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The sustainable management of byproducts of the steel industry: Egypt case study

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The Sustainable Management of Byproducts of the Steel Industry:
Egypt Case Study

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Abstract

In society today, the world is faced with multiple challenges within the realm of sustainability in the economic, social, and environmental sectors. Egypt has also been faced with challenges that have been growing over the decades that require a vision that will put forward mitigation efforts and recommendations.

Egypt's steel industry has been rapidly and vastly expanding over the past decade due to an overall increase in demand in steel, this is also linked to the fact that with population growth the supply demanded increases which in turn requires that the demand meet.

The growing steel market has sparked the emergence and opening of a number of newly introduced companies who have joined this viable production sector. As steel production in Egypt is increasing, the country must also adapt and develop ways to sustainably treat the by-products of steel production, which are harmful to the environment, society, and the economy.

The types of waste generated from steel production include byproducts that are usually left unrecycled or that are thrown away. These byproducts include slag and dust. Sustainable methods of reusing byproducts generated by steelmaking plants would help develop more viable production cycles for steel plants in Egypt, especially with their current uses that are not being employed correctly.

However, to date, no sustainable practices for the reuse of steelmaking byproducts have been implemented by the steel making industry in Egypt. By researching ways in which steel byproducts are dealt with in other countries and assessing how such methods are suitable in the Egyptian context, this thesis will make important recommendations for a more sustainable management of byproducts of steel in Egypt.

This thesis will employ a case study method and pros and cons will be discussed to examine which approach is the optimal choice for the industry in Egypt.

Further research regarding the procedures of implementations, the current and potential difficulties that will be faced and the lessons learnt from case studies abroad will also be taken into consideration.

Ultimately, this thesis shows positive results from the mathematical calculations that have

forecasted the potential reuse profits of slag and dust. This will imply that these methods are viable for Egypt to implement as recommendations for the next steps forward. In addition to that looking and learning from countries methodologies abroad that have implemented vast methods of byproduct dealings and their impacts on the three pillars of sustainability.

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1.0. Introduction

The waste of the steel industry in Egypt has been experiencing a major change in its management techniques regarding the procedures that are carried out in steel production plants.

In order to fully grasp and comprehend the process of this phenomenon, one must first understand how the process works around the world in steel plants.

One must first understand the entire procedure of the steelmaking process for the research information to sufficiently analyze the management of its waste. Most importantly, it should first be defined as the act itself and in saying so, a definition of steelmaking is "Refining or removal of unwanted elements or other impurities from hot metal produced in a blast furnace or similar process or the smelting and refining of scrap and other forms of iron in a melting furnace in an Electric Arc Furnace (EAF)." (Patil, 1998). It is also crucial to differentiate between the steel making processes, as there exists various methods and are implemented differently globally. Many countries around the world use differing forms of technologies whereas in Egypt, they have similar practices to certain countries around the world but what is clearly a point of comparison is the 'way' or the 'means' of different industry processes.

The main scope of this research will focus on a specific steelmaking process that uses the EAF process of which it is highly known to be a process that causes certain by-products to occur as a result of this production method. The focus on Electric Arc Furnace is of high importance as it is the mainly used technology in Egypt and as such the focus on its byproducts will gain the most focus.

From a different point of view, the realm of enhancing the economic growth of a nation is argued that it is calculated by its industrialization. Research shows that rapid industrialization is sometimes not purely beneficial on the nation yet can cause amounts of distress on its environment as there occurs an increase of toxins into the atmosphere (Khunte & Mukuldev, 2018).

With rapid industrialization, there is an automatic increase of industrial waste, most of this waste has economic value which can be extracted, and as such correct management of them will entail proper stability and motivation for the industries to ensure practice of sustainable management will become more vital (Khunte & Mukuldev, 2018).

Focusing on the steel industry globally and locally, it is shown that steel produces large amounts of waste, whereby certain countries have dealt with in a proper way in the past decade, yet currently in Egypt due to the generation of high amounts of waste, management practices have yet to be developed efficiently.

To begin the concept of a 'Sustainable Management' has to be introduced to grasp the full issue of mitigation due to rapid industrialization. Sustainable Management is defined as an "intersection of business and sustainability." It is done to ensure long term profitability and prospering of the people, planet, and profit to support a business's long-term viability. Also. It is preventive rather than reactive. (Queenstown District, 2007) It also plays a role in the desire of a business to grow and creating opportunities for this is how protecting resources and valuing environment occurs.

1.1 The Steel Making Process

The steel making process has different processes, each require various energy levels and as such one process is seen as the more economically, and environmentally friendly process.

The two major processes that make up the majority of the worlds production of steel are the 'Basic Oxygen Furnace' (BOH) process and the 'Electrical Arc Furnace' (EAF) process. The first process that will be discussed is the Basic Oxygen Furnace process which has raw materials as inputs, this occurs by having coal dumped into the large ovens and heating is commenced, this process enables the alteration from coal to coke as the main gases are removed. Then, coke, iron ore, and limestone are added into the BOH, air is blasted to melt the ore, and when the ore is melted it is drained at the bottom, finally, the impurities rise to the top and as such they are glided off. The molten iron is then converted to steel by adding small amounts of scrap. Alloys are added, and as such molten steel is found at the top of the caster which required spraying of water to cool down the solid. The steel is then refined by coiling and roughing stands (Britannica, 2017).

The second process is the 'Electrical Arc Furnace' process employs scrap as the original input

and essentially the use of lesser energy is needed. The EAF process has been chosen and will be discussed in further details during this chapter, yet the reason behind this is as it has advantages that the BOH procedure does not including that the energy required for the EAF process is significantly less, and the raw materials required are also much less in the EAF process.
Figure 1 shows the consumption of the various inputs, energy, and carbon levels used as a comparison between the 'Blast Oxygen Furnace' process and the 'Electrical Arc Furnace' process. The levels used are significantly less in the EAF process which entails its route on sustainability, hence why this method was chosen for this research.

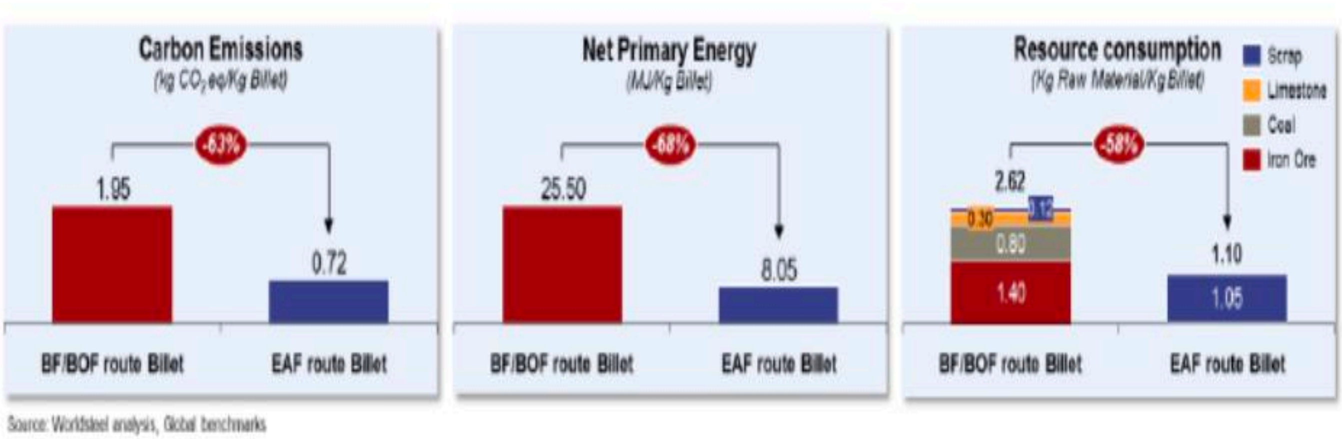

Figure 1 – Comparison of BF vs EAF routes on sustainability (NITI Aayog, 2018)

1.2 The History of 'Electrical Arc Furnace' process in Steelmaking

The history of steelmaking is a pivotal point in further understanding how far the industry has evolved by new technology, innovation, and research. Almost 4,000 years ago the first traces of steelmaking were said to have occurred, hence the use of steel was done to have stronger material than bronze in matters of weaponry. From that to date, it has seen some changes and the first documented was during the 19th century where a major turn of events showed the steel industry a new way of using oxygen in the process by Henry Bessemer in 1856.
Paul Heroult revolutionized the process by designing the EAF whereby certain heating would occur of around 1800 C which would allow the required heating of steel. EAF was found to be

cheaper in costs and as such lower in investment costs as they would use scrap to produce steel from; differing from the BOH which uses higher costs, today almost 33% of steel is produced using the EAF method globally (de Aduloju & Schalch 2014).

