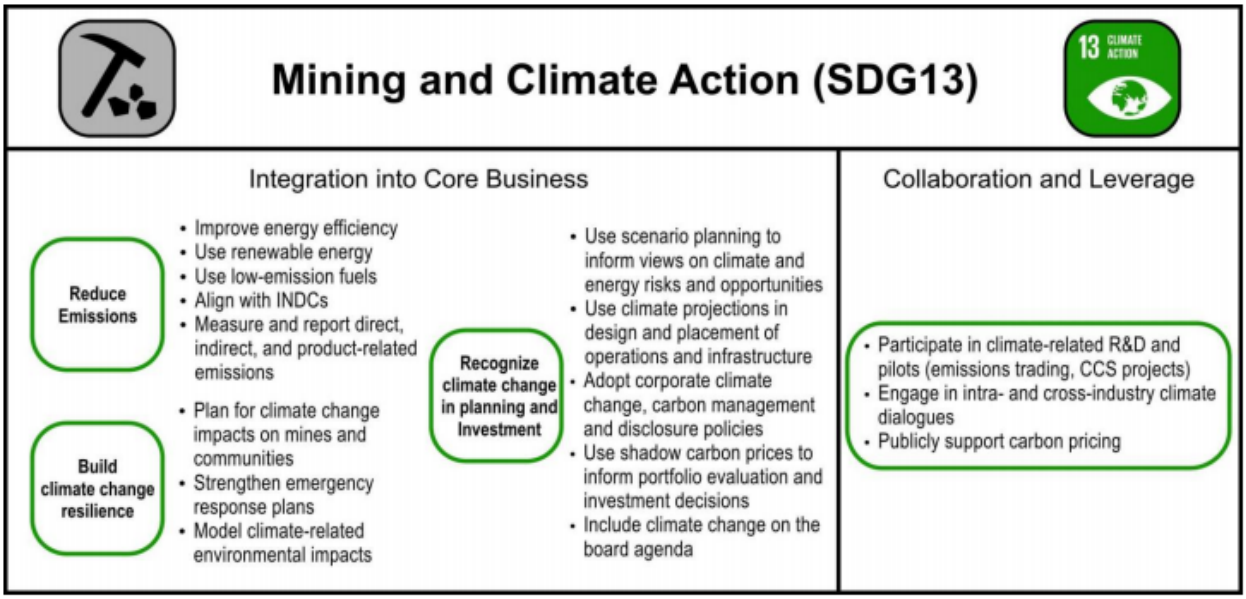

Figure 5: SDG13 Mining and Climate Action (UNDP, 2016)

3.2. Green Energy and Renewable Technologies

Green power is a subset of renewable energy and represents those renewable energy resources and technologies that provide the highest environmental benefit. These include resources that rely on fuel sources that restore themselves over short periods of time and do not diminish. Such fuel sources include the sun, wind, moving water, organic plant and waste material (eligible biomass), and the earth's heat (geothermal). Other renewable energy sources, such as hydroelectric energy, can have small impacts on the environment (Environmental Protection Agency, 2019).

All energy sources have some impact on our environment. Fossil fuels, coal, oil, and natural gas, do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions. However, renewable sources such as wind, solar, geothermal, biomass, and hydropower also have environmental impacts, some of which are

significant. The exact type and intensity of environmental impacts varies depending on the specific technology used, the geographic location, and several other factors.

The following sections examine the green energy and renewable technologies and processes whose adoption by mining companies has been examined in order to help address the first research objective from Section 1.1 – Establishing the mining companies' energy management culture, which is the systems, policies and best practices they have put in place to ensure a reduction in their GHG emissions.

3.2.1. Mining and Renewable Energy Technologies

Research conducted shows that there is a developing trend where mining and other industrial companies are gradually moving from conventional power sources to more renewable and green energy because of their benefits as illustrated in Figure 6 below. More companies are finding renewable energy sources to be more economical and environmentally friendly as compared to the conventional sources.

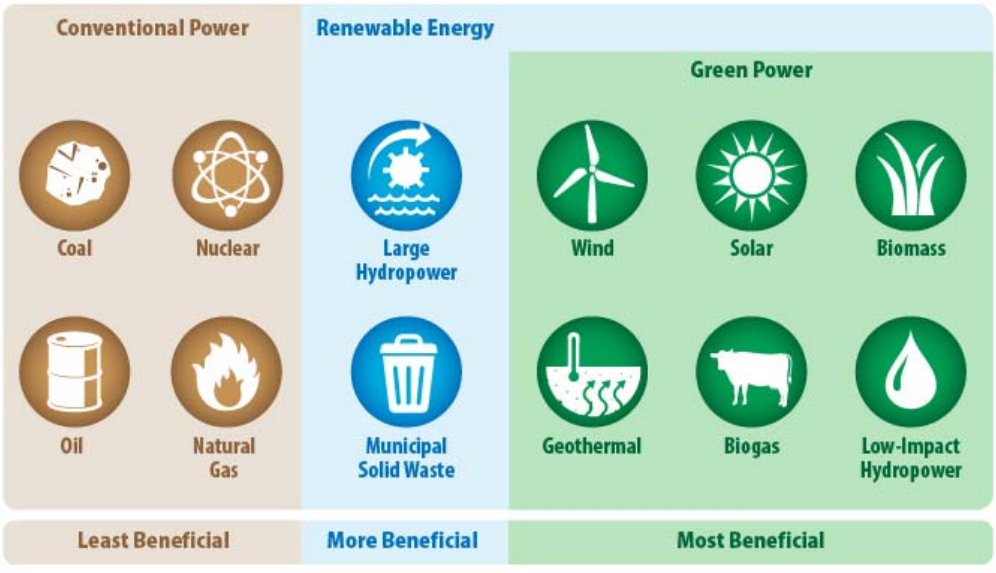

Figure 6: Various Electricity Supplies (Environmental Protection Agency, 2019)

The mining industry, known to be one of the notoriously energy intensive industries predominantly powered by traditional fossil fuels, has in recent times experienced a notable willingness to incorporate renewables into the mining process and operations, offsetting some of the carbon costs of mining. In the past decade, mining companies have embarked on several renewable projects for various reasons which will be discussed later in this research. This research suggests that an expected significant growth of renewables in mining operations will be the trend for mining companies going forward.

Many renewable energy sources have been adapted by various mining companies according to their needs and carbon saving goals. The most common renewable energy sources currently used by mining companies are; solar power, wind power, biomass, biodiesel and biogas, geothermal energy and hydropower. Apart from using these natural and eco-friendly power sources, mining companies are using other means to reduce their energy usages and carbon footprint or to offset their carbon emissions. This section of the research will expand on these CO_2 emission control options and a comparative analysis of their individual and combined effectiveness. This will be explained in the next chapter.

Various renewable energy technologies have been developed in the last couple of decades and with the pressing need to protect our environment by reducing our carbon emissions to stop global warming and in effect, climate change. A number of these technologies have been in use by mining companies for the past decade while new innovations are currently emerging and being trialed or implemented. This section discusses the common renewable energy technologies currently being used and a few of the new innovations.

Solar Energy

The most common renewable energy source in use is solar energy and some mines are transitioning to primary solar energy. Solar energy uses radiation from the sun to create concentrated solar power (CSP) or photovoltaic power (PV), which happens to be one of the most sustainable power sources. Aside its low cost, solar energy is known to be one of the renewable power sources with very low GHG emissions, hence serving its purpose of environmental friendliness (Anglo American, 2019).

Figure 7: Solar panels installed on a mine site (Anglo American, 2019)

Wind Energy

Wind energy is one of the most popular ways to generate electricity by converting kinetic energy from wind into a mechanical power source. In fact, according to the World Wind Energy Association wind is so popular that installed wind turbines reached 597 Gigawatts (GW) in 2018 (WWEA, 2019). Harnessing energy from the wind to turn two or three propeller-like blades around a rotor, wind turbines are built to generate a great amount of electricity for industrial use.

Figure 8: A constructed wind farm to power a mine (Goldwind Australia, 2016)

Biomass Energy

Biomass energy refers to energy that is produced from organic materials to be used as a source of energy for heat and/or electric power or liquid fuels. These organic materials include agricultural and forestry residues, the organic components of municipal solid wastes and water treatment processes, and terrestrial and aquatic crops, such as fast-growing trees, switch grass, or algae, grown solely for energy purposes (VA DMME, 2015). Biomass energy is used in place of fossil fuels to power steam turbines and generate electricity. Biomass can also potentially be converted to methane through anaerobic digestion, or to liquid fuels, also called biofuels, such as ethanol or biodiesel for transportation (VA DMME, 2015). Remote mining projects in agricultural areas have a great potential to generate baseloads of electricity from biomass plants powered by farm residues.

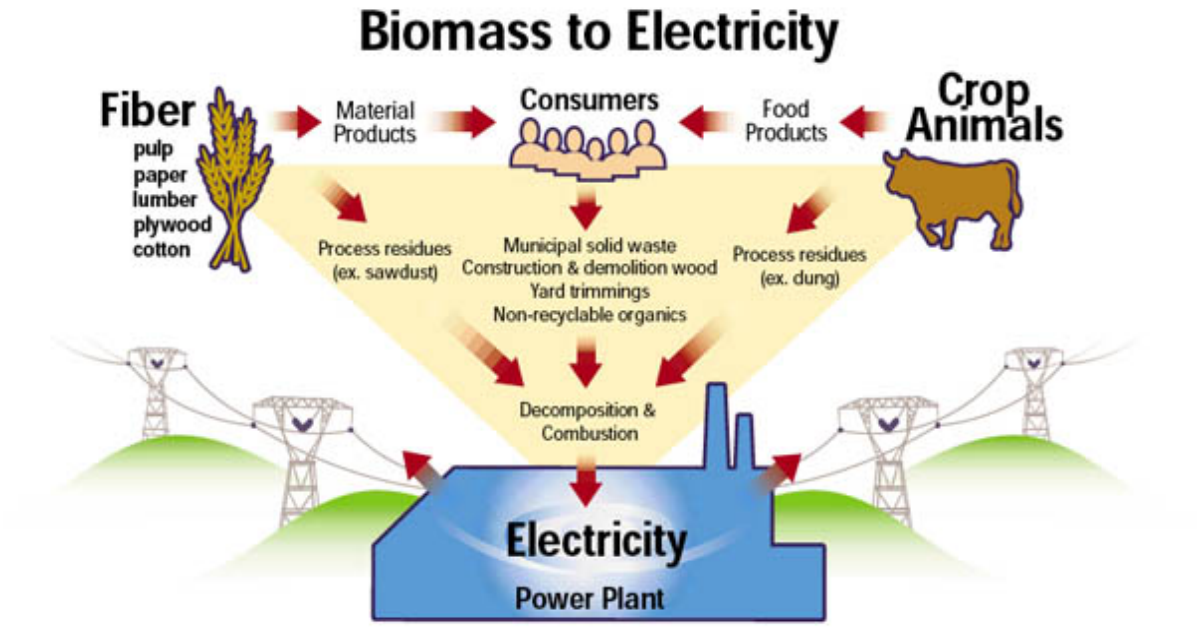

Figure 9: Illustration of power generation from biomass (Green Blogger, 2014)

Geothermal Energy

Geothermal energy is defined as energy stored inside the earth's crust in the form of high temperature. Rock near the magma gets heated (potentially to a molten state) and interacts with rain water which percolates through major faults and fractures results in the formation of a dilute brine (Bakane, 2013). Electrical energy can be generated from hot fluids found in geothermal reservoirs deep within the Earth's crust. Drilled wells are constructed to tap into these reservoirs and provide a pathway to the surface, at which point the steam portion of the produced fluid is harvested and passed on to steam turbines, thereby converting part of the steam's thermal energy content to electricity. The amount of thermal energy that can be converted to electricity is largely a function of the quality and quantity of the produced fluid (Patsa, 2018). The use of geothermal energy has gained considerable grounds outside of the mining industry, yet not as significant within the mining sector.

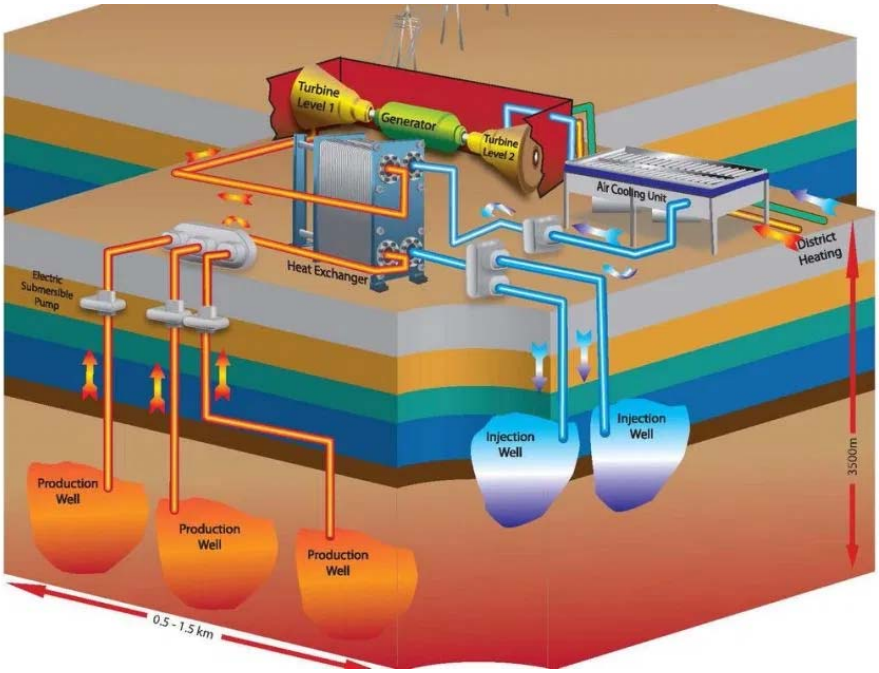

Figure 10: Illustration of a geothermal power plant (White-Crummey, 2018)

Hydropower

Hydropower is used to generate electricity which is termed as hydroelectricity. Hydropower plants harness water's energy and use simple mechanics to convert that energy into electricity. Hydropower plants are based on a rather simple concept -- water flowing through a dam turns a turbine, which turns a generator (Bonsor, 2001). Hydroelectric power is one of the cleanest sources of renewable energy powered by an adequate and readily available water source. Hydropower plants have proven to be an economical source of power with lesser environmental hazards such as air emissions or waste byproducts, as compared to other energy sources such as fossil fuels. The water is not consumed during electrical production but can be reused for other purposes. According to the National Renewable Energy Laboratory, world hydroelectric power plants have a combined capacity of 675,000 megawatts that produces over 2.3 trillion kilowatt-hours of electricity each year; supplying 24 percent of the world's electricity to more than 1 billion customers. (Atkins, 2010).