1.3 Steel Making EAF Process:

The ‘Electrical Arc Furnace’ is highly used across the globe as it is seen as a move environmentally friendly process than the BOH. The process as a whole must be understood to enable the understanding of the byproducts that are a result of this. The EAF is essentially where steel is melted and results in liquid steel, along with the inputs including differing chemical elements, and specific heating this process is completed.

The process of EAF is a slightly different path than that of the older generation steel production facilities, the first step of the EAF process is the ‘charge’, this is where scrap is placed into the EAF to make it the “major charge material” and as such the quality of the scrap is essential in this stage as it positively affects the end product (Brittanica, 2017). It also plays a role in ensuring that the steel is melted in good conditions. Lime and carbon are then injected during the charging process, and lastly it has a decreased amount of reheating needed in this process as a concept called ‘continuous casting’ (American Steel Organization, 2009).

The second step is the melting phase, which is the most vital phase of the process. From its suggested name one can understand that this is where the scrap starts to melt along with certain elements to have maximum melting capacity. The process of melting requires an abundant amount of energy which can be either electrical or chemical. During this phase, the arc commences the process by being unstable and erratic, then slowly stabilizes resulting in complete stability towards the end. The chemical energy used usually need oxygen in many amounts to have certain reactions with the scrap, which includes aluminum, silicon, manganese, phosphorous, carbon, and iron. All these reactions are correlated with the speed and efficiency the steel is melted. When multiple charges have occurred to ensure all the scrap has melted, tapping commences. Yet, sometimes a foamy slag occurs which has its advantages. Finally, samples are taken and as such chemical analysis is conducted to allow understanding of how much Ferro alloys are needed and the quantity needed for the next steps.

The third step is called the refining phase, this is where certain elements are taken out which were injected in the melting phase.

The following is a summary of most equipment needed for the entire process of the EAF that is needed for the manufacturing of steel:

“1) Electric Furnace,

2) Transport facility for ladle,

3) Scrap charging,

4) Auxiliary injection facilities,

5) Electrode movement mechanism,

6) Charging of raw materials and weighing system,

7) Slag disposal.” (Pretorius, 2009).

These have variations of organization yet in order to have optimum process from input to output, the above-mentioned bundle should be present and as such operation will work easily.

EAF are power intensive as opposed to the blast furnaces which need many gaseous fuels. EAF produces the needed requirements to melt the steel into the efficient grade or quality of steel.

The EAF process takes into it the scrap and with the help of differing charges of steel scrap and graphite electrodes produces electricity that is struck into the metal.

The method of how the EAF works is essential in order to understand how the process can aid in the sustainability of steel plants in Egypt.

Scrap is placed into the EAF whereby mixing occurs with the lime and dolomite in order to produce liquid. The liquid phase is reached through the help of electrical currents, then removal of certain elements is done including phosphorus, aluminum, silicon, and carbon. This removal is aided through the addition of lime and dolomite. After all the removals and reactions of these elements liquid slag is formed and this is the stage whereby the gases have a factor of contribution to the end quality of the slag and the impurities becoming seen. Finally, during the tapping stage, steel is drained and lastly the molten slag is solidified, this is the stage where multiple uses of slag become available.

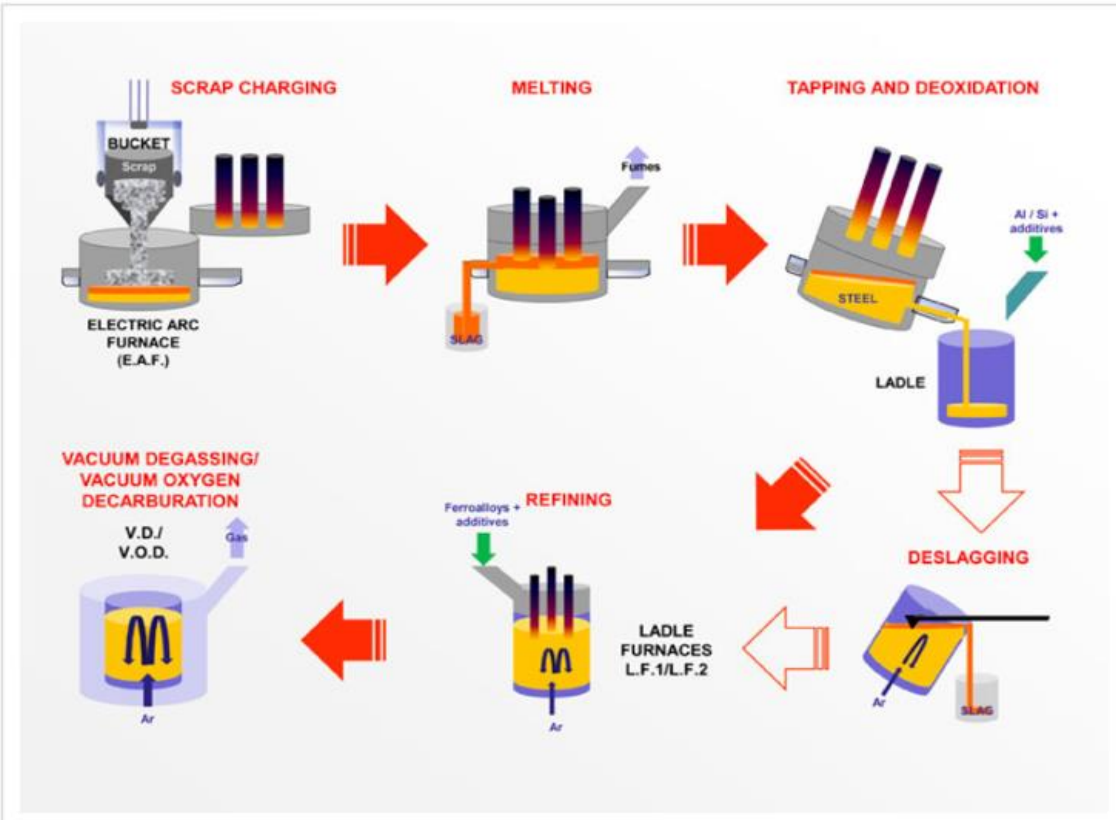

Figure 2 - The EAF Process (Warrian, 2012)

Figure 2 highlights the 'Electric Arc Furnace' process in a simplified way showing the different stages of what occurs from the moment scrap is added to the furnace to the last stage that finishes with steel being produced.

The EAF has lower maintenance CAPEX and as its new technology, its ability to use scrap in the furnace is another benefit. Therefore, the investment shifts into EAF are highly amicable and much needed in the days to come (NITI Aayog, 2018).

1.4 Inputs in the EAF Process:

The main input that goes into the EAF is scrap. Scrap according to the Steelmaking and Refining Volume is "an energy intensive and valuable commodity, comes primarily from three main sources." (Patil, 1998).

Scrap comes from various sources yet the most commonly used are three which include reclaimed, industrial, and revert scrap. These different types of scrap have various sources as to where they are acquired from. Reclaimed scrap is usually acquired from cars, buildings, and old machinery that is either obsolete or unused. Whereas industrial scrap is acquired through any industry that uses steel in its production process and is left again unused or thrown away. Lastly, revert scrap is the one generated through the steel making process, which include rejects or excess steel after the efficient amount is placed inside the process. The most scrap that is used in the steel making process are industrial and revert scrap as their actual chemical composition is the most guaranteed for molten steel composition. Reclaimed scrap has certain compositions that do not make it efficient to be used in the steel making process including certain issues that affect the quality of the product (Patil, 1998).

It is also worth mentioning that the quality of the scrap also plays a big role in the melting process, which can also be defined and categorized into different grades of scrap.

In addition to scrap, another major input is carbon. Carbon is vital as it is the decider of the grade the steel will acquire. Carbon supplements the steel with energy efficient amounts that are needed in the process. In the EAF process carbon is required in more amounts, as the chemical reaction that occurs during the process, supplies a decrease in the amount of electrical power consumed, along with the reduction it also contributes to the lower concentration levels in the gases, which is a beneficiary (Patil, 1998).

1.5 Outputs in the EAF Process:

The steelmaking process shows that the generated waste has been broken down into two types, which include processed waste and non-processed waste. The differing by-products include various generations of waste and those include but not limited to, "slag, dust, GCP, sludge, scrap, refractories, scale, muck and debris, etc. Other than GCP sludge all other waste materials are usually generated in mixed condition" (Ambasta et al., 2016). Non-processed waste includes materials of glass, electric wires, and other materials.

One of the outputs in the steelmaking process is slag. Slag is defined as "a non-metallic product, consisting essentially of calcium silicates and ferrites combined with fused oxides of iron, aluminium, manganese, calcium and magnesium that are developed simultaneously with steel in basic oxygen, electric furnace, or open-hearth furnaces." (Fronek, 2012).

With reference to the above types of byproducts, the main focus of this research will be heavily skewed towards slag and dust as they are the by products that are generated the most during the process and have potentially the highest significance in either recycling or reselling for a more sustainable approach of the industry as well as having a negative impact on the sustainability of the industry as a whole. Approximately 15% of slag is generated in the of the EAF steel making process (Rastovcan-Mioc, 2015).

Figure 3 shows the byproducts of the steelmaking routes in comparison to their generation in the BOH process and the EAF process. The figure highlights the amounts of byproducts generated as per the process and shows that the generation of them are high in numbers in the 'Blast Oxygen Furnace' model, but also are generated abundantly in the EAF process.

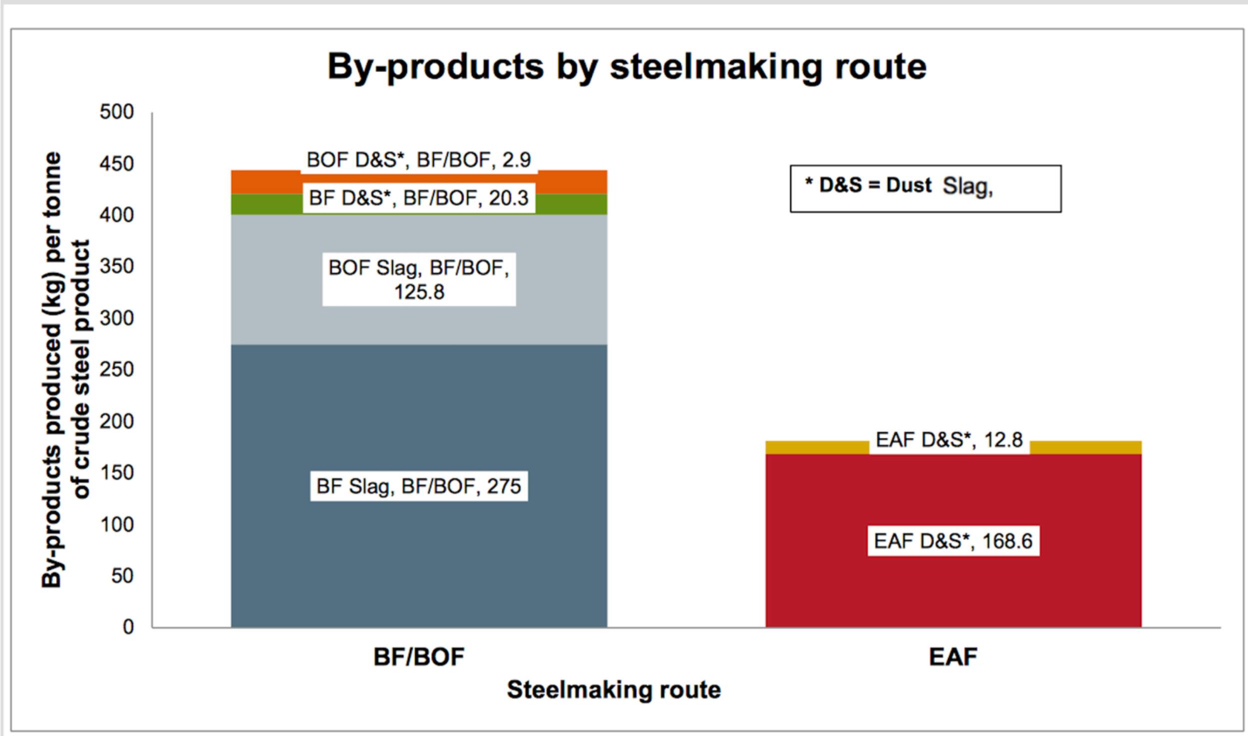

Figure 3 – Byproducts of the Steelmaking route (World Steel Association, 2009)

1.5.1. Slag Generation in the Steelmaking Process:

When slag is generated there are multiple processes that occur for the choice of reusing or recycling or even disposing of it. The differing processes can be broken down into four assorted stages, these stages are as follows as per Rastovcan-Mioc's application of EAF Slag study:

1) Cooling of the molten slag, sometimes solidifying the molten slag
2) Recovery of the metal irons found (which are rich natural resources)
3) Crushing of the slag which aids in the classification of slag
4) Aging of the slag to improve the overall quality of it.

It is important to solidify and cool the slag in stage 1 as it comes out from extreme high temperatures, this process could either be air cooled or water cooled. Not all plants go through with this sort of cooling as it is high in time consumption and in addition to the fact that time is a key factor in the actual process (Rastovcan-Mioc, 2015).

Stage 2 which deals with the recovery of the metal irons, is also important as it entails that some natural resources are preserved throughout the process, these irons can be used in other processes.

In Stage 3 the process of crushing of the slag is also vital as it counts for the recovery of iron as sometimes certain irons are found to be impure and as such actually affect the grade or quality of the final product. Crushing also is important as it is the stage that the slag is often specialized in order to be efficient for the customer; this process occurs by crushing and as such adjusting the slag grain size.

Finally, Stage 4 which is the aging treatment has two different methods, one is by allowing the hydration to take place through natural rainfall on the yard where the slag is placed or by manually placing some water and leaving it to air dry.

The global steel industry has been seeing a vast increase in its production in the past few years, this is due to changes that have been occurring worldwide. The steel industry has seen a leap in numbers and reached around production of 1,629 million tonnes worldwide, with consumption reaching 1,600 million tonnes (Deloitte, 2017).

1.6 Aim

The aim of this research is to develop a sustainable steel industry in Egypt through a theory that is called a 'Cradle to cradle' concept. The cradle to cradle can be introduced as a creation of a continuous flow of materials, where valuable materials are reused and not disposed of.

This approach is essential to conserve natural resources and save the environment from the negative impacts of waste disposal, in addition to yielding economic benefits in many industries (ElHaggar, 2007).