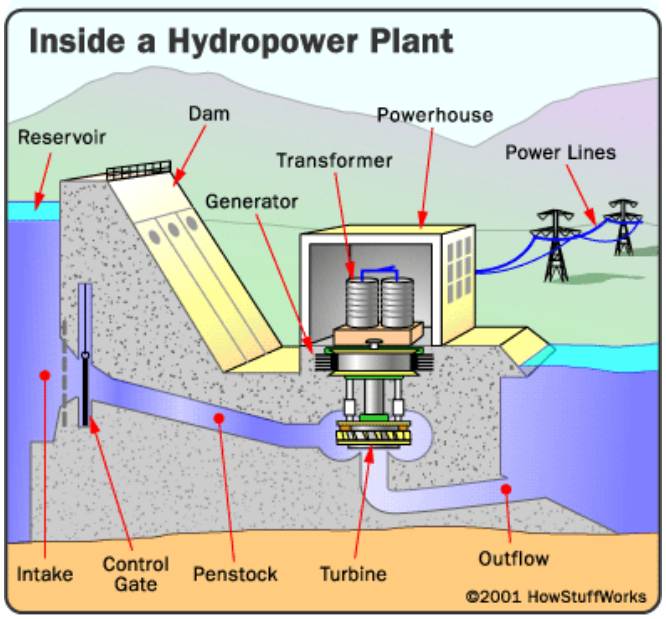

Figure 11: Illustration of a Hydropower Plant (Bonsor, 2001)

3.2.2. Fuel Switch Technologies

Another effective way of reducing greenhouse emissions is by fuel switching. Fuel switching is the substitution of one energy source for another in order to meet requirements for heat, power, and/or electrical generation (Encyclopedia.com, 2019). A number of mining companies have adopted fuel switching to reduce their carbon footprints as one of many reasons. They are either making substitutes or modification to equipment and plants in order to achieve this goal. The following section describes the most common methods of fuel switching.

Electrification

The goal of running an entire mine on electricity is gradually gaining the attention of some mining companies. A recent survey commissioned by EY and conducted by the University of Queensland found that miners and original equipment manufacturers (OEMs) see the electrification of mines offering much more than just lower carbon emissions and improved worker benefits. For example, Newmont Goldcorp has partnered with Sandvik and MacLean Engineering to develop the "world's first all-electric underground mine. This partnership is expected to expand benefits to include further innovation, cost reduction and even competitive advantage. *International Mining* also reports that Nouveau Monde Graphite is using a similar model to develop an all-electric open-pit graphite mine in Quebec, Canada (Gleeson, 2019).

As mining companies work to reduce emissions, demands to reduce carbon emissions are growing even louder and expecting greater reductions. The study recognizes that swapping diesel for electricity is a step forward, but only if that electricity comes from renewable sources. In the past, clean energy was not cost-effective when compared to fossil fuels, however costs have fallen and put renewables on track to outpace all other sources of energy and account for 60% of all capacity additions by 2040 (Mitchell, 2019).

The survey respondents also indicated that the workplace health benefits of replacing the diesel-powered engines in underground mines with electrified equipment is a significant driver for electrification. Switching from diesel to electric not only makes economic sense by reducing operating costs and ventilation requirements, but also enables onsite health and safety improvements and helps mines strengthen their social license to operate (Mitchell, 2019).

Diesel-LNG Combo

In the event of hiking fuel prices and the bid to reduce carbon emissions generated by diesel engines, there is a demand for equipment manufactures to come up with retrofits that convert diesel powered equipment to operate using liquified natural gas (LNG) or other cleaner energy sources. For example, Caterpillar has begun offering its dynamic gas blending retrofit kit for the Cat® 785C Mining Truck. A press release from Caterpillar says that the "Cat Dynamic Gas Blending™ (DGB) technology allows engines to run on both diesel and liquefied natural gas (LNG). DGB lowers fuel cost while maintaining diesel power and transient performance" (CAT, 2017). Retrofit and new equipment designs will offer both economic and environmental benefits.

Biodiesel/Fuel Clean Up (Additives)

Oil from plants or animals, referred to as biodiesel, can be used as an alternative to or blended with petroleum diesel in diesel engines. These biofuels have gained popularity as the economy has transition to lower carbon energy sources. They are considered renewable energy sources and emit less carbon than equivalent fossil fuels (DeMates, 2013).

Another option in cleaner fuel technology is the use of fuel additives that promise to save fuel and limit emissions by cleaning the fuel system and engine. Fuel additives have a controversial history and are considered by many to not have significant benefit. (Haner, 2004).

3.2.3. Carbon Emission Offset

Carbon Emission Offsets, or simply Carbon Offsets are a unit of equivalent carbon dioxide (CO_2eq) that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere. In some jurisdictions, these credits are an alternative that companies can utilize to meet their GHG targets in a cap-and-trade system. The goal of buying offsets is to reduce the cost of meeting the GHG reduction targets of a cap-and-trade program. In some instances, it may be more economical to reduce GHG emissions operations in areas that are not capped than it is to reduce emissions at operations that are capped. Organizations can also purchase Carbon Offsets to help meet voluntary commitments to reduce their GHG emissions (Goodward & Kelly, 2010).

While many carbon offset projects are based in concerns for the climate, Duncan Clark (2011), the author of *The Rough Guide to Green Living,* suggests that some projects are based more on the concept of scheming the system:

> Carbon offset schemes allow individuals and companies to invest in environmental projects around the world in order to balance out their own carbon footprints. The projects are usually based in developing countries and most commonly are designed to reduce future emissions. This might involve rolling out clean energy technologies or purchasing and ripping up carbon credits from an emissions trading scheme. Other schemes work by soaking up CO_2 directly from the air through the planting of trees.

As the ICMM report suggests, many mining companies are truly trying to learn to adapt to the modern expectations of our carbon-conscious world and play their role in combating climate change. As part of a series on the Future of Mining 2018, Raconteur documents that some mining companies are offsetting their carbon emissions by buying, protecting or planting forests and a few companies are even developing new technologies to improve their carbon

footprint. For example, De Beers driving toward carbon neutral mines in South Africa and Canada by 2021, primarily by refining carbon storage techniques If successful, De Beers will not only have a method for reducing their carbon footprint but it will also have a market for its proprietary carbon storage technology (Gagan, 2018).

Biological Carbon Sequestration (BCS)

The United States Department of Agriculture (2016) defines carbon sequestration as "the process by which atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliage, and roots) and soils." By investing in biomass through reforestation or agriculture, companies can offset their sources of carbon dioxide. Specifically, sustainable forestry practices increase a forest's ability to sequester atmospheric carbon and enhance other properties of the ecosystem, such as improved soil and water quality (USDA, 2016). Figure 12 shows the typical carbon sequestration process.

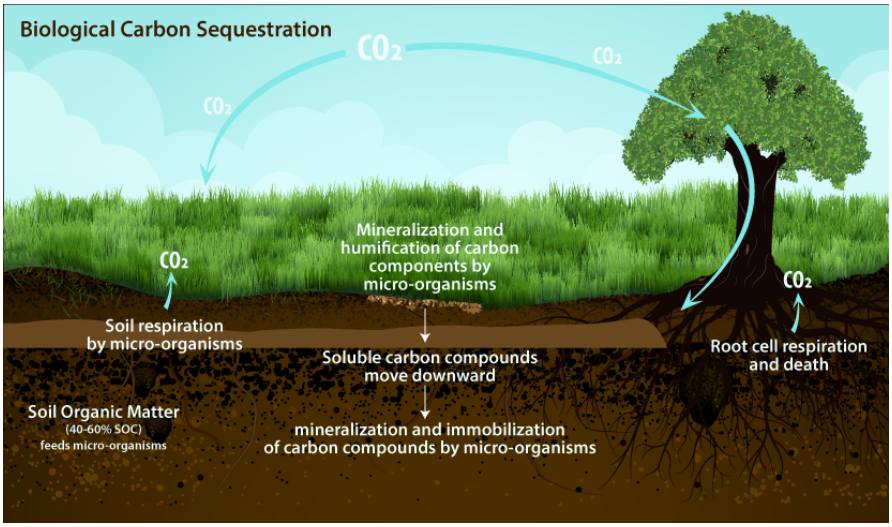

Figure 12: Biological Carbon Sequestration Process (Calrecycle, 2019)

Carbon Capture and Sequestration (CCS)

While biological sequestration is a natural process, carbon dioxide can also be captured and sequestered directly from power plants and large industrial sites. The EPA views Carbon

Capture and Sequestration (CCS) as a three-step process that includes:

- Capture of CO_2 from power plants or industrial processes.
- Transport of the captured and compressed CO_2 (usually in pipelines).
- Underground injection and geologic sequestration (also referred to as storage) of the CO_2 into deep underground rock formations. These formations are often a mile or more beneath the surface and consist of porous rock that holds the CO_2. Overlying these formations are impermeable, non-porous layers of rock that trap the CO_2 and prevent it from migrating upward (EPA, 2017).

Figure 13 illustrates the general CCS process and shows a typical depth at which CO_2 would be injected, either in amenable geologic formation or in deep water. A difficult component to CCS is that sequestration sites must undergo significant study and site characterization to ensure they can safely and securely store CO_2. Once the carbon dioxide has been transported to the site, the compressed CO_2 is injected deep underground into porous rock formations. To be suitable, these porous formations must be under one or more layers of cap rock to trap the CO_2. Operational sites are monitored to ensure that the CO_2 remains underground (EPA, 2017).

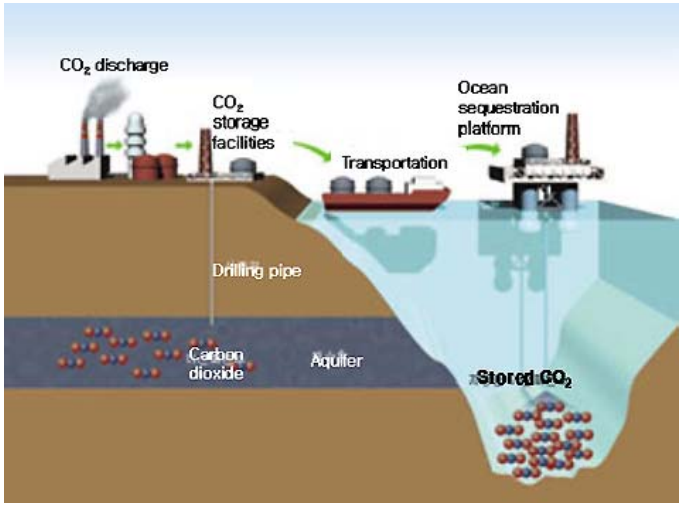

Figure 13: Carbon Dioxide Capture and Sequestration Process (Xueli, 2012)

3.2.4. Control of Usage

One other common way in which mining companies are working toward achieving a low-carbon status is to control their energy usage. Reducing the use of electricity through changes in processes and how efficiently energy is used around the mine. Some of the methods adopted by most mining companies are discussed in the following sections.

Energy Management Tips

Some mining companies have adapted energy management tips that are continuously being rolled out to ensure a reduction in the consumption of electricity or fuel on the mine and in effect reducing the emissions of CO_2. Below are a few of the management tips adopted:

- ***Using energy saving appliances***: The mining industry has gradually moved towards the idea of using only appliances with good energy ratings. Sodium and traditional incandescent bulbs have been replaced with Light-emitting diode (LED) energy saving bulbs, air conditioners are gradually being replaced with inverted type air conditioners known to operate in a more energy efficient way. All other appliances mostly used in the offices and lunchrooms have high energy ratings. Preferably 5-star ratings.

Figure 14: Energy Saving Flier (Carter, 2014)

- ***Encouraging an energy saving culture****:* Some mining companies periodically run energy saving campaigns where every mine worker is encouraged to pitch in to ensure responsible consumption of energy. Examples of these practices are as below:
  - Switching off lights and air conditioners, unplug appliances such as printers, coffee pots and fans overnight and when not in use.
  - Shut down your computer at night and put it on sleep mode during the day when not in use. Use low power mode.
  - Adjust break room refrigerator to optimum setting
  - Reduce energy for heating water by using eco showerheads, lowering geyser temperature and using as much cold water as possible.
  - Carpool when necessary to save fuel consumption
  - Adhere to periodic vehicle maintenance to ensure vehicles are in good condition and to avoid high fuel burn rates.
  - Eco driving skills is highly advised.
  - Properly graded roads are much needed policy.
  - Operational performance; availability and utilization of mine fleet

Utility Changes for Energy Savings

In most cases, the solution to energy management is making changes to the system of operation and processes. There are many sections of the mining process that require high power consumption and changes made in these sections could reap huge energy savings. Some of the changes that mining companies have made to their processes and operations to save energy are as below:

- Installing motion sensors to control lights, air conditioners and sinks according to usage.
- Installing Variable Speed Drives (VSDs)
- Installing Capacitor banks to correct power factor lags
- Replacing motors with more efficient and lesser rating motors
- Variable remuneration program; rewarding employees based on KPIs associate with the continuous improvement of specific energy consumption indicators (fuel and electricity), which result in the improvement of GHG emissions.

3.3. Major Global Mining Companies Reviewed

Mining is recognized as having global importance both as a source of raw materials but also as a significant component to global economies and source of employment. Figure 15 shows the global footprint of commonly mined minerals.