The proposed field of application include using the EAF slag as aggregates for pavement production instead of the natural aggregates and the benefits of utilizing these waste products into more viable options. A focus on the EAF dust is also vital in implementing best management practice to not harm the environment further.

The main objective of this research is to fully sustainably manage the byproducts of the steel industry in Egypt by:

1) An overall change of management of EAF slag and its current uses to be examined
2) To recommend an alternative management practice,
3) To analyze potential cost and feasibility studies of the reutilization of EAF slag by a processor in particular products and the extraction of zinc from EAF Dust to better manage its reuse.

2.0 Literature Review

2.1 Sustainability

Sustainability is defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 2009).

The definition of sustainability is a key factor in being able to fully grasp a vision of a sustainable steel industry. At a glance, sustainability is a major concept affecting the world today, with many of the resources decreasing and the world population increasing a long-term fix is needed in all aspects of life. Population growth entails a dire need in increase of supply as the demand naturally increases for goods and services.

Sustainable Development has been growing over the years and this is shown in the adoption of the UN Sustainable Development Goals expanding the goals from 8 to 17 in total whereby encompassing the new needs of the globe. The new goals have a wider variety of production sustainability and a detailed scope of the workforce, sustainable industrialization, and fostering innovation which in the end is an important factor to consider during this research.

As such, the concept of a 'Sustainable Business' comes to life as the world needs practices that will help elongate the cycle life and the longevity of the product itself. It also showcases the comprehension of why the world needs more businesses turning sustainable as the future need of generations are reliant on the capacity and innovation of the present ones.

According to Dyllick and Muff (2015, page 2), a 'Sustainable Business' is defined as "managing the triple bottom line - a process by which companies manage their economic, social and environmental risks, obligations and opportunities. These three impacts are sometimes referred to as profits, people and planet." Accordingly, sustainable development in an industry must focus on the broader aspect of economy, society, and environment. Dyllick and Muff (2015, page 3) state that there are different practices that focus on aiding a business in becoming more sustainable which include: "Stakeholder engagement, Environmental Management style, reporting and disclosure, and life cycle analysis". These various types of implementation methods for a business to reach a more sustainable cycle in its processes. Dyllick and Muff (2015, page 5) also highlight that businesses "that are sustainable have been shown to attract and retain employees more easily and experience less financial and reputation risk. These firms are also more innovative and adaptive to their environments."

A widely used method of sustainability as mentioned is 'Triple Bottom Line' concept whereby it takes all aspects of the economy, society, and environment into consideration when enhancing business performance. The 'TBL' concept is a framework that basically deals with people, planet, and profit. This framework is unique as it takes into account all three pillars of sustainability, this framework plays an important role in attempting to conceive a sustainable steel industry in Egypt, as each factor in the TBL model should be used accordingly to gain positive impact on this industry. The TBL model "captures the essence of sustainability by measuring the impact of an organizations activity on the world, including both its profitability and shareholder values, its social, human, and environmental capital." (Elkington, 1994).

2.2 Management Practices of Steel Byproducts

The reuse of steel according to the World Steel Association requires that an end of life steel is not re-melted and enter a new phase of production.
Accordingly, in the United States, around 33% of straight rail is recycled and over 340,000 tonnes of rail were reused which showed a CO_2 saving of around 811,600 tonnes that has a high economic value and can be profited from through the business in reducing costs which would turn in turn profit the business in many ways (World Steel Association, 2009).

Steel scrap is highly used in making new steel, more than 475 million tonnes of steel in the US was transferred to recyclable streams in 2008 (World Steel Association, 2009).

Table 1 – Steel industry Recycling Rates in the United States for 2050

Market	2007 (est.)	2050 Target
Construction	85%	90%
Automotive	85%	95%
Machinery	90%	95%
Appliances	50%	75%
Containers	69%	75%
Total	83%	90%

(Morfeldt, Nijs & Silveira, 2015)

Table 1 shows the estimated real and targeted amounts of recycling that occurs during the steel production process in the US in 2007 versus 2050. These figures correspond to around 68 million tonnes less CO2 produced or emitted which will also impact costs. Finally, the saving of around 1,200 kg of iron ore, 51KG of limestone, raw materials and energy are immense and great impact on the costs savings (Morfeldt, Nijs & Silveira, 2015).

2.3 Management of Slag

There are different slags that occur from the various technologies used in steelmaking. Air cooled blast furnace slag is found in plants that use the Blast furnace operating system. This process essentially deals with water hitting the slag and the reaction itself which in the end provides the slag becoming stronger. This sort of slag is reused in roads such as gravel, and concrete, and as such no impurities are found in this slag.

Granulated blast furnace is used in cement and deals with reactions with water also. It is used in construction and has high durability and as such is efficient in its reuses.

Finally, Steelmaking slag; which is the slag type this research will be focusing on; is usually used in road-based material as its composition are high in density and hardness and as such is used in asphalt concrete. This type of slag has high resistance which makes it ideal for its reuses.

The EAF slag have differing categorizations which fall under either the slag that is produced via carbon steel or stainless-steel production, in other terms EAF C and EAF S consecutively (Euro Slag, 2010).

Slag is classified as a non-hazardous waste and is usually put into landfills. This is usually the case in Egypt. This process is expensive and can be dangerous to the surrounding environments (Rastovcan-Mioc, 2015).

The different uses of slag around the world differ, but as shown in figure 4 below, the major use of slag is road construction at 48%.

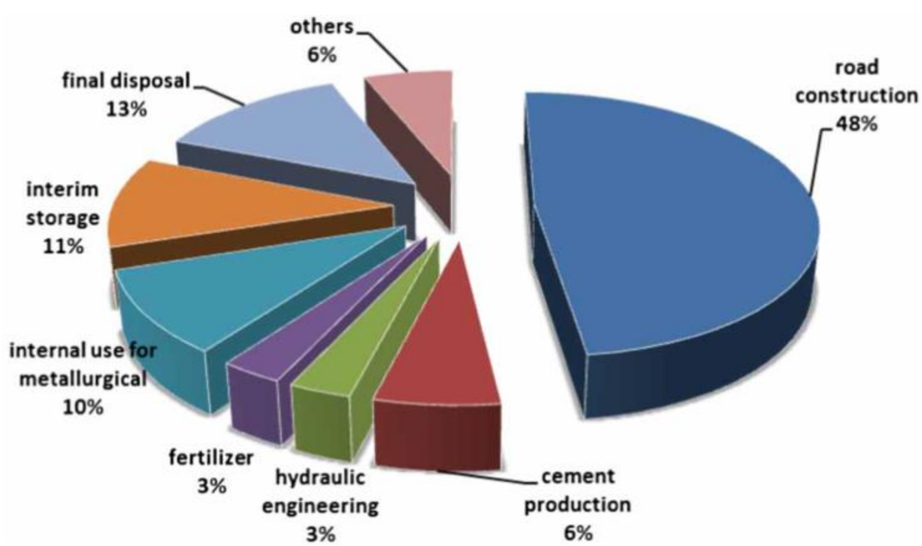

Figure 4 – Uses of slag Across the Globe (Maghool, Arulrajah, Du, Horpibulsuk & Chinkulkijniwat, 2016)

The reuse or the application of slag as opposed to burying it in landfills or disposing of it which is costly not only on the company yet on the environment also is a highly amicable alternate to the existing process. The various reuses/applications of slag will be discussed in more details with a concentration of the methods that are done in Egypt and how they are more sustainable.

Application in the cement industry is of high percentage around the globe, as slag can be used as an aggregate in road base courses. This is efficient as it is able to decrease amount of needed natural resources.

According to Chandana, steel slag is the way to be more economical in the construction phases. The advantage of these EAF slags is that across the world the actual natural aggregate is becoming scarce and as such cannot be found easily, whereas adding slag to the ground can be the way into conserving resources and enhancing the protection of the environment as well as diminishing waste that would have been placed into the environment (Chandana, 2012).