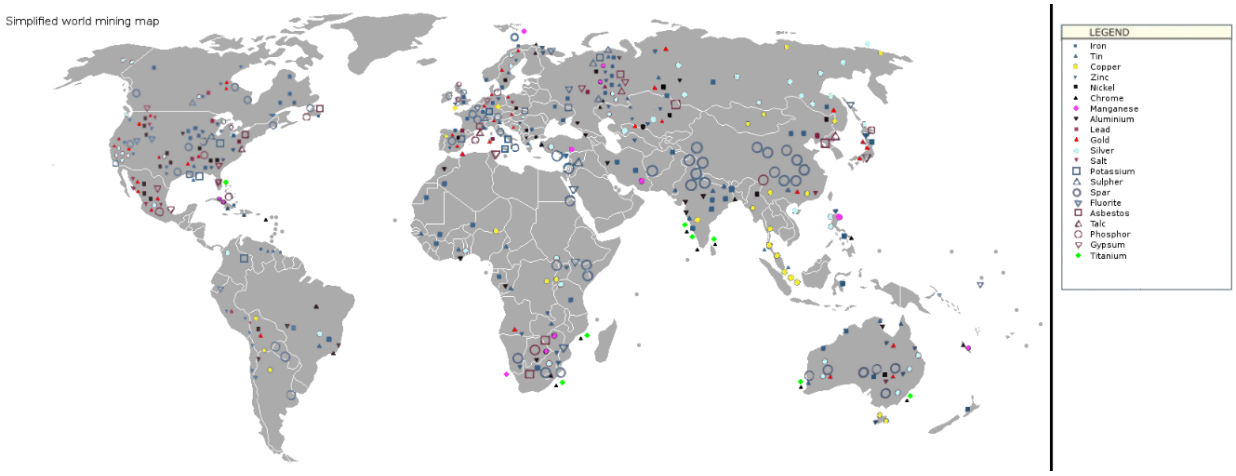

Figure 15: World Mining Map (Wikimedia Commons, 2009)

There are many mining companies all over the world, extracting these minerals at economic value. Some of the mining companies have a strong presence in almost all the continents, excluding Antarctica. These companies either extract one commodity or a variety of commodities and are listed on various stock markets or privately held. For the purpose of this research, twenty (20) leading mining companies, with global presences have been selected for study. Refer to Table II and Figure 16 for details of the selected corporations.

Figure 16: Global site locations of 20 selected mining companies

Table II. List of selected mining companies highlighting their countries of presence and minerals mined

Mining Company	Number of Sites	Countries of presence	Minerals Mined
Rio Tinto	*35*	*Australia, Canada, Iceland, Madagascar, Mongolia, New Zealand, South Africa, USA, Guinea, Brazil, Mozambique, Chile and Serbia,*	*Iron Ore, Aluminum, Copper, Borates, Diamonds, Salt, Titanium*
Barrick Gold	*24*	*Canada, USA, Argentina, Australia, Chile, Cote d'ivore, Democratic Republic of Congo, Dominican Republic, Mali, Papua New Guinea, Peru, Saudi Arabia, Senegal and Zambia*	*Gold*
Newmont Goldcorp	*15*	*Australia, Ghana, USA, Mexico, Suriname, Dominican Republic, Peru, Argentina*	*Gold*
Gold Fields	*8*	*Ghana, South Africa, Peru, Australia, Chile, USA*	*Gold*
Vale	*30*	*Brazil, China, Oman, Indonesia, Caledonia, Malaysia, Australia, Japan, Canada, Mozambique, Philippines, Taiwan, UK, Malawi, Argentina*	*Iron ore and pellets, Nickel, Coal, Copper, Manganese and ferro-alloys*
Freeport McMoran	*12*	*USA, Indonesia, Peru, Chile*	*Copper, Molybdenum, Gold*
Newcrest Mining Limited	*6*	*Australia, Indonesia, Canada, Papua New Guinea*	*Gold, Copper*
Glencore	*	*DR Congo, Zambia, Philippines, Australia, Canada, Chile, Peru, Norway, New Caledonia, Kazakhstan, Germany, Italy, Spain, UK, Argentina, Bolivia, South Africa*	*Copper, Cobalt, Zinc, lead, Nickel, Ferroalloys, Aluminum, Iron ore*
Kinross Gold	*8*	*Russia, USA, Ghana, Brazil, Mauritania, Chile,*	*Gold*
Teck	*19*	*Canada, Peru, Chile, USA*	*Copper, Zinc, Steelmaking Coal*
BHP	*11*	*Australia, Chile, USA, Canada, Peru, Algeria, Colombia, Brazil*	*Copper, Iron Ore, Coal, Nickel, Potash, Zinc*
Anglogold Ashanti	*14*	*Ghana, Guinea, Mali, DR Congo, Tanzania, South Africa, Australia, Argentina, Brazil*	*Gold*
Lundin Mining	*5*	*Chile, Portugal, Sweden, USA*	*Copper, Zinc, Lead, Nickel*
Anglo American	*58*	*Australia, Canada, Chile, Brazil, Namibia, South Africa, Botswana, Finland, Peru*	*Diamonds, Copper, Platinum, Coal, Iron Ore, Nickel, Manganese*
Sibanye Stillwater	*2*	*US, South Africa, Zimbabwe, Argentina*	*Gold, Uranium, Copper, Platinum, Palladium, Rhodium*
Hecla	*16*	*USA, Canada, Mexico*	*Gold, Silver*
Northern Star Resources	*6*	*Australia, USA*	*Gold*
Codelco	*9*	*Chile*	*Copper, Silver concentrates*
China Shenhua Energy	*	*China*	*Coal*
KGHM	*15*	*USA, Canada, Chile, Poland*	*Copper, Silver, Molybdenum, Rhenium, Precious metals, other products*

4. Data Analysis and Discussions

This chapter presents the data gathered, analysis and discussion of the findings. A quantitative survey approach was taken through the review of sustainability reports, 10-Ks, financial reports and news releases from 2016 to 2018, of the twenty (20) selected mining companies. The aim of the first survey was to determine the types of renewable technologies these companies have employed to reduce their heavy dependence on fossil fuels and to reduce their carbon emissions. The second survey employed both a quantitative and qualitative approach using the same resources, with the aim of establishing the companies' performance against the UN's SDG 7(Affordable Clean Energy) and 13 (Climate Action). Data was analyzed using Microsoft Excel with descriptive statistics in terms of percentages, a grading scale of 0 to 3 and simple tally. The research results are presented in the following sections.

4.1. First Data Collection, Presentation and Discussion

To address the second research objective – Establish their adaptation to the use of renewable and green energy technologies and the reasons or motivations behind their choices – the first data collection process involved painstakingly reviewing sustainability reports, 10-Ks, financial reports and news releases from 2016 to 2018, of the twenty (20) selected mining companies and documenting the renewable energy technologies and projects that these companies have going on. Future projects slated for 2019 and 2020 were included because it was assumed that these projects have been implemented. Table III below presents the gathered data by companies and types of renewables. In addition to renewables, the data gathered also highlights other clean energy and technologies that these companies are using.

Table III: Data Collection of Renewable Energy Type by Companies

	Renewable Energy											Other Clean Energy	
Company	Solar	Wind	Biomass	Biofuel	Geothermal	Hydropower	BCS	CCS	Thermoelectric	Other Tech	% Renewable	Nuclear	Natural Gas
Rio Tinto	★	★				★		★		AP™ Technology	71	★	★
Barrick Gold	★	★		★		★							★
Newmont Goldcorp	★						★	★					★
Gold Fields	★	★				★							★
Vale		★	★	★		★	★			Truckless system	25		★
Freeport McMoran	★	★				★					36	★	★
Newcrest Mining Limited	★				★	★							★
Glencore		★				★		★		Premus Technology			
Kinross Gold						★							
Teck	★	★				★							★
BHP							★	★		Mistibushi Light Electric Vehicles (LEV)		★	★
Anglogold Ashanti	★					★							★
Lundin Mining	★	★		★		★			★	IPPA	49		★
Anglo American	★		★					★	★	FutureSmart MiningTM technologies			
Sibanye Stillwater	★					★		★					
Hecla				★		★				Autonomous 24hr trucks			
Northern Star Resources	★												★
Codelco	★									Electric vehicles			
China Shenhua Energy		★				★				Ultra-low emission coal-fired power plant			
KGHM	★	★			★								★

★ - implemented project

★ - pipeline project

4.1.1. Renewable Energy Usage

Figure 17 shows the results of the renewable and clean energy survey of the 20 selected mining companies along with the median carbon emissions for each technology and the baseline emissions of coal power production. A significant portion of the emissions project in the mining industry focus on the adoption of renewable energy and the summary shown in Figure 19 indicates that 95% of mining companies are using some form of renewable technology and this is likely to expand as the costs of these technologies decrease. These results will be discussed further in the following section.

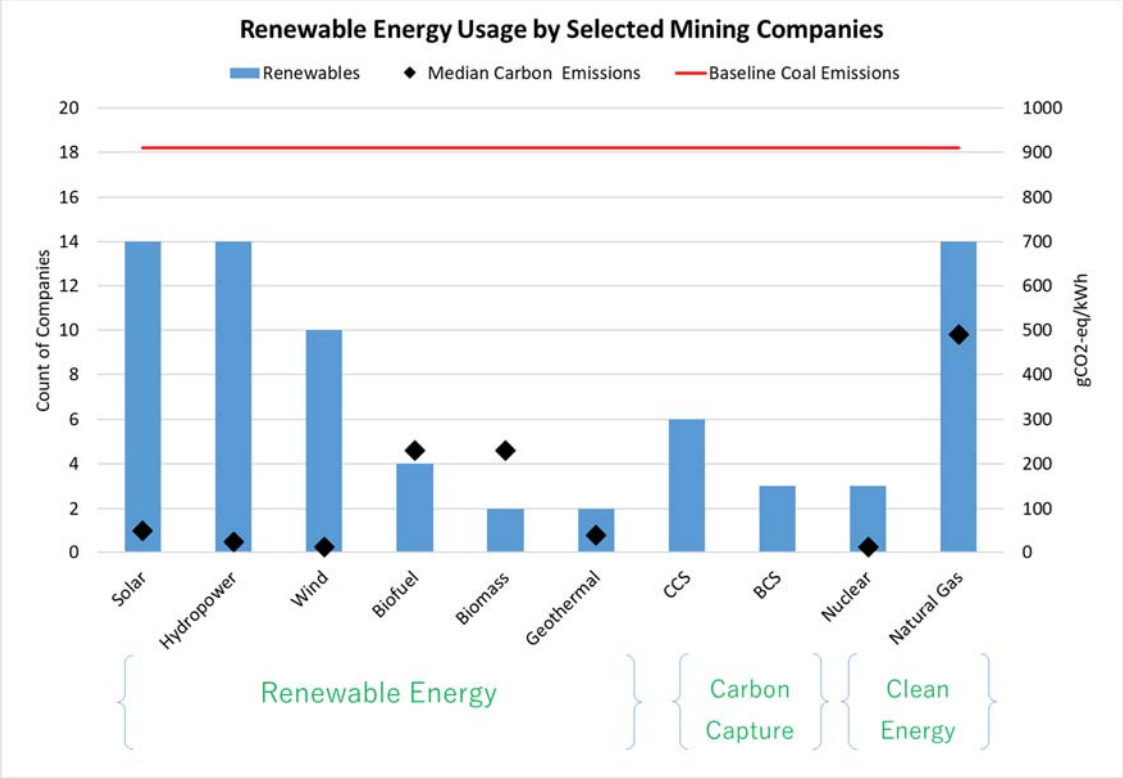

Figure 17: Graph of Renewable Energy Usage by Selected Mining Companies

The research study showed that most of the companies are more inclined to using Solar (19%), Wind (13%) and Hydropower (19%) as renewable energy sources. This corresponds with the Renewables 2019 Global Status Report shown in Figure 18 below, revealing that there has

been a steady growth in the use of solar energy globally in the last decade with hydropower and wind experiencing more of a bell-shaped growth but still more preferred to other renewable technologies. This is encouraging because as shown in the graph in Figure 17, these renewable energy sources have significantly less carbon emissions as compared to emissions from coal powered plants and other conventional power sources. It is also evident that most of these companies still rely heavily on natural gas (19%), which even though is a non-renewable energy source, it is considered a cleaner energy source. As shown in Figure 17, it has emissions that are approximately 50% less than coal and other fossil fuels but still higher than emissions from renewable technology.

The summary shown in Figure 19, shows that only 3% of the companies use geothermal energy. This can be explained by the fact that geothermal energy is harvested only in regions where there is a presence of hot fluids found in geothermal reservoirs deep within the Earth's crust. Hence, in spite of its low emission advantage, it is only a feasible source of energy if the company is located within such a region. Similarly, thermoelectric energy is also dependent on an available source of heat that can be harvested, hence does not come as a surprise that only 3% of the companies studied go in that direction.

Biofuel and Biomass usage were 5% and 3%, respectively, which is not surprising because they both have emissions higher than the other renewable energy sources. However, these energy sources are developed from readily available primary sources; living or recently dead organisms and any byproduct of those organisms, plant or animals and so one will think that they are more likely to be used.

Biological and Carbon Capture Sequestration, being the two carbon offset methods employed by some of these companies, have proven to be a very effective way of reducing the

presence of CO_2 in the atmosphere. However, it has been a challenge quantifying how much CO_2 is effectively captured with these processes. Research has indicated that carbon capture processes can range from 15% effectiveness up to 90% effective, depending on the specific circumstances. Even though it is difficult to quantify how much CO_2 emissions can be avoided with the carbon capture process, evidence of its effectiveness still presents the opportunity of using it alongside coal power plants as a solution to the problem of high CO_2 emissions.

Nuclear power, known to be one of the cleanest and cheapest form of large-scale energy-producing technology, only has 4% of the companies reviewed venturing into it. The study showed that this is due to the difficulties associated with the storage and disposal of radioactive waste.