As Chandana has demonstrated that the reuse of slag is underutilized globally, whereas it can be used in the following sources:

“Cement production, concrete aggregate, asphalt aggregate, road bases, soil stabilization, steelmaking, fertilizer production, linings for waterways, landfill daily covers, railroad ballast.” (Chandana, 2012).

EAF steel slag as mentioned above is a non-hazardous waste, and by such there is potential to place it in an area that will not have any negative impacts on the environment, hence why this method must be rigorously studied and implemented, also the cost of the correct placement is extremely high and as such not all companies have the ability or the social responsibility awareness of disposing it correctly. The reuse of the steel slag has a potentially beneficial aspect from an economic, social, and environmental point of view (Sofilic et al., 2018).

As the steel slag has lime content, the process of processing the slag is of extreme importance, there are multiple ways of processing it, either by normal ageing treatment, this is where a hydration reaction occurs by natural rainfall on to the slag in the yard, or by accelerated ageing treatment whereby the hydration is induced. The lime content in slag must be brought down to normal levels in order to use it as an aggregate in any construction methods.

The normal ageing treatment is a slow process and would take time whereby the more time is waited the less effect the steel slag might have and might even have restrictions to its usage (Khunte & Mukuldev, 2015).

2.4 The Practice of Management of Slag Internationally:

There are current practices of recycling methods that take place across the globe when dealing with steel.

As Khasreen shows, there are three approaches to recycling during the steel process. These include the 'Cut-off Approach', the 'End Life Approach' and the '50-50 Method'.

The 'Cut-off Approach' essentially shows the differing benefits of the process (Khasreen, Banfill & Menzies, 2009). It is said that the metal scrap does not have impact on upstream environments after the re-melting occurs. This shows that the process considers the input side as the benefits of the metals are only seen from the input and not beyond which also neglects the end of life even if the rate of recycling is high; also known as 'recycled content method' (Khasreen, Banfill & Menzies, 2009).

The 'End Life Approach' is another method that takes the assignment of environmental impacts and credits that "between different product systems across different life cycles and the environmental impact of the product system is dependent on the recycling rate at end-of-life." (Khasreen, Banfill & Menzies, 2009). This is also known as a 'closed material loop' method as it aids in the redeeming of the materials that are still in their first phase of life.

Lastly, the third approach the '50-50 method' compromises both input and output recycling. It is seen as a solution for systems when one is not clear on whether it is beneficial to pay or receive payment for recycled content or recycling at end of life products. (Khasreen, Banfill & Menzies, 2009)

In the framework of current steel recycling practices globally, there are two phases during which this occurs, the first being during the 'primary production' whereby the blast furnace and iron ore are extracted and processed into the basic oxygen furnace, and secondly the 'secondary production' which occurs when the route of recycling goes through the Electric arc furnace which melts the scrap which is the input product into new steel (Khasreen, Banfill & Menzies, 2009).

According to Khasreen, steel is 100% recyclable and he states that scrap is changed to graded steel depending on the raw materials that are in the product. Scrap with a low number of residual elements have a higher market price as a result of the facilitation of processing (Khasreen, Banfill & Menzies, 2009).

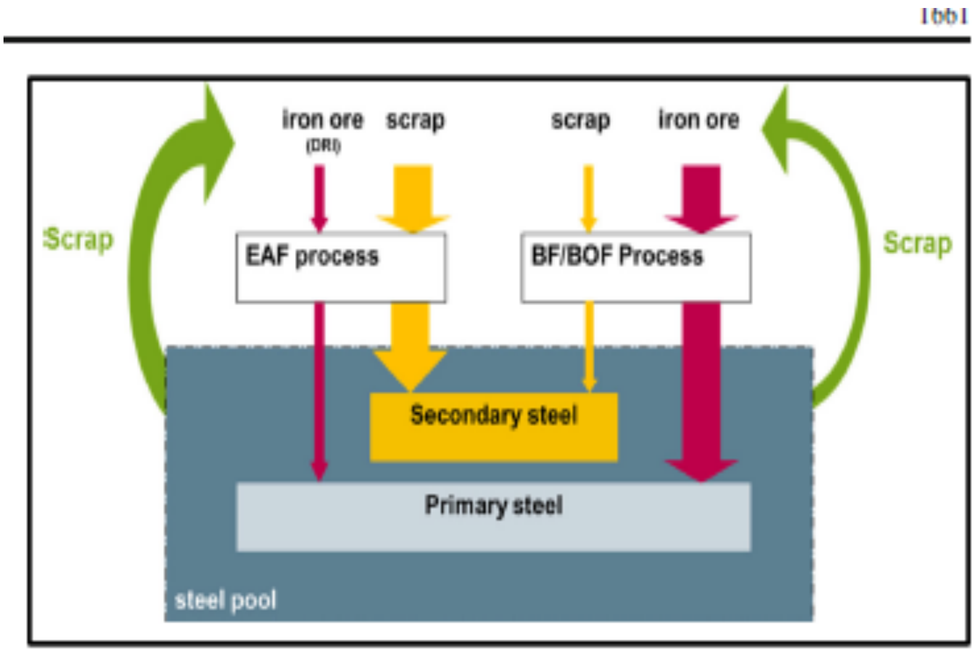

Figure 5 – Scrap And Steel process (Khasreen, Banfill & Menzies, 2009).

Figure 5 showcases the process of how scrap can be recycled into the steel process.

According to Khasreen, there are various types of recycling during the steel making process to better profit the business and these include:

- "Allocation for scrap inputs to the steelmaking process.
- Allocation for steel scrap outputs from whole product system," (Khasreen, Banfill & Menzies, 2009).

Research conducted in India has shown the beneficial impacts of the reuse of byproducts in the steel making process which include:

- "Solve the waste disposal problems created by land bans
- Reduce waste disposal costs
- Reduce costs for energy, water and raw materials

- Reduce operating costs
- Protect workers, the public and the environment
- Reduce risk of spills, accidents and emergencies
- Reduce vulnerability to lawsuits and improve its public image
- Generate income from wastes that can be sold." (Ambasta, et al. 2016).

There are various types of wastes that occur during the process of Steel. The beneficial aspects of these wastes are important as they show whether or not the reuse of them is an advantage to the industry or not.

The Blast furnace waste produces slag, the BF Slag is important as it is used for concrete aggregate, sand, glass, filter. Whereas the BF dust that is produced has high amounts of iron and zinc which can be reused in the process of glass, ceramic, and cement production.

Basic Oxygen Steelmaking slag is used as road ballast and land fillers, whereas the dusts can be used in the BOH process as they are "self reduced pellets" (Khunte & Mukuldev, 2015).

There are multiple types of reuse of slag during the steel process which show that instead of throwing the slag, one can reuse the material in fertilizers or soil improvements (Horri et al., 2013).

Finally, EAF dust is recycled using sintering in which almost 2% is produced in the production of steel, around 10% - 15% of EAF slag is produced during the steel process, which in large capacities is abundant for reuse in other processes or industries.

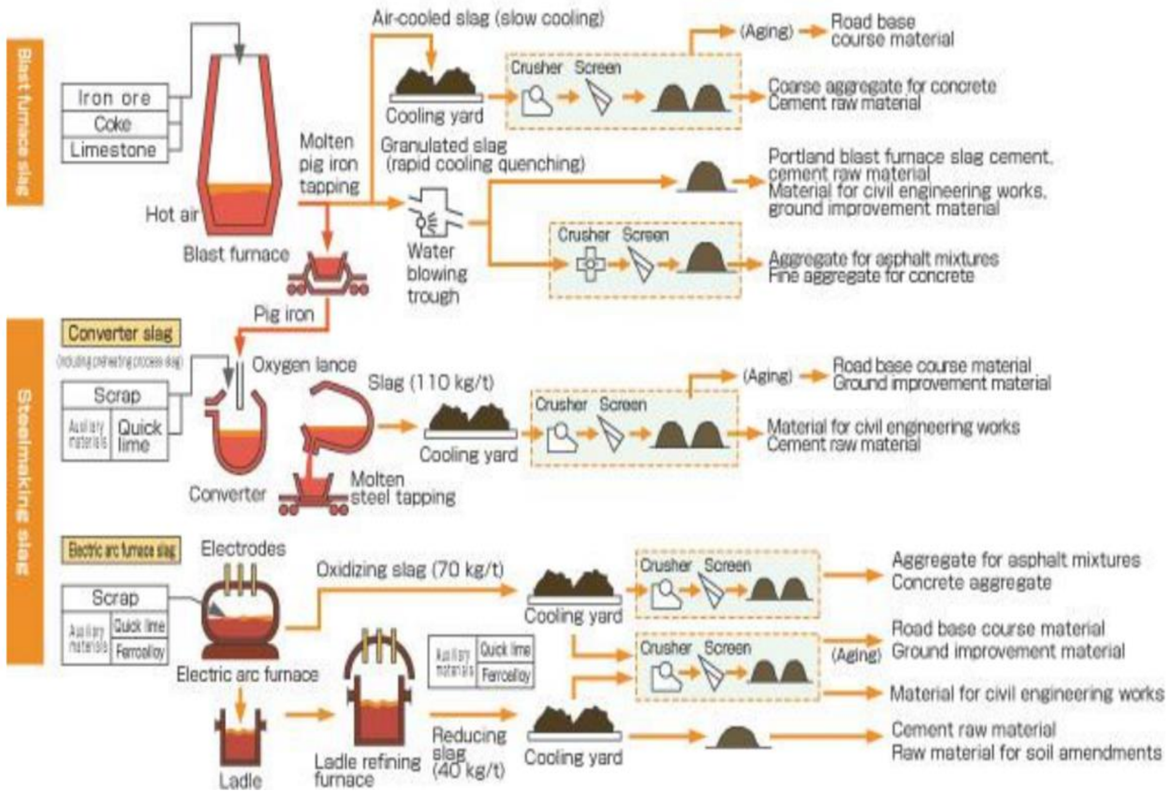

Figure 6 – Typical Slag generation and Utilization (Horri, et al. 2013)

Figure 6 shows the different practices across the globe and how steel slag is utilized around the world with its end results (Khunte & Mukuldev, 2015).

Research shows that the increasing methods of reducing energy use by enhancing the steelmaking process is vital and is done through some methods that contain the recycling of the products, and the use of byproducts from steel that yielded more increases. (World Steel Association, 2009)

One of the main reuses includes cement making, slag is taken from the steel industry and sold to the cement industry to find better ways of disposal and reusing it in the production of cement. Countries around the world are already using this method, including Japan, China, Germany (Ambasta, et al. 2016).

The major uses and means of reuses of byproducts in the steel melting process include many utilizations of waste that are beneficial and profitable for either the same company or another. These include various economic advantages, the saving of raw materials, conservation of resources, cleaner environment, reduced cost of disposal, and conservation of energy to name a few (Ambasta, et al. 2016).

There are multiple ways of recycling steel production byproducts from which a steel production company can profit. There are certain methods that need to take place for to be reused, the first procedure includes 'Slag Atomisation' whereby the slag is converted into small spherical balls that are placed under water and high air blowing systems. These atomization methods are efficient methods of utilizing the molten slag in the most economical way (Ambasta, et al. 2016). Slag can be reused as rail ballast which is a way in finding suitable quality that is used into railways. They are also used in road and pavement material as they are an aggregate for the building of pavements. There are multiple researches that show that by enhancing the level of slag, the road making material would be much more efficient (Ambasta, et al. 2016).

In Europe the production of slag are around 12 million tons. 35% of the slag produced is thrown/dumped into the surrounding areas. This percentage is still high as there are negative aspects of this dumping.
In Germany they have an efficient reuse of steel slag with a high percentage of 93% whereas only 7% is disposed of. One of the reuses of slag that is used in Germany is as aggregate for road construction. The need for certain characteristics is vital as they must be up to par in order to withhold all types of environmental hazards. The elements in the steel slag hence play a factor in whether or not it can be reused, these include the specific amounts of lime and magnesium that affect the use of slag in road construction (Motz & Geiseler, 2001). Germany has used around 400,000 tonnes per year as aggregate from steel slag (Motz & Geiseler , 2001).
Properties of the road construction must be strong enough to deal with forces hence the steel slag must have properties that match the following:

"Bulk Density, shape, resistance to fragmentation, strength, water absorption, resistance to freezing and thawing, volume stability, and resistance to abrasion and polishing." (Motz &. Geiseler, 2001).
These factors are important as across the world various environmental conditions are present and as such the aggregate must be strong enough to endure weather conditions and as such remain

intact. The reasons behind slag reuse in construction is of vital importance to be viewed, especially with the success rate in Germany being this high, one should consider why the world is not practicing or following in their footsteps. With the high percentage of slag being reused in other construction material, it should be an indicator to other countries to research the reason behind this method practice. There are benefits for reuse of slag which have been stated and show that the overall longevity of roads has an elongated lifespan compared to using natural aggregate.

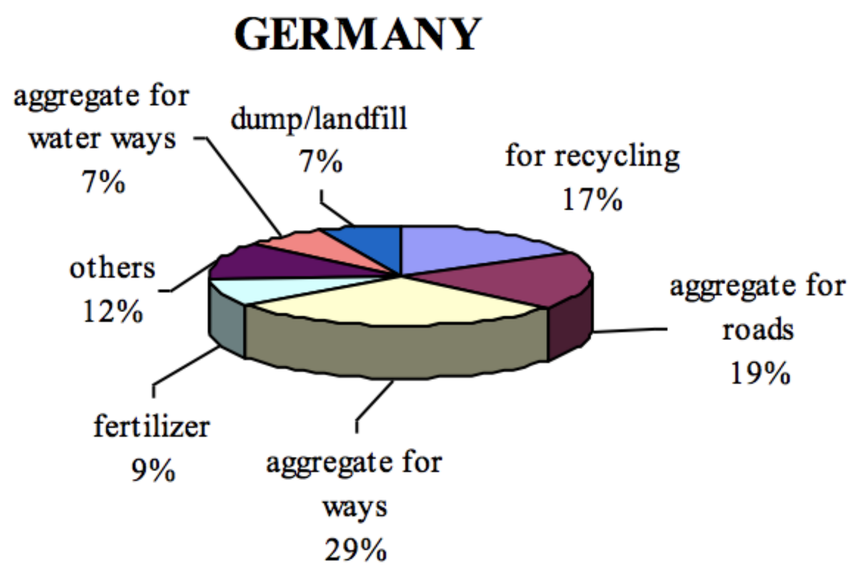

Figure 7 – Slag management practices Globally- Germany (Hosseini, Soltani, Fennell, Choong & Aroua, 2016)

As shown in Figure 7 inn Germany around 48% is used for roads and ways, whereas only 7% is placed into landfills.

In Greece, certain applications of slag have gone underway that pave the idea that it is viable. The case study has shown that there are certain benefits to the reuse of EAF slag in construction and as such have a positive impact on the environment and economy. Under differing degrees and processing, steel slag is beneficial when reused in aggregates instead of natural ones, it has the ability for heat retention that is higher than one using natural aggregate, it is also a solid ground for mixing with hot mix asphalt construction. Because of its characteristics of having frictional and abrasion resistance is makes the steel slag a valid substitute for industrial roads (Havanagi et al. 2012). According to Horri et al. (2013), who carried out a case study in Japan, the reuse of slag in fertilizers and soil improvers were around 0.5% of the total consumption of steel slag (Horri et al, 2013).