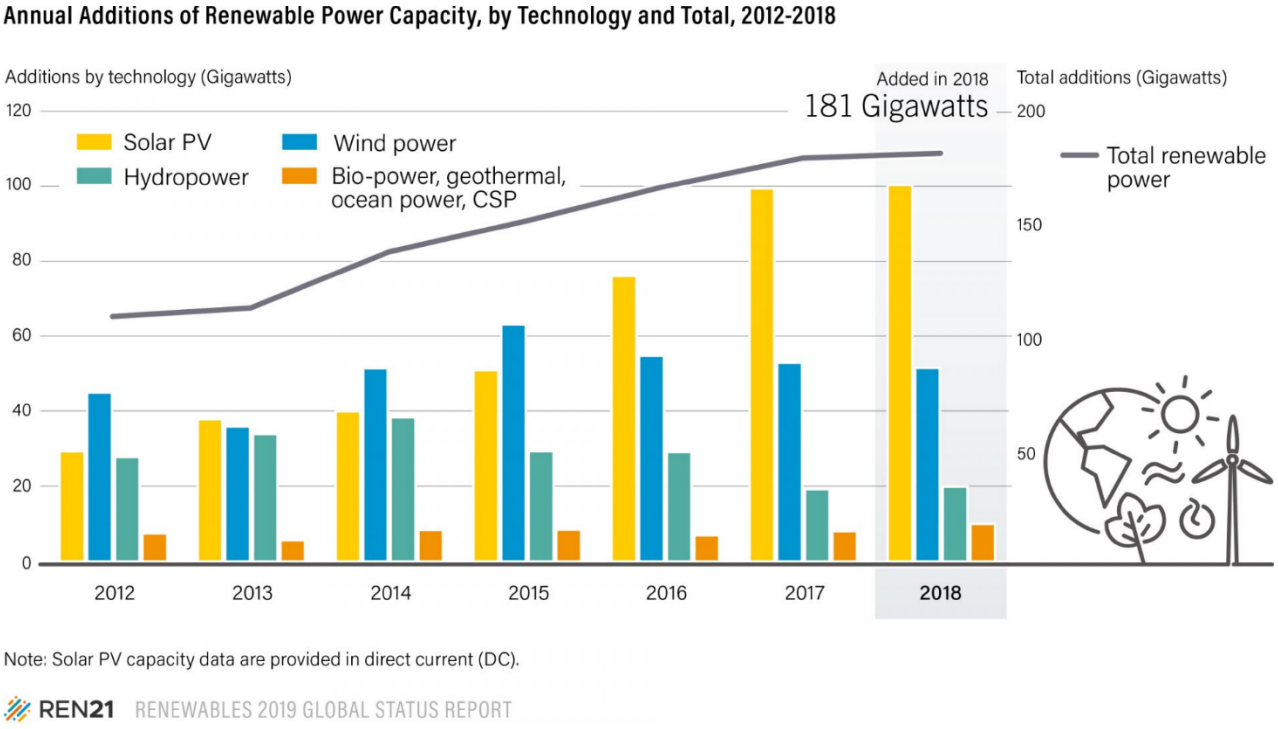

Figure 18: Renewables 2019 Global Status Report (REN21, 2019)

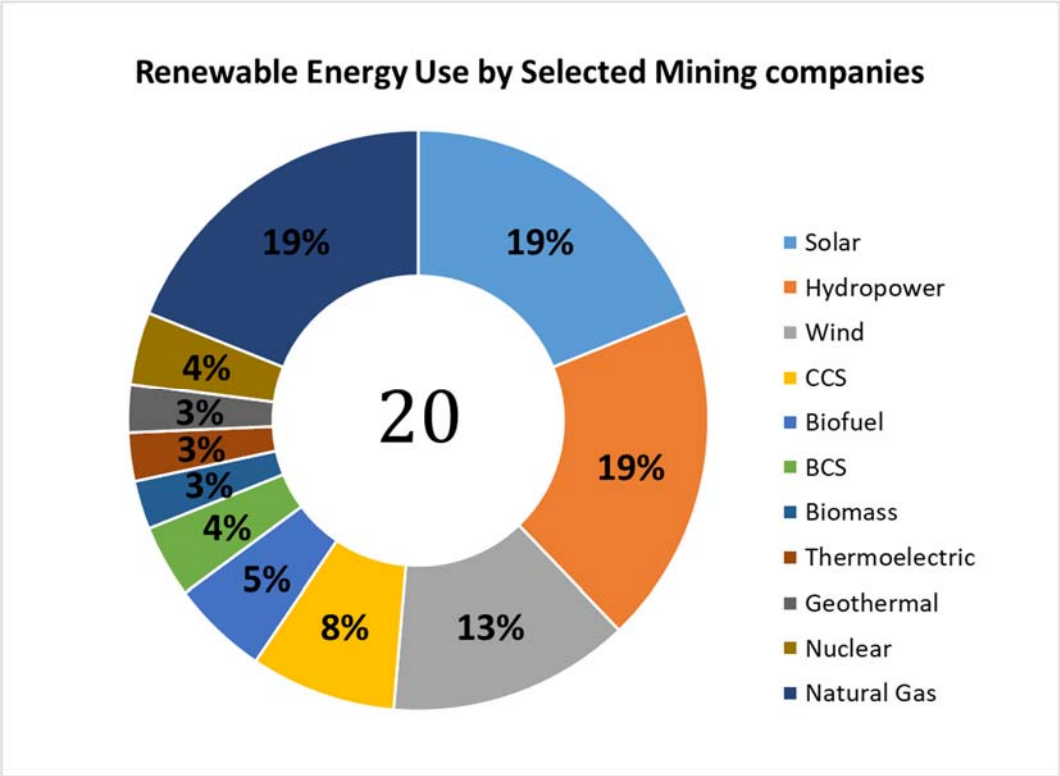

Figure 19: Pie Chart of Renewable Energy Use by Selected Mining Companies

4.1.1.1. Carbon Emissions from Renewables

Contrary to the notion that renewable energy is CO_2 emission free, current existing renewable energy technologies do emit some levels of CO_2 which on the upside is much less than emissions from conventional energy sources. Renewable technologies have a small amount of CO_2 emissions associated with their output resulting from their manufacturing and installation.

According to (Amponsah, Troldborg, Kington, Aalders, & Hough, 2014), although there are other environmental emissions (e.g., NOx and SO_2), the focus is usually on emissions of greenhouse gases (GHG), such as CO_2 and CH_4 from renewable energy sources addressed in numerous studies. The standard unit for measuring greenhouse gas emissions, Carbon dioxide equivalent (CO_2eq), is used to express the impact of each greenhouse gas in terms of the amount

of CO_2 that would create the same amount of warming. Using CO_2-equivalent, one can evaluate a total carbon footprint of the various greenhouse gas emissions. The values shown in this paper are based on the work by Amponsah, et al which estimated GHG emissions (CO_2eq/ kWh) according to Equation 1 for the full operational life cycle of each renewable energy source. This "cradle to grave" analysis included the full cycle from manufacturing of the plant to full operation and ultimate dismantling of the system. With low emissions processes, such as solar and wind energy systems, most of the emissions are associated with electricity and fuel consumption during manufacturing and is based on the region where it is typically produced to calculate GHG emissions (Amponsah, Troldborg, Kington, Aalders, & Hough, 2014).

Equation 1: GHG Emissions Calculation

$$GHG\ emissions = \frac{Total\ CO2\ emissions\ throughout\ life\ cycle\ (gCO2eq)}{Annual\ power\ generation\left(\frac{kWh}{yr}\right)lifetime(yr)} \quad (1)$$

To compare emissions from renewable energy sources as seen in Figure 17, emission values were taken from the 2014 IPCC, Global Warming Potential of Selected Electricity Sources using Life Cycle CO2 equivalent and measured in CO2eq/kWh. Below in Table IV are the various emissions from renewables as established by the IPCC in 2014.

Table IV: 2014 1PCC, Global Warming Potential of Selected Electricity Sources

Technology	Minimum Emissions (gCO2eq/kWh)	Median Emissions (gCO2eq/kWh)	Maximum Emissions (gCO2eq/kWh)
Coal -PC	740	820	910
Biomass – Cofiring with coal	620	740	890
Gas -combined cycle	410	490	650
Biomass -Dedicated	130	230	420
Solar PV – Utility scale	18	48	180
Solar PV – rooftop	26	41	60
Geothermal	6.0	38	79
Concentrated solar power	8.8	27	63
Hydropower	1.0	24	2200
Wind Offshore	8.0	12	35
Nuclear	3.7	12	110
Wind Onshore	7.0	11	56
CCS – Coal – PC	190	220	250
CCS – Coal – IGCC	170	200	230
CCS – Gas – combined cycle	94	170	340
CCS – Coal – oxyfuel	100	160	200
Ocean (Tidal and wave)	5.6	17	28

*available on Wikipedia

4.2. Second Data Collection, Presentation and Discussion

The third research was to establish and make recommendations based on the companies' performances against the UN's SDG7, Affordable Clean Energy and SDG13, Climate Action. In view of this, the second data collection was for a qualitative analysis of the performance of mining companies regarding their commitment to achieving the UN's SDG7 and SDG13. As seen in Figures 5 and 6 of the research methodology section, the UN detailed it's SDG7 and SDG13 goals to suit the mining industry with the aim of helping them achieve the ultimate goals. These goals where sub divided into sub goals (in colored boundaries) and targets. This analysis involved reviewing the targets individually to see if the companies were adhering to them. The number of targets achieved by the companies amounted to a score (refer to Table V below) for the achievement of the sub goals and ultimately the main goals. Tables in Appendix A give a detailed account of company performance, both individually and collectively.

Table V: Grading Scale for Energy Management Performance against SDGs

Grade	Interpretation	Range
0	Poor	Achieved none or less than 20% of the Targets
1	Fair	Achieved 20% - 49% of the Targets
2	Good	Achieved 50%- 89% of the Targets
3	Excellent	Achieved 90% - 100% of the Targets

4.2.1. Energy Management Performance against SDG7 & SDG13

Figure 20 shows the number of companies in each grade range of the qualitative analysis and the following section further analyses the results.

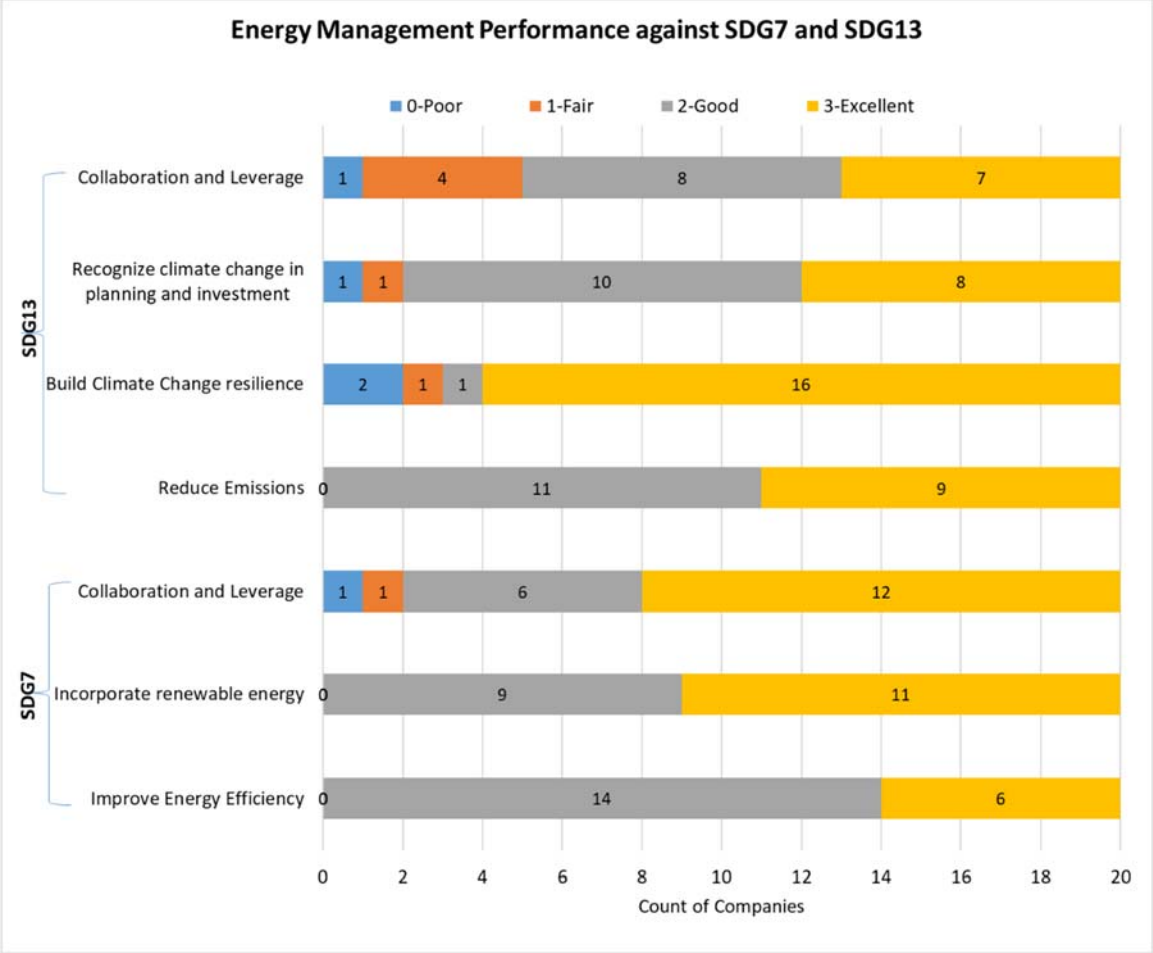

Figure 20: Energy Management Performance against SDG7 and SDG13

Analysis showed that most of the companies are performing either good or excellent in achieving the SDG sub goals. However, we still have a few of the companies performing poorly and fairly with 3 out of the 4 sub goals under the SDG13 and 1 out of 3 sub goals under the SDG7. With these performances, it was essential for a more in-depth analysis involving how these companies performed against the individual targets.

4.2.1.1. Performance Against SD7 (Affordable Clean Energy) Targets

Under the UNDP's detailed summary of expectations for mining companies to achieve the SDG7, the targets in Table VI were to be met. Figure 21 shows the performance of the selected mining companies with regard to each target, note that the highlighted targets are considered to not be achieved and will be discussed further in this section.

Table VI: Detailed Summary of SDG7 Sub Goals and Targets

	Sub Goals	Targets	Legend
SDG 7	Improve Energy Efficiency	Undertake energy audits	7.1.1
		Improve energy infrastructure maintenance	7.1.2
		Reduce energy demand onsite	7.1.3
	Incorporate renewable energy	Deploy off-grid wind, solar, or geothermal power	7.2.1
		Diversify power sources for reducing outages	7.2.2
		Replace diesel generators	7.2.3
	Collaboration and Leverage	Support local energy initiative	7.3.1
		Integrate into rural electrification schemes	7.3.2
		Share benefits of energy infrastructure	7.3.3
		Explore co-financing arrangements	7.3.4

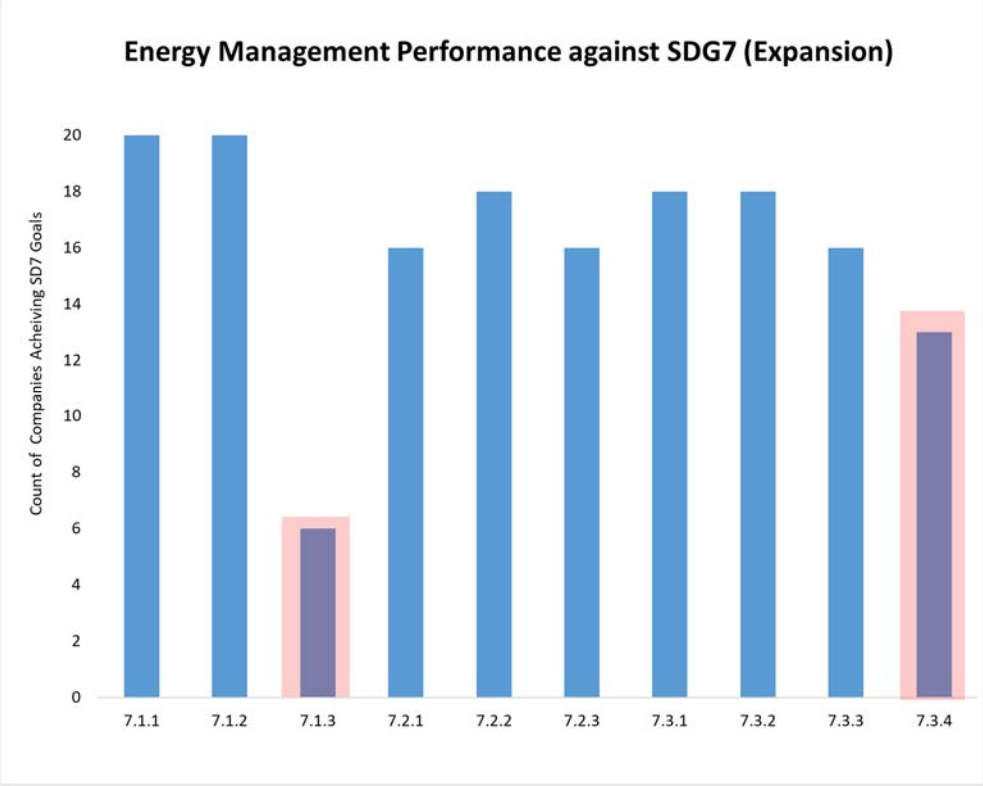

Figure 21: Expanded Analysis of Energy Performance against SDG7

An in-depth review of the companies' performance against the SDG7 targets showed that on an average, the companies collectively achieved a performance of 81% with over 15 companies achieving almost all the targets with the exception of two: Reduce Energy Demand and Explore Co-Financing Arrangements.

Reduce Energy Demand

It is expected by the UN that by reducing energy demand, the mining industry will be able to cut down GHG emissions by a corresponding percentage, hence their recommendation as a target the mining companies must meet. However, this has proven to be a hurdle for the industry, in that, mining is heavily reliant on energy to run its processes. With the continuous increase in the demand of minerals, it is evident that there will be a need for mine and process plant expansions, pits and underground mines to get deeper and haul roads to get longer. All these will require an increase in the demand of energy. In view of this, it is very important that the industry concentrate on achieving the use of zero emission energy which would offset the effect of this increase in energy demand.

Explore Co-Financing Arrangements

The vision of the UN in making this recommendation is to allow for the easy access and financing of energy efficient projects. It is recommended that the mining companies liaise with members within their supply chain (equipment manufacturers, energy providers, fuel suppliers, etc.) to undertake more energy efficient projects to reduce GHG emissions. However, the analysis showed that only 65% of the companies reviewed, meet this target. A few examples of such arrangements are Newmont Goldcorp's partnership with Sandvik and MacLean Engineering to develop the "world's first" all-electric underground mine (this partnership is expected to expand benefits to include further innovation, cost reduction and even competitive

advantage) and Goldfields Ghana Limited's power purchase agreement with Genser Energy, to install and run gas turbine power plants on their sites, delivering electricity to their operations.

4.2.1.2. Performance Against SD13 (Climate Action)

In similar fashion, the UNDP's detailed summary of what is expected of the mining companies to achieve the SDG13, rolls out the following targets to be considered. Figure 22 shows the results of the analysis completed of these targets.

Table VII: Detailed Summary of SDG13 Sub Goals and Targets

	Sub Goals	Targets	Legend
SDG 13	Reduce Emissions	Improve energy efficieny	13.1.1
		Use renewable energy	13.1.2
		Use low-emission fuels	13.1.3
		Align with INDCs	13.1.4
		Measure and report direct, indirect, and product-related emissions	13.1.5
	Build Climate Change resilience	Plan for climate change impact on mines and communities	13.2.1
		Strengthen emergency response plans	13.2.2
		Model climate-related environment impacts	13.2.3
	Recognize climate change in planning and investment	Use scenario planning to inform views on climate and energy risks and opportunities	13.3.1
		Use climate projections in design and placement of operations and infrastructure	13.3.2
		Adopt corporate climate change, carbon management and disclosure policies	13.3.3
		Use shadow carbon prices to inform portfolio evaluation and investment decisions	13.3.4
		Include climate change on the board agenda	13.3.5
	Collaboration and Leverage	Participate in climate- related R&D and pilots(emissions trading, CCS projects)	13.4.1
		Engage in intra-and cross-industry climate dialogues	13.4.2
		Publicly support carbon pricing	13.4.3

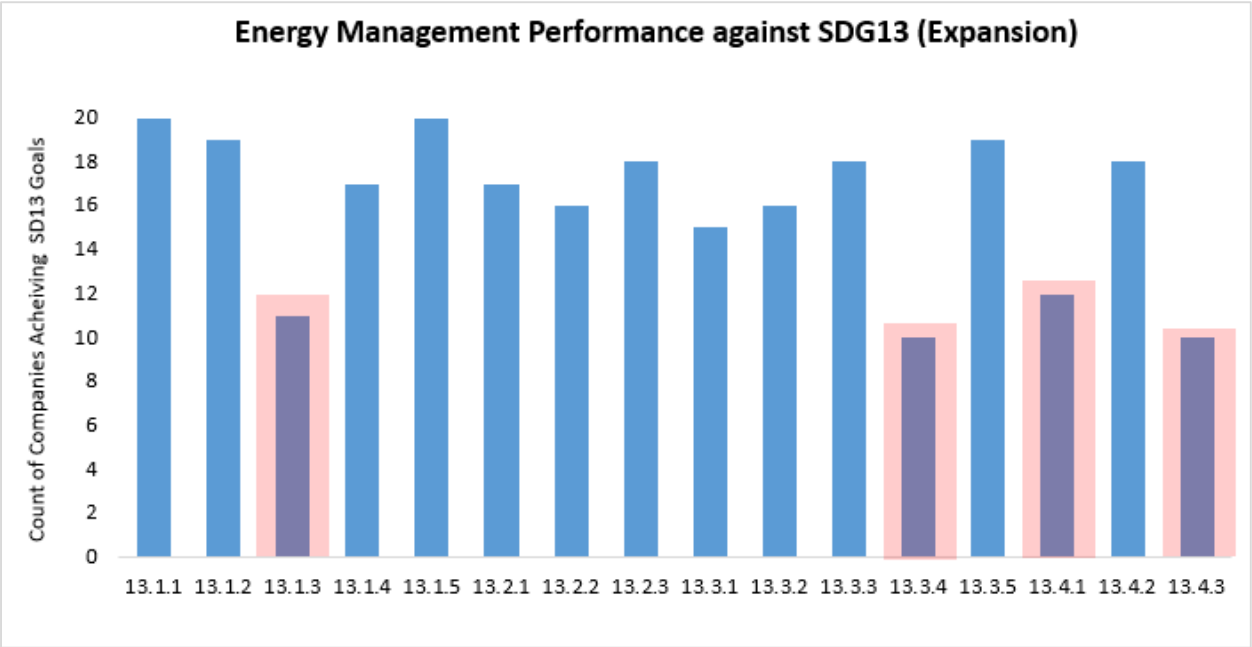

Figure 22: Expanded Analysis on Energy Management Performance against SDG13

An in-depth review of the companies' performance against the SDG13 targets showed that on an average, the companies collectively achieved a performance of 78% with over 15 companies achieving almost all the targets except four: Use Low-Emission Fuel, Use Shadow Carbon Prices to inform portfolio evaluation and investment decisions, Participate in Climate-Related R&D and Pilots and Publicly Support Carbon Pricing.

Use Low-Emission Fuel

The use of diesel fuel on mine sites contributes to a large percentage of GHG emissions. In view of this, the UN recommends that companies move from the use of diesel to low emission fuels such as LNG, biofuels, biodiesels, etc. They are also encouraged to use fuel additives that clean up diesel to a level of low emissions.

Use Shadow Carbon Prices to Inform Portfolio Evaluation and Investment Decisions and Publicly Support Carbon Pricing

In order to reduce carbon emissions and meet the zero emissions goal, one simple but powerful idea that has been proposed and critiqued is carbon pricing. Carbon pricing involves placing a price on produced carbon and reflecting the hidden carbon risks and opportunities in investment. Internal carbon pricing (ICP) can also help financial institutions assess carbon risks and identify opportunities to shift capital from high-carbon to low-carbon investment and lending, decarbonize their portfolios, and increase their resilience in a low-carbon transition (Navigant & Generation Foundation, 2019).

The concept of carbon pricing has not yet been fully accepted in many parts of the world, however in a few countries such as South Africa, the government has passed laws and policies that bind companies to the use of carbon pricing to inform their investment and operational decisions. Even though the UN expects all the mining companies to eventually accept the idea of carbon pricing, only a few of the companies reviewed made statements in their recent sustainability reports supporting the use of carbon pricing in their business model.

Participate in Climate-Related R&D and Pilots (Emissions Trading, CCS Projects)

Research & Development has proven to be an avenue through which important discoveries with respect to innovation and technology have been made. Considering this, the UN recommends that the mining industry invests and participates more in climate-related research and development to enhance the possibilities of discovering ultra-low or zero emission technologies that could help curb the issue of climate change. For example, a partnership between Rio Tinto Borates and the Institute for Superconducting and Electronic Materials (ISEM) at the University of Wollongong in Australia has been established to explore new

applications for boron in low-carbon energy. Additionally, BHP's five-year, US$400m Climate Investment Program aims to develop technologies to reduce emissions from their operations as well as those generated from the use of their resources is another example of how mining companies can participate in climate-related R&Ds.

4.3. Statements of Commitment

To answer an important question that has been posed by environmentalists, climate activists and many more; the fourth research objective focused on whether or not the mining industry is concerned about climate change. It was necessary to "mine" through public materials for statements of commitment from these companies under review. Through the review, it was revealed that these companies not only acknowledge the science of climate change but also how their activities contribute to it. These companies are also committed to the fight against climate change by adhering to policies and recommendations made by the ICMM, UN, ISO and other governmental and organizational bodies.

Statements of commitments made on company websites for public access can be referred to in the tables under Appendix B. These companies have established measures to move from the use of heavy fossil fuels to the use of more energy efficient technologies and emission targets have been set and constantly improved. In terms of accountability, most of these companies have submitted their operations to both internal and external auditing. These audits include reporting on Scope 1 Emissions (emissions directly due to the company's use of fossil fuels), Scope 2 Emissions (indirect emissions from the production of electricity used onsite (internally or externally)) and Scope 3 Emissions (indirect emissions that have no link to operations on site, e.g. employees flying from one place to another).

4.4. Mining Fuels Renewables

Very relevant to the topic of this research is the importance of the vital role the mining industry plays in advancing climate action. Apart from the fact that the industry is doing so much to curb the effects of their activities on the climate, it is also undeniable that the world needs products from mining to build the green energy technology it needs to successfully move from a heavy fossil fuel consuming world to a green earth. The importance of this topic is such that it is beginning to work its way into the dialog of popular culture. An example includes the following excerpt from an article by Avery Thompson published by *Popular Mechanics:*

> Plenty of high-tech electronic components, like solar panels, rechargeable batteries, and complex circuits, require specific rare metals. These can include magnetic neodymium, electronic indium, and silver, along with lesser-known metals like praseodymium, dysprosium, and terbium. These metals are mined in large quantities in countries around the world, and they make their way into the supply chains of all sorts of electronics and renewables companies (Thompson, 2018).

Another excellent example is the infographic shown below that comes from Cambridge House before the Vancouver Resource Investment Conference 2018 and was published by *Visual Capitalist* in January 2018. A major theme of the conference was sustainable energy and the infographic shows that to fully transition to a green economy, society will need vast quantities of a wide range of metals. The article by Jeff Desjardins further states that "These metals and minerals are needed to generate, store, and distribute green energy. Without them, the reality is that technologies like solar panels, wind turbines, lithium-ion batteries, nuclear reactors, and electric vehicles are simply not possible" (Desjardins, 2018).