In China, where some of the highest production of Steel occurs, according to Hue Chen, around 626.7 million tonnes of steel was produced in 2010 which in such produced around 7% slag (90 million tonnes). However, with this generous percentage of slag production, only 22% is used which is an indicator that something must occur as in the more developed countries the percentage of utilization is much higher, at around 98%. The main utilization of slag globally in developed or more industrial efficient countries has gone to road utilization with around 50% of the slag produced being mainly used in the production of concrete and road construction (Chen et al). This shows also a major point as China has one of the highest growing economies in the world and the need for massive optimization of utilization of wastes in order to preserve natural resources is vital.

The beneficial aspect here is that slag has extreme levels of strength and durability and as such the processing of it make it available to be used as aggregates in the construction phases.

In India, the slag production is reaching around total of 42 million tonnes annually, with EAF slag accounting for 6 million tonnes annually, whereas it is expected to reach more than double by 2030. This is due to the high levels of population growth and demand that India is facing today. This also states that roads and areas are expanding and as such more aggregates are needed. The common practice in India shows that around 30-40 million tonnes of steel slag is being buried or left in steel plants across the country, therefore a potential need to utilize the steel slag.

Currently in India, only about 25% of steel slag is being used, this shows that India is lagging and this is a lower number than the globe and as such the potential business behind the reuse is extensive and massive, which makes it a market potential.

In the Indian sector, they have shown that they are researching for more ways to minimize the actual generation of waste, and recycle the ones that do get produced, this is done through extensive research as to how the sources are produced, the quantities of them, along with the types of byproducts produced

In Poland, a case study carried out on the possibility of having a ‘Zero waste steel industry’ was conducted to see the extent to which it is viable. The case stated that many of the benefits from an environmental point of view are that recycling of by products in the steel industry essentially save on natural resources, and reduce the greenhouse gases produced, saves energy, and finally reduces the amounts of space needed for landfills or occupancy of landfills decreases also. It is argued that recycling of all the elements produced in waste of steel industry is possible, yet with huge financial investments and new and innovative technology. What Poland has in place currently is a system whereby there are centers that are progressively and proactively finding new methods on dealing with byproducts in the steel industry. These are sent to the companies producing in Poland in a method to promote cleaner production in the country (Smol, 2015).

Qatar Steel produces slag of around 400,000 tonnes, which is a large amount of slag to be produced. As per the case, it shows that the slag is not utilized efficiently and as such puts a burden on the company to dispose of it. Accordingly, it is shown that Qatar usually imports aggregate as they are an expanding country with many new construction projects which require many materials. As such, the importation from neighboring countries occurs for efficient aggregate whereas one can reuse the slag produced in large amounts from the industry for these matters (Taha R, et al. 2014).

A case was carried out and found that the efficiency of the reuse of slag was successful, yet multiple issues were cited as potential threats to the theory, including not having to use 100% of steel slag as in certain cases causes some deterioration of the actual final product especially in countries with high intensity of heat, which was the case in Qatar.

A similar case was found in 1995 in the United States, when cracking of the pavement was seen, yet after further investigation it was found that an excess amount of lime was placed during the processing of the steel slag and as such caused certain expansion when it came into contact with water.

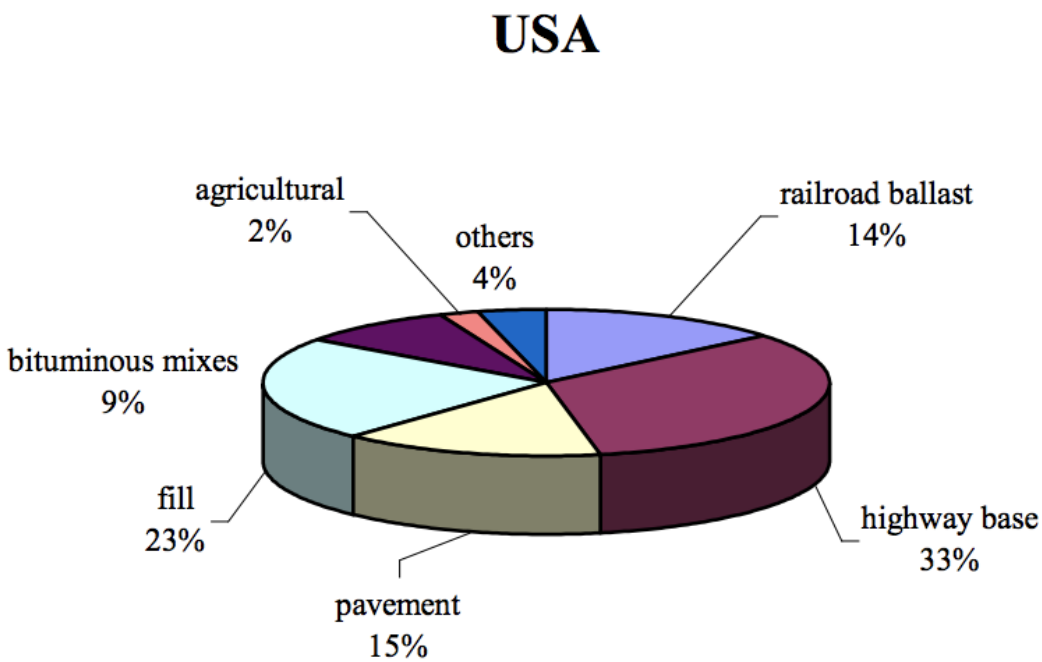

Figure 8 – Slag management practices Globally- USA (Hosseini, Soltani, Fennell, Choong & Aroua, 2016)

In the USA almost 62% is used for road construction material whereas other practices are at 4%. This indicates that there are certain technologies around the globe not found in the other countries to reuse the slag in an efficient and cost-effective way and as such must be studied extensively and even find training facilities to expand the knowledge of individuals who should be implementing these sorts of practices around their industries. This can be done through governmental involvement of attaining the best from different countries to come transfer their knowledge to individuals across the globe.

Turkey has production capacities that are not immense in numbers, yet it utilizes its waste in an efficient way. They have made profitable investments into processing machines and methods to integrate the waste produced in the steel production process into other industries and not disposing of it in non-environmental ways.

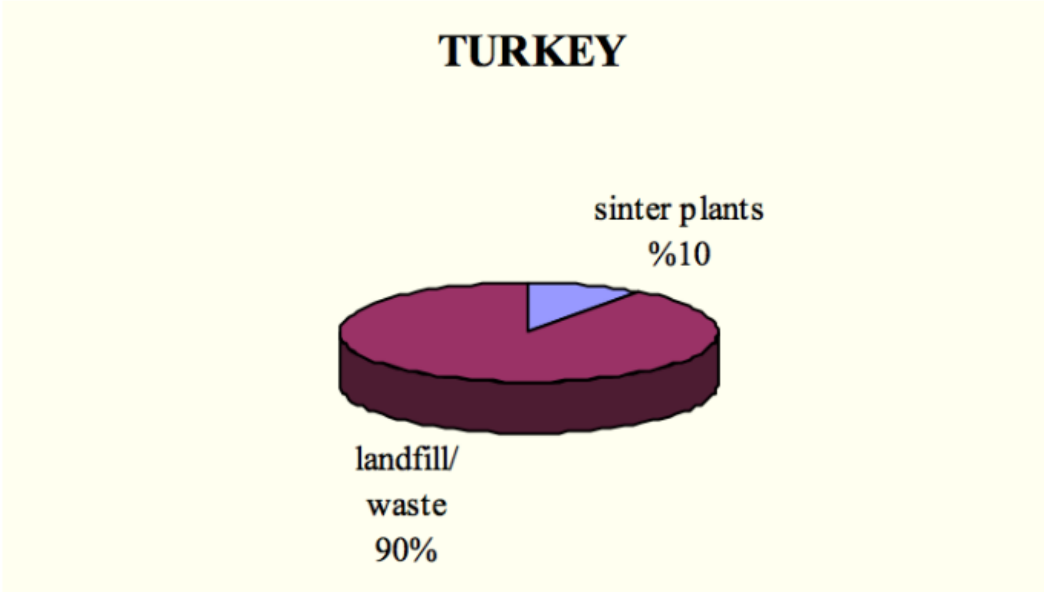

Figure 9 – Slag management practices Globally – Turkey (Hosseini, Soltani, Fennell, Choong & Aroua, 2016)

As seen in Figure 9, the usage of steel slag in around the globe differs from the lesser developed countries.