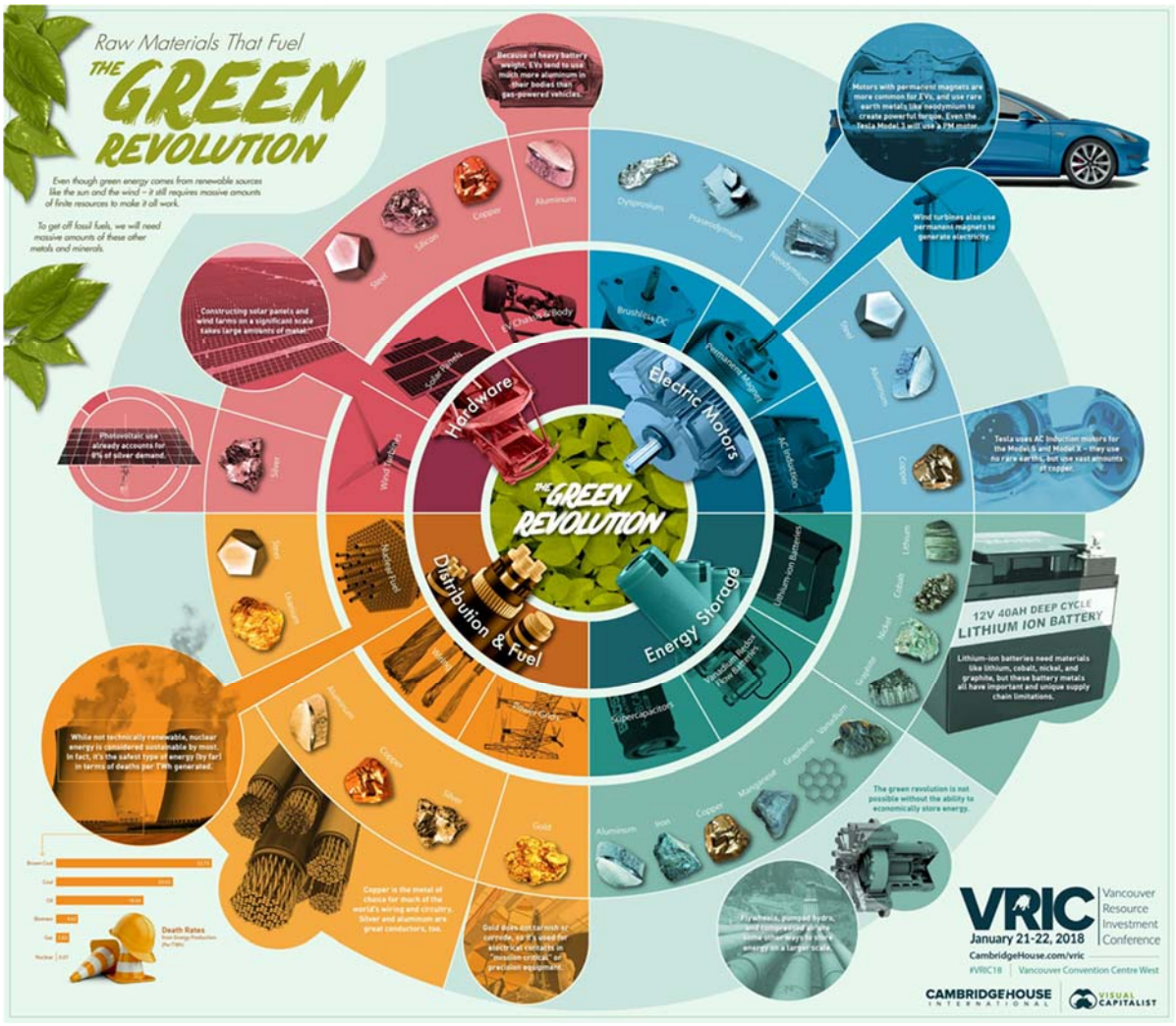

Figure 23: An Infographic of Metals and Minerals used for Green Energy Technology (Desjardins, 2018)

Thompson (2018) also notes that researchers from the Dutch Ministry of Infrastructure analyzed how many of the important "rare earth metals" will be required in order to meet all of the global pledges to achieve 100 percent renewable energy by 2050. According to the analysis, by 2050, global demand for indium will be 12 times current production while neodymium production will need to grow by approximately 7 times. Silver demand, which is considered less rare, and has significantly higher production than the other critical minerals, will also increase by approximately 3 times (Thompson, 2018).

The World Bank has even addressed the increase in demand for minerals and metals related the focus on various climate and greenhouse gas scenarios. The report, published in 2017 suggest the demand of these metals will be an exponential increase in the next 50 years due to the boom in low-carbon energy technologies. (The World Bank Group, 2017)

In view of this, it is of great essence that the world recognizes the mining industry as a solution to the issues of climate change. Stakeholders, investors, organizations and governmental bodies must make it an agenda to support the sustainability of the mining industry to ensure a continuous supply of raw materials for the green energy technology.

5. Conclusion

In conclusion, it was evident from the research into the first and second research objectives that mining companies are introducing and constantly improving various policies, systems and best practices as a way of effectively managing their energy consumptions and GHG emissions. The review and analysis conducted showed that the mining industry, represented by 20 international companies, is committed to the use of renewable technology and curbing carbon footprints while maintaining an effective energy management culture.

A critical look into the third and fourth research objectives revealed that the global mining industry has been proactive to the growing effects of climate change, acknowledging the effects of their activities on the climate and vice versa. It was also revealed that the industry is achieving most of the UN's SDG7 and SDG13 targets.

The performance of these leading mining companies sets the standard for the rest of the mining industry. It goes to show that the sustainable development goals and targets set by the UN are achievable and aimed at ensuring that the mining industry achieves its aim of zero emissions by 2030. It is also evident that these goals are in line with the 2015 Paris Agreement on climate change which calls on governments to limit global warming to well below 2ºC with an ambition to keep it below 1.5ºC to avert the worst effects of climate change.

6. Recommendations

While acknowledging that great steps have been taken by the mining industry to ensure a reduction in their GHG emissions and its commitment to the green earth agenda, there is always room for improvement to meet world-wide expectations. The following recommendations focus on areas where improvement is likely possible and will contribute to continual advancement toward meeting global expectations regarding climate change and energy management.

Investment in climate-related Research & Development, could lead to a breakthrough in the quest for a zero emissions operation. Research & Development has proven to be an avenue through which important discoveries with respect to innovation and technology have been made. Hence, the mining industry investing more in climate-related R&D is essential to achieving their goal. Studies and researches conducted by universities and research facilities could lead to the discovery of ultra-low or zero emissions technologies that can be used by the industries.

Mining companies should explore co-financing arrangements with members within their supply chain. It is very important that the mining companies liaise with their supply change to undertake more energy efficient projects and only supply energy efficient products for mining.

Companies should also continue working towards an increase in the use of low-emission fuels, renewables and more importantly, reducing energy demand. This will also go a long way in toward achieving the goal of zero emissions.

Finally, the global mining industry should embrace energy management with the same urgency as safety and environment concerns. The leading mining companies assessed here have proven that progress can be made and other companies should aspire to meet the same goals.

7. Future Work

Future work with regards to this research will be to investigate the impact of energy management on the financial models of these mining companies. While some believe that the advanced technologies required to reduce carbon emissions would raise mining company costs, there is potential for many of these technologies to offer significant financial incentives over the long-term.

A holistic comparison of total mine electrification and conventional mine operations would also be an interesting exercise to ascertain the feasibility of total mine electrification as it is a trend the mining industry looks to take going forward. Total mine electrification has a number of benefits related not only to carbon emission reductions but also improvements in safety and environmental concerns and reduced need for ancillary activities (e.g. less ventilation required).

8. References Cited

Amponsah, N., Troldborg, M., Kington, B., Aalders, I., & Hough, R. L. (2014). Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations. *Elsevier*, 461-475.

Anglo American. (2019, September 24). *4 Ways the Mining Industry Uses Renewable Energy*. Retrieved from Anglo American: https://www.angloamerican.com/futuresmart/our-world/environment/mining-with-renewable-energy

Atkins, W. A. (2010). *Hydroelectric Power*. Retrieved from Science and Issues - Water Encyclopedia: http://www.waterencyclopedia.com/Ge-Hy/Hydroelectric-Power.html

Bakane, P. (2013, Janurary). Uses and Advantages of Geothermal Resources in Mining. *GHC Bulletin*, 30-34.

Barrick Gold. (2020). *Sustainability: Managing our impacts on the natural environment*. Retrieved from Barrick.com: https://www.barrick.com/English/sustainability/managing-our-impacts-on-the-natural-environment/default.aspx#section=climate-change

Böhling, K., Murguía, D. I., & Godfrid, J. (2017, April 11). Sustainability Reporting in the Mining Sector: Exploring Its Symbolic Nature. *Sage Journals, 58* (1), 191-225. Retrieved December 23, 2019, from https://journals.sagepub.com/doi/full/10.1177/0007650317703658

Bonsor, K. (2001, September 6). *How Hydropower Plants Work*. Retrieved from howstuffworks: https://science.howstuffworks.com/environmental/energy/hydropower-plant1.htm

Boston College. (2019). *Sustainability Reporting*. Retrieved from Boston College Center for Corporate Citizenship: https://ccc.bc.edu/content/ccc/research/corporate-citizenship-news-and-topics/sustainability-reporting.html

Calrecycle. (2019, October 9). *Carbon Sequestration*. Retrieved from California Department of Resources Recycling and Recovery: https://www.calrecycle.ca.gov/organics/compostmulch/toolbox/carbonsequest

Carter, B. (2014, February 15). Top Reasons to Invest in Energy-efficient Appliances. *Bargainbriana*.

CAT. (2017). *CATERPILLAR TO OFFER DUAL FUEL RETROFIT KIT FOR 785C MINING TRUCK*. Retrieved from CAT: https://www.cat.com/en_US/news/machine-press-releases/caterpillar-to-offer-dual-fuel-retrofit-kit-for-785c-mining-truck.html

Clark, D. (2011, September 16). *A complete guide to carbon offsetting*. Retrieved from The Guardian: https://www.theguardian.com/environment/2011/sep/16/carbon-offset-projects-carbon-emissions

Cunanan, P. M. (2018, APRIL 12). *carbon-intensive-industries-industry-sectors-emit-the-most-carbon*. Retrieved from ecowarriorprincess.net: https://ecowarriorprincess.net/2018/04/carbon-intensive-industries-industry-sectors-emit-the-most-carbon/

Deloitte. (2019). *Driving value through energy management.* Retrieved from Deloitte Corporate Website: https://www2.deloitte.com/jp/en/pages/energy-and-resources/articles/driving-value-through-energy-management-mining.html

DeMates, L. (2013, December 26). *What are the differences between Biofuel, Bioethanol, Biodiesel, and Biogas?* Retrieved from THE SUSTAINABILITY CO-OP: https://thesustainabilitycooperative.net/2013/12/26/the-difference-between-biofuel-bioethanol-biodiesel-and-biogas/

Desjardins, J. (2018, January 10). *The Raw Materials That Fuel the Green Revolution*. Retrieved from Visual Capitalist: https://www.visualcapitalist.com/raw-materials-fuel-green-revolution/

Encyclopedia.com. (2019, December 03). *Fuel Switching*. Retrieved from Encyclopedia.com: https://www.encyclopedia.com/environment/encyclopedias-almanacs-transcripts-and-maps/fuel-switching

Environmental Protection Agency. (2019, December 18). *Green Power Partnership*. Retrieved from What is Green Power?: https://www.epa.gov/greenpower/what-green-power

EPA. (2017, January 6). *Carbon Dioxide Capture and Sequestration: Overview*. Retrieved from United States Environmental Protection Agency: https://archive.epa.gov/epa/climatechange/carbon-dioxide-capture-and-sequestration-overview.html

Gagan, O. (2018, April 27). *Cleaning up mining for the sake of the planet*. Retrieved from Raconteur: https://www.raconteur.net/business-innovation/cleaning-mining-sake-planet

Gleeson, D. (2019, July 16). *Mine electrification hinged on reskilling, collaboration and mine design, EY says*. Retrieved from International Mining: https://im-mining.com/2019/07/16/mine-electrification-hinged-reskilling-collaboration-mine-design-ey-says/

Goldwind Australia. (2016). *Gullen Range Wind Farm*. Retrieved from Goldwind: https://gullenrangewindfarm.com/

Goodward, J., & Kelly, A. (2010). *Bottom Line on Offsets.* Washington: World Resources Institute.

Green Blogger. (2014, December 30). *Biomass Energy: Reviving the traditional sources through Modern Technology*. Retrieved from Follow Green Living: https://followgreenliving.com/biomass-energy-reviving-traditional-sources-modern-technology-rtr/

GRI. (2019). *About Sustainability Reporting*. Retrieved from GRI Empowering Sustainable Decisions: https://www.globalreporting.org/information/sustainability-reporting/Pages/default.aspx

Haner, N. C. (2004, July 12). *Fuel additive revving engines*. Retrieved from Orlando Business Journal: https://www.bizjournals.com/orlando/stories/2004/07/12/story2.html

Holly, S., Randal, J., Susan, C., & Daniel, B. (2020, Jan 28). *Climate Change: How Do We Know?* Retrieved from Global Climate Change: Vital Signs of the planet: https://climate.nasa.gov/evidence/

ICMM. (2019). *ADAPTING TO A CHANGING CLIMATE: Building resilience in the mining and metals industry.* London: International Council on Mining & Metals.

ICMM. (2019). *The Sustainable Development Goals*. Retrieved from ICMM, International Council on Mining & Metals: https://www.icmm.com/en-gb/metals-and-minerals/making-a-positive-contribution/sdgs

ICMM. (2020). *Setting a benchmark for energy performance and carbon management in the mining industry*. Retrieved from International Council on Mining & Metals: https://www.icmm.com/en-gb/case-studies/setting-a-benchmark-for-energy-performance-and-carbon-management

IPCC. (2007, April 11). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. Retrieved from United States Environmental Protection Agency: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

ISO. (2019). *ISO 50001:2018 Energy management systems*. Retrieved from International Organization for Standardization: iso.org

Jessie, L., & Thomas, K. (2018, August 20). Mining for emissions reductions? Strike while the earth is cool. *GreenBiz*. Retrieved from rmi.org: https://rmi.org/mining-for-emissions-reductions-strike-while-the-earth-is-cool/

Kumar, S. V. (2017, September 9th). MINING AND THE SUSTAINABLE DEVELOPMENT GOALS. *National Conference on Extractive Industry and Sustainable Development.* New Delhi: International Institute of Corporate Sustainability and Responsibility (IICSR). Retrieved from teriin.org.

Mitchell, P. (2019, Jul 15). *Will electrification spark the next wave of mining innovation?* Retrieved from EY Global Mining & Metals: https://www.ey.com/en_us/mining-metals/will-electrification-spark-the-next-wave-of-mining-innovation

National Geographic. (2019, 28 March). *National Geographic Resource Library*. Retrieved from Climate Change: https://www.nationalgeographic.org/encyclopedia/climate-change/

Navigant & Generation Foundation. (2019). *Internal Carbon Pricing for Low-Carbon Investment – A briefing paper on linking climate-related opportunities and risks to financing decisions for investors and banks.* Prepared under the Carbon Pricing Unlocked partnership.

Patsa, E. (2018). *The use of geothermal energy in mining : a decision-making framework.* Vancouver: University Of British Columbia. Retrieved from Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0365825

REN21. (2019). *What are the current trends in renewable energy?* Retrieved from REN21 Renewables now: https://www.ren21.net/what-are-the-current-trends-in-renewable-energy/

The World Bank Group. (2017, July 18). *The Growing Role of Minerals and Metals for a Low Carbon Future.* Washington, DC: World Bank Publications. Retrieved from The World Bank: https://www.worldbank.org/en/news/press-release/2017/07/18/clean-energy-transition-will-increase-demand-for-minerals-says-new-world-bank-report

Thompson, A. (2018, December 13). *We Might Not Have Enough Materials for All the Solar Panels and Wind Turbines We Need*. Retrieved from Popular Mechanics: https://www.popularmechanics.com/science/energy/a25576543/renewable-limits-materials-dutch-ministry-infrastructure/

UN. (2019). *About the Sustainable Development Goals*. Retrieved from Sustainable Development Goals: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

UNDP. (2016). *Mapping Mining to the Sustainable Development Goals: An Atlas.* Switzerland: World Economic Forum.

UNFCCC. (2015, December 12). Adoption of the Paris Agreement. *United Nations Framework Convention on Climate Change* (pp. 1-32). Paris: United Nations. Retrieved from NRDC: assets.documentcloud.org/documents/2646274/Updated-l09r01.pdf

UNFCCC. (2020). *What is the Paris Agreement?* Retrieved from United Nations Climate Change: https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

Union of Concerned Scientists. (2019, June 20). *Holding Major Fossil Fuel Companies Accountable for Nearly 40 Years of Climate Deception and Harm*. Retrieved from Union of Concerned Scientists: https://www.ucsusa.org/resources/holding-major-fossil-fuel-companies-accountable

United Nations. (2019). *Sustainable Development Goals*. Retrieved from United Nations: https://www.un.org/sustainabledevelopment/climate-change/

USDA. (2016, October 7). *Carbon Sequestration*. Retrieved from United States Department of Agriculture Forest Service: https://www.fs.fed.us/ecosystemservices/carbon.shtml

VA DMME. (2015). *Alternative and Renewable Energy - Biomass*. Retrieved from Virginia Department of Mines, Minerals and Energy: https://www.dmme.virginia.gov/DE/Biomass.shtml

White-Crummey, A. (2018, May 19). Canada's first-ever geothermal power plant in the works for Torquay area. *Regina Leader-Post*. Retrieved from https://leaderpost.com/news/saskatchewan/canadas-first-ever-geothermal-power-plant-in-the-works-for-torquay-area/

Wikimedia Commons. (2009, January 18). *Mining*. Retrieved from Wikipedia.org: https://commons.wikimedia.org/wiki/File:Simplified_world_mining_map_1.png

WWEA. (2019, June 4). *Wind Power Capacity Worldwide Reaches 597 GW, 50,1 GW added in 2018*. Retrieved from World Wind Energy Association: https://wwindea.org/blog/2019/02/25/wind-power-capacity-worldwide-reaches-600-gw-539-gw-added-in-2018/

Xueli, B. (2012, April 6). *The future of Carbon Capture and Storage*. Retrieved from Web Energy Blog: https://webberenergyblog.wordpress.com/2012/04/06/3272/

9. Appendix A: Performance Assessment against SDG7 and SDG13

			Rio Tinto	Barrick Gold	Newmont Goldcorp	Gold Fields	Vale
SDG 7	Improve Energy Efficiency	Undertake energy audits	•	•	•	•	•
		Improve energy infrastructure maintenance	•	•	•	•	•
		Reduce energy demand onsite	-	-	-	-	-
	Incorporate renewable energy	Deploy off-grid wind, solar, or geothermal power	•	•	•	•	•
		Diversify power sources for reducing outages	•	•	•	•	•
		Replace diesel generators	•	-	•	•	•
	Collaboration and Leverage	Support local energy initiative	•	•	•	•	•
		Integrate into rural electrification schemes	-	•	•	•	•
		Share benefits of energy infrastructure	•	•	•	•	•
		Explore co-financing arrangements	-	-	•	•	-
SDG 13	Reduce Emissions	Improve energy efficieny	•	•	•	•	•
		Use renewable energy	•	•	•	•	•
		Use low-emission fuels	•	•	-	-	•
		Align with INDCs	•	•	•	•	•
		Measure and report direct, indirect, and product-	•	•	•	•	•
	Build Climate Change resilience	Plan for climate change impact on mines and	•	•	•	•	•
		Strengthen emergency response plans	•	•	•	•	•
		Model climate-related environment impacts	•	•	•	•	•
	Recognize climate change in planning and investment	Use scenario planning to inform views on climate	•	•	-	•	•
		Use climate projections in design and placement of	•	-	•	•	•
		Adopt corporate climate change, carbon	•	•	•	•	•
		Use shadow carbon prices to inform portfolio	•	-	•	•	•
		Include climate change on the board agenda	•	•	•	•	•
	Collaboration and Leverage	Participate in climate- related R&D and	•	•	•	-	•
		Engage in intra-and cross-industry climate	•	•	•	•	•
		Publicly support carbon pricing	•	-	•	•	•

• - Achieved

- - Not Achieved

			Freeport McMoran	Newcrest Mining Limited	Glencore	Kinross Gold	Teck
SDG 7	Improve Energy Efficiency	Undertake energy audits	•	•	•	•	•
		Improve energy infrastructure maintenance	•	•	•	•	•
		Reduce energy demand onsite	-	-	•	-	-
	Incorporate renewable energy	Deploy off-grid wind, solar, or geothermal power	•	•	•	-	•
		Diversify power sources for reducing outages	•	•	•	•	•
		Replace diesel generators	•	•	•	-	•
	Collaboration and Leverage	Support local energy initiative	•	•	•	•	•
		Integrate into rural electrification schemes	•	•	•	•	•
		Share benefits of energy infrastructure	•	•	•	-	•
		Explore co-financing arrangements	•	-	•	-	•
SDG 13	Reduce Emissions	Improve energy efficieny	•	•	•	•	•
		Use renewable energy	•	•	•	•	•
		Use low-emission fuels	•	-	-	-	-
		Align with INDCs	•	•	•	-	•
		Measure and report direct, indirect, and product-	•	•	•	•	•
	Build Climate Change resilience	Plan for climate change impact on mines and	•	•	•	•	•
		Strengthen emergency response plans	•	-	•	•	•
		Model climate-related environment impacts	•	•	•	•	•
	Recognize climate change in planning and investment	Use scenario planning to inform views on climate	•	•	•	•	•
		Use climate projections in design and placement of	•	•	•	•	•
		Adopt corporate climate change, carbon	•	•	•	•	•
		Use shadow carbon prices to inform portfolio	-	•	•	-	•
		Include climate change on the board agenda	•	•	•	•	•
	Collaboration and Leverage	Participate in climate- related R&D and	•	-	•	•	•
		Engage in intra-and cross-industry climate	•	•	•	•	•
		Publicly support carbon pricing	-	•	•	-	•

• - Achieved

- - Not Achieved

			BHP Bilinton	Anglogold Ashanti	Lundin Mining	Anglo American	Sibanye Stillwater
SDG 7	Improve Energy Efficiency	Undertake energy audits	*	*	*	*	*
		Improve energy infrastructure maintenance	*	*	*	*	*
		Reduce energy demand onsite	-	-	*	*	*
	Incorporate renewable energy	Deploy off-grid wind, solar, or geothermal power	-	*	*	*	*
		Diversify power sources for reducing outages	*	*	*	*	*
		Replace diesel generators	*	*	*	*	-
	Collaboration and Leverage	Support local energy initiative	*	*	*	*	*
		Integrate into rural electrification schemes	*	*	*	*	*
		Share benefits of energy infrastructure	*	*	*	*	-
		Explore co-financing arrangements	*	*	*	*	*
SDG 13	Reduce Emissions	Improve energy efficieny	*	*	*	*	*
		Use renewable energy	*	*	*	*	*
		Use low-emission fuels	-	*	*	*	-
		Align with INDCs	*	*	*	*	*
		Measure and report direct, indirect, and product-	*	*	*	*	*
	Build Climate Change resilience	Plan for climate change impact on mines and	*	-	*	*	*
		Strengthen emergency response plans	*	-	*	*	*
		Model climate-related environment impacts	*	*	*	*	*
	Recognize climate change in planning and investment	Use scenario planning to inform views on climate	*	-	*	*	*
		Use climate projections in design and placement of	*	-	*	*	*
		Adopt corporate climate change, carbon	*	*	*	*	*
		Use shadow carbon prices to inform portfolio	*	*	-	*	-
		Include climate change on the board agenda	*	*	*	*	*
	Collaboration and Leverage	Participate in climate- related R&D and	*	-	-	*	*
		Engage in intra-and cross-industry climate	*	*	*	*	*
		Publicly support carbon pricing	*	*	-	*	-

- * - Achieved
- \- - Not Achieved

			Hecla	Northern Star Resources	Codelco	China Shenhua Energy	KGHM
SDG 7	Improve Energy Efficiency	Undertake energy audits	•	•	•	•	•
		Improve energy infrastructure maintenance	•	•	•	•	•
		Reduce energy demand onsite	•	-	-	-	•
	Incorporate renewable energy	Deploy off-grid wind, solar, or geothermal power	-	•	•	-	•
		Diversify power sources for reducing outages	•	-	-	•	•
		Replace diesel generators	•	•	•	•	-
	Collaboration and Leverage	Support local energy initiative	-	-	•	•	•
		Integrate into rural electrification schemes	-	•	•	•	•
		Share benefits of energy infrastructure	-	-	•	•	•
		Explore co-financing arrangements	-	-	•	•	•
SDG 13	Reduce Emissions	Improve energy efficieny	•	•	•	•	•
		Use renewable energy	•	•	•	-	•
		Use low-emission fuels	•	•	•	•	-
		Align with INDCs	-	•	•	-	•
		Measure and report direct, indirect, and product-	•	•	•	•	•
	Build Climate Change resilience	Plan for climate change impact on mines and	-	•	-	•	•
		Strengthen emergency response plans	-	•	-	•	•
		Model climate-related environment impacts	-	•	-	•	•
	Recognize climate change in planning and investment	Use scenario planning to inform views on climate	-	•	-	•	-
		Use climate projections in design and placement of	-	•	-	•	•
		Adopt corporate climate change, carbon	-	•	•	-	•
		Use shadow carbon prices to inform portfolio	-	-	-	-	-
		Include climate change on the board agenda	-	•	•	•	•
	Collaboration and Leverage	Participate in climate- related R&D and	-	-	-	•	-
		Engage in intra-and cross-industry climate	-	•	•	-	•
		Publicly support carbon pricing	-	-	-	-	-

• - Achieved

- - Not Achieved

	On a scale of 0-3
0	Poor
1	Fair
2	Good
3	Excellent

	SDG7					SDG13					
	Improve Energy Efficiency	Incorporate Renewable Energy	Collaboration and Leverage	Overall	Average	Reduce Emissions	Build Climate Change Resilience	Recognize climate change in planning and investment	Collaboration and Leverage	Overall	Average
Rio Tinto	2	3	2	78%	2.33	3	3	3	3	100%	3.00
Barrick Gold	2	2	2	67%	2.00	3	3	2	2	83%	2.50
Newmont Goldcorp	2	3	3	89%	2.67	2	3	2	3	83%	2.50
Gold Fields	2	3	3	89%	2.67	2	3	3	2	83%	2.50
Vale	2	3	2	78%	2.33	3	3	3	3	100%	3.00
Freeport McMoran	2	3	3	89%	2.67	3	3	2	2	83%	2.50
Newcrest Mining Limited	2	3	2	78%	2.33	2	2	3	2	75%	2.25
Glencore	3	3	3	100%	3.00	2	3	3	3	92%	2.75
Kinross Gold	2	2	2	67%	2.00	2	3	2	2	75%	2.25
Teck	2	3	3	89%	2.67	2	3	3	3	92%	2.75
BHP	2	2	3	78%	2.33	2	3	3	3	92%	2.75
Anglogold Ashanti	2	3	3	89%	2.67	3	1	2	2	67%	2.00
Lundin Mining	3	3	3	100%	3.00	3	3	2	2	83%	2.50
Anglo American	3	3	3	100%	3.00	3	3	3	3	100%	3.00
Sibanye Stillwater	3	2	2	78%	2.33	2	3	2	2	75%	2.25
Hecla	3	2	0	56%	1.67	2	0	0	0	17%	0.50
Northern Star Resources	2	2	1	56%	1.67	3	3	2	1	75%	2.25
Codelco	2	2	3	78%	2.33	3	0	1	1	42%	1.25
China Shenhua Energy	2	2	3	78%	2.33	2	3	2	1	67%	2.00
KGHM	3	2	3	89%	2.67	2	3	2	1	67%	2.00
Collective Averages	**2.3**	**2.6**	**2.5**	**81%**	**2.4**	**2.5**	**2.6**	**2.3**	**2.1**	**78%**	**2.33**

			Achievements	81%	2.43				Achievements	78%	2.33
			Shortfall	19%					Shortfall	23%	
				100%						100%	

10. Appendix B: Statements of Commitment

Rio Tinto	Rio Tinto has publicly acknowledged the reality of climate change for over a decade. We recognise that it is largely caused by human activities and has the potential for a lasting, negative impact on our business, our communities and the world. Indeed, from forest fires to hurricanes to loss of biodiversity, we are already experiencing some of these negative impacts.	Over the past nine years we have reduced our GHG intensity by 26 per cent and cut our absolute emissions by 35 per cent. At Rio Tinto we support a market-based price on carbon. We believe this is the best way of achieving emissions reductions at least cost.We are aiming for a substantial decarbonisation of our business by 2050 and are working to define new emissions reduction targets from 2020
Barrick Gold	Climate change and the transition to a low carbon future bring physical, regulatory and reputational risks for us and for the mining industry in general. We understand the important link between energy use and climate change. By effectively managing our energy use, we are able to reduce our greenhouse gas (GHG) emissions, achieve more efficient production, reduce our draw from local energy grids and save a significant proportion of our direct mining costs. Managing our energy use is therefore a business imperative	As part of our approach to climate change, we are committed to assessing and understanding our climate-related risks and opportunities. Barrick's Climate Change Strategy before the merger set a goal to keep Scope 1 and 2 emissions flat in the short term, and to achieve a 30% reduction by 2030, against a 2016 baseline.
Newmont Goldcorp	Extreme weather events, which impacted a number of Newmont's operations in recent years, are a growing risk and demonstrate the need to assess and build resiliency to a changing climate.Continuing to improve the efficiency of our operations, reduce energy use and associated costs, and lower our greenhouse gas (GHG) emissions are top sustainability priorities for the business	Through our global energy and climate strategy – which supports the International Council on Mining and Metals' (ICMM) position statement on climate change – we work to fulfill our commitments
Gold Fields	Gold Fields has developed integrated energy and carbon management strategies at both Group and operational level that are aligned with the global ISO 50001 energy management system standard. The key pillars of this strategy are to reduce our diesel usage, to switch from dieselgenerated electricity to cleaner gas-generated, increasing the use of renewables and rolling out training and awareness programmes	We voluntarily report to the CDP on our greenhouse gas emissions, energy use and the risks and opportunities arising from climate change. In 2017 we were ranked as one of the top JSE listed companies on the CDP.
Vale	Vale follows global and regional trends in combating climate change and engages with governments, associations, academia, and civil society, directly or through forums, to assist in the management of risks associate with climate change, in accordance with its Global Policy on Mitigation and Adaptation to Climate Change.	The global climate policy also establishes the Vale's guiding principles on the subject through ten commitments – which include a GHG reduction target, known as the Carbon Target 8 , which aims to reduce direct GHG emissions by 5% in 2020
Freeport McMoran	Freeport-McMoRan recognizes that climate change poses significant near-term, medium-term and longer-term challenges for society. We also understand that climate change presents risks and opportunities for our operations and our financial performance. We aim to manage and mitigate, to the extent possible, associated risks to our business with the ambition of being a net positive contributor to climate solutions through delivery of copper to global markets.	We are continuing a multi-year process to address the core reporting recommendations of the Task Force on Climate- Related Financial Disclosures (TCFD). In doing so, we focus on the copper-producing operations1 of Freeport Minerals Corporation (FMC) where we can make meaningful improvements in energy efficiency as well as increase the percentage of power purchased from low-carbon sources.

Newcrest Mining	Newcrest is committed to the sustainable discovery, development and production of gold and copper. As a responsible miner, we must identify, assess and report our responses to climate change challenges	Newcrest has committed to a greenhouse gas (GHG) intensity target – a 30% reduction in GHG emissions per tonne of ore treated by 2030 against the 2018 baseline. We are supporters of the Task Force on Climate-related Financial Disclosures and are progressively reporting in our Sustainability Report. We are a supporter of TCFD and commited to progressively report on TCFD via Sustainability Report
Glencore	We recognise global climate change science, as laid out by the United Nations Intergovernmental Panel on Climate Change. Find out how we are responding to the shift to a lower-carbon economy. We believe that the global response to climate change should pursue twin objectives: both limiting temperatures in line with the goals of the Paris Agreement and supporting the United Nations Sustainable Development Goals, including universal access to affordable energy.	To meet the growing needs of a lower carbon economy, Glencore aims to prioritise its capital investment to grow production of commodities essential to the energy and mobility transition and to limit its coal production capacity broadly to current levels. In 2017, we announced a target to reduce our greenhouse gas emissions intensity by 5% by 2020 compared to a 2016 baseline.
Kinross Gold	We recognize that climate change is one of the most important issues on the global sustainability agenda. In that context, we believe that the global mining industry can contribute positively to global efforts to mitigate the risks arising from climate change through responsible energy consumption and emissions reduction.	For our part, we continuously review our energy supply matrix to identify opportunities to diversify sources of non-renewable and renewable energy and reduce both cost and emissions.We incorporate energy effciency into the design of our operations from the outset, including life-cycle assessment, and assess climate change as part of the Environmental Impact Assessment (EIA) process for permitting new mine projects.
Teck	We recognize that human activities are contributing to climate change and are taking action to reduce greenhouse gas emissions by improving energy efficiency, implementing low carbon technologies and advocating for carbon pricing.Teck has partnered with organizations worldwide to work together on the challenge of climate change. Teck is a signatory to the Paris Pledge for Action in support of reducing emissions and achieving the objectives of the Paris Agreement.	We recognize that our activities consume energy and generate significant greenhouse gas (GHG) emissions. This is why Teck has set ambitious targets to reduce our carbon footprint. To date, we have cut our GHG emissions by over 289,000 tonnes and our long-term target is to reduce GHGs by 450,000 tonnes by 2030.
BHP Bilinton	BHP accepts the Intergovernmental Panel on Climate Change (IPCC) assessment of climate change science, which has found that warming of the climate is unequivocal, the human influence is clear and physical impacts are unavoidable.	Playing our part in responding to climate change is a priority governance and strategic issue for BHP.Our climate change strategy focuses on reducing our operational greenhouse gas (GHG) emissions, investing in low emissions technologies, promoting product stewardship, managing climate-related risk and opportunity, and working with others to enhance the global policy and market response.

Anglogold Ashanti	AngloGold Ashanti (AGA) emits greenhouse gases (GHGs) directly by its operations, and indirectly via the external utilities from which it purchases power. Currently, a major international measure to address or limit GHG emissions, is the 2015 Paris Agreement. For the first time, developed and developing countries have committed to reduce their GHG Emissions in an effort to cap warming at 1.5 Degrees Celsius. The Agreement translates into nationally determined commitments which are to start in 2020 and signals the end of Business as Usual for the energy industry. As countries define and roll out their commitments in future, this could require AngloGold Ashanti to reduce its direct GHG emissions or energy use or to incur significant costs for GHG emissions permits or taxes or have these costs passed on by electricity utilities which supply the company, and also through purchased consumables in those countries.	In 2008, AngloGold Ashanti announced a long-term target of reducing its greenhouse gas (GHG) emission intensity by 30 percent from 2007 levels. The time-frame was later confirmed as 15 years (2022)
Lundin Mining	Climate change has become an increasingly significant global issue in recent years, and Lundin Mining recognizes the need for effective approaches to managing its climate related responsibilities, especially in consideration of the remote locations in which we operate, the energy-intensive nature of our extractive industry sector, and the sometimeslimited availability of renewable energy in national energy mixes.	In 2018, climate change was included as a key component of Lundin Mining's Five-Year Sustainability Strategy.
Anglo American	Climate change is one of the defining challenges of our era. In living Anglo American's Purpose to re-imagine mining to improve people's lives, we recognise the role we have to play in being part of the global response to climate change. Combined with our values and guiding our strategy, it is the context against which we consider the defining challenges of our era, including climate change. It is how we start to answer the questions of what our contribution could (and should) be in the transition to a low carbon world.	Anglo American has taken decisive steps for more than a decade to contribute to the global effort to reduce emissions, while continuing to provide the materials that modern life requires. We are working towards ambitious 2030 targets as part of our roadmap for developing a carbon-neutral mine.We need to do things differently if we are to transform our carbon footprint. We need to reduce our energy and water usage, and our emissions – and we are committed to doing exactly that. We're on track to achieve our 2020 targets (8% improvement in energy use, 22% saving in GHS emissions) and are confident that our FutureSmart MiningTM technologies will be a key driver of emissions reductions and of driving our operations towards carbon neutrality.
Sibanye Stillwater	Climate change is one of the most pressing global environmental challenges of our time, and we are committed to contributing to a global solution by proactively managing our carbon footprint. We strive to reduce our carbon emissions year-over-year with an aim to reduce emissions annually by an average of 2.1%.	The implementation of energy efficiency projects has been instrumental in the continuous reduction of our carbon footprint. These include initiatives relating to ventilation optimization at our gold operations, compressed air optimisation projects at our PGM operations, and the installation of solar arrays.
Hecla	Extraction and production processes at mines can be energy intensive. Reducing energy consumption through streamlined processes, adoption of technology and use of renewable energy sources is not only good for our bottom line, it's important for the environment and the reduction of our carbon footprint	Company-wide, Hecla has established an energy intensity reduction target of 5 percent over the next 3 years from the 2017-2018 baseline years. Once all the Ventilation On Demand fans are converted at Greens Creek, we expect $1M in energy savings per year

Northern Star Resources	Northern Star acknowledges that there is climate change risk associated with all business activity and that the assessment, management and considered acceptance of this risk ensures both the sustainability and growth of our business.	With the rapid advancement of renewable energy technology, Northern Star is constantly reviewing the ability to incorporate emissions friendly means of generating electricity into our business
Codelco	In Codelco we seek a preventive and transparent management of environmental risks, complying with the regulations, considering the effects of climate change, increasing water and energy efficiency and reducing the consumption of continental water and the emission of gases and particulate matter.	CALAMA, Chile—The three industrial boilers at the state-owned Codelco mine high in the mountains here once consumed 67,000 barrels of diesel a year to turn out shiny copper sheets for export. Now, the job is powered by nearly 3,000 solar panels that take advantage of the Atacama Desert's cloudless blue sky.
China Shenhua Energy	We continuously promote green management system, proactively carry out pollution prevention and control, actively strengthen energy conservation and consumption reduction, and lead the industry towards to green upgrading.	China Shenhua continuously optimizes the carbon management system, promotes the construction of management system for carbon emission reduction, organizes operation training of carbon trading, and carries out diversified forms of promotion on energy saving and low carbon to enhance the awareness of active management of carbon emissions, and promote the harmonious development between people and nature
KGHM	In 2009, the Company launched the Energy Saving Energy Saving Program of KGHM Polska Miedź SA, In 2015, due to the need to adapt the project to the assumptions of PN-EN ISO 50001: 2012, change the implementation approach and intensify work on improving energy efficiency, the scope of the program was expanded.	Due to the fact that the savings are mainly based on the reduction of energy demand, the effect of beneficial impact on the natural environment has also been achieved by reducing CO 2 emissions .The company has already identified the savings potential for the coming years and is still looking for new opportunities to reduce energy demand while developing production capacity.

11. Appendix C: Links to Reports Reviewed

Companies	Links
Rio Tinto	https://www.riotinto.com/sustainability/climate-change
Barrick Gold	https://www.barrick.com/English/sustainability/reports-policies/default.aspx
Newmont Goldcorp	https://www.newmont.com/sustainability/sustainability-reporting/default.aspx
Gold Fields	https://www.goldfields.com/sustainability-reporting.php
Vale	http://www.vale.com/EN/investors/information-market/annual-reports/sustainability-reports/Pages/default.aspx
Freeport McMoran	https://www.fcx.com/sustainability/reports-and-documents
Newcrest Mining Limited	https://www.newcrest.com/investor-centre/reports?type=8
Glencore	https://www.glencore.com/sustainability/reports-and-presentations
Kinross Gold	https://www.kinross.com/corporate-responsibility/environment/default.aspx?section=energy
Teck	https://www.teck.com/responsibility/approach-to-responsibility/sustainability-report-disclosure-portal/
BHP	https://www.bhp.com/environment/climate-change/
Anglogold Ashanti	https://www.anglogoldashanti.com/sustainability/reports/
Lundin Mining	https://www.lundinmining.com/responsible-mining/sustainability-reports/
Anglo American	https://www.angloamerican.com/sustainability/environment/climate-change
Sibanye Stillwater	https://www.sibanyestillwater.com/sustainability/reports-policies/
Hecla	http://ir.hecla-mining.com/CustomPage/Index?KeyGenPage=315096
Northern Star Resources	https://www.nsrltd.com/sustainability/
Codelco	https://www.codelco.com/memoria2015/en/descargas-reporte.html
China Shenhua Energy	http://www.csec.com/shenhuaChinaEn/1382683238892/shzrbg.shtml
KGHM	https://kghm.com/en/sustainable-development

*The links provided in the table above, contain sustainability reports, financial reports, annual reports and 10-k forms of the companies that were reviewed.

SIGNATURE PAGE

This is to certify that the thesis prepared by Irene A. Ateng entitled "Assessing the Energy Management Culture of Global Leading Mining Companies: Curbing Carbon Emissions in A World of Growing Climate Change Concerns" has been examined and approved for acceptance by the Department of Mining Engineering, Montana Technological University, on this 1st day of May, 2020.

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