Turkey has an extremely high percentage of placing the slag into landfills with 90%, yet this was based during the early 21st century and as will be discussed further on, it shows that Turkey has made an immense effort and has started the correct utilization of their slag.

Table 2 – Top Five steel producers in Europe and Slag Generation

Country	Annual production (10^6 tonnes)	EAF Slag generation (10^6 tonnes)	LF Slag generation (10^6 tonnes)
Germany	42.90	1.63	0.39
Turkey	34.00	2.97	0.71
Italy	23.70	2.15	0.52
France	16.10	0.69	0.16
Spain	14.20	1.25	0.30
Based on 125 kg EAF slag/t LS and 30 kg LF slag /t LS			

(Smol, 2015)

Table 2 shows the countries with extensive generation of EAF slag, with Turkey having a high number of generations, the reutilization is vital in understanding.

Table 3 - Highest Reuse of Slag worldwide through case studies

Country	Highest Reuse Industries
India	Fertilizers
	Cement
	Road Construction & Concrete
	Landfills
Japan	Fertilizers
	Cement
	Road Construction & Concrete
	Coral Reefs
China	Road Construction & Concrete
Germany	Road Construction & Concrete
	Fertilizers
Greece	Road Construction & Concrete
Poland	Sent to Outsourced Companies to deal
Qatar	Unutilized
United States	Road Construction & Concrete
Turkey	Road Construction & Concrete

Table 3 is a summary of each examples highest reuse industries.

2.5 Benefits of Recycling EAF Slag:

Recycling of the EAF slag ensures that natural resources are saved as well as that the acidic levels become neutralized with the use of slag. The fact that steel slag has the certain chemical and mechanical characteristics make it stable enough for certain binding properties with bituminous materials. It also increases the performance of pavements as it endures high temperatures.

More benefits include that the use of EAF Slag as an aggregate in construction ensures an increased level of skid resistance, which in turn shows a longer lifespan and resistance to the degeneration of the current pavements, it also requires less maintenance and as such replacement is not needed in the short term as its lifespan is quite long. Along with that, the slag aggregate has found that it has less noise levels, and has good resistance to water permeability which is ideal in countries that see a lot of rainfall, and in low temperature countries also has higher resistance to cracking (Lim, Chew Choong, Teraza & Yazdi, 2016).

Using the aggregate into pavements as mentioned has certain advantages that the normal pavements with normal natural aggregates lack. Along with its high ski resistance, it shows a resistance to water, resistance to the stripping in the presence of moisture, resistance to rutting, increase stiffness, increased stability, an increase in fatigue resistance, another resistance to permanent deformation, increased levels of cohesive strength, electric currents and conductive, and finally it was found that it is compatible with normal asphalt binders.

The advantages found were that high-volume expansion can occur potentially in the presence of moisture, steel slag has a porous structure and as such found an increase in binder demand (24 %-30%), having high specific gravity found that it results in lower volumes of the mix and higher transportation costs, overall the higher cost of applications.

When used in cement concrete pavements, it was found that there was better abrasion resistance, lower permeability as a whole. However, it was found that volume expansion occurred, and high density had heavy concrete more than normal, and higher porosity levels which made it need higher water demand (Washington State DOT, 2015).

As the industry grows, there is a scare regarding what happens with the slag that is produced, the burial of this product in landfills requires dire attention to attempt to stop this process as a whole, the process of the use of landfills is becoming a controversial one as it is affecting the natural elements of the earth along with health of humans. Along with the fact that the cost of disposal is increasing globally with more countries becoming environmentally conscious and the topic of depletion of natural resources becoming a popular one there is more of a need now more than ever to find solutions to the by-products (Boin et al. 2004).

A benefit of steel slag is that it is viewed as a secondary source of raw material, hence this can be reintroduced into the steel making process and the elements can be recovered which can be useful for other sources. It also shows volume stability which in turn does not have a direct impact on the environment by leaching. Another use of steel slag is that of the powder that comes out as a wastewater treatment, which lowers the cost of treatment (Boin, et al. 2004).

The byproducts from steel slag as such can be reused in natural aggregate form, which in turn shows more benefits that are showcased when using the slag as an alternative to construction materials (Venkateswaran et al, 2007).

As the world is facing a diminishing source of natural resources, the reuse of by products is becoming more of a vital solution more than ever. The use of slag in concrete and aggregate as mentioned should have specific mechanical properties, as they need to be strong, they should also have flexural strength, and high-water penetration.

2.6 International Management of EAF Dust:

Unlike EAF Slag, dust poses a huge health risk onto the people and the ecological wellbeing of the surrounding environments as it contains chemical elements that are hazardous to society. Therefore, the correct maneuver of dealing with dust is vital as to not increase the harm of it.

EAF Dust is a problematic issue in the EAF plants, it is produced during the melting stage and as such needs to be collected efficiently by using filters or electrostatic precipitators. The high levels of zinc in EAF dust make it a valuable commodity to be processed or extracted for reuse or to be sold to differing industries, as the cost of disposal of the dust has become more expensive and the methods more complicated (de Araujo & Schalch 2014).

EAF dust is produced as mentioned during the melting phase, this is due to the vaporization or metals, and CO bursting bubbles, and certain other materials in the furnace. Due to the EAF having extreme high temperatures, this vaporization is issued and as such the production occurs. As the dust is produced, it is in a form of particulates and as such it is then collected via the baghouse. Scrap plays a role in the composition of the EAF as certain quality levels showcase various levels of EAF mineral, chemical, and physical composition (Buzin, Heck & Vilela, 2017).

EAF Dust contains chemical elements that include iron oxide, and high levels of zinc, which is a major contributor as to what can be extracted and also is one of the reasons behind why EAF dust is highly hazardous if not dealt with efficiently, along with certain metals including lead and cadmium, is also a reason as to why EAF dust is considered highly hazardous. It is said that the composition of dust varies from heat to heat and not daily (de Araujo & Schalch 2014).

Around 2% of dust is formed during steel production, which in larger quantities poses a higher threat to the environment and society. As such application methods are vital as they decrease the chances of negative impacts on the ecology (Rizescu, et al. 2010).

There are three popular ways in dealing with dust, According to Buzin, they are through either:

1) Industrial Waste Landfills,
2) Recycling, incorporation into other processes/products,
3) Return to steel production process.

The problem with the waste landfills, become of its hazardous composition, major regulations are needed in place and as such the cost of this disposal has increased drastically in the past years. Overall the practices needed, and processing methods are high in cost, training of personnel, and control levels and as such not all plants undergo the reuse or return of the EAF dust into the steel process or the recycling it into other products.

In the process of EAF dust extraction, zinc is one of the most important to recover, as it has the most expensive commodity for resale.
Zinc can be extracted of around 55%. Yet, regulations need to be placed in order to certify no misconduct or mistreatment occurs. These include the following "Ability to support, a varying composition and physical presentation of the EAF dust being processed, in addition to zinc content, it is important to observe the presence of elements which are harmful to the recycling or incorporation processes under assessment, especially chlorine levels and metals such as lead, chromium and cadmium (including consideration of human health and environmental issues); and possession of a clear delimitation in mass and energy streams, in order to enable the assessment of viability in a broad sense, including the economy, logistics and product destination – among other factors, consideration of investments required to meet the environmental aspects of the proposal (emission control and generation of waste and effluents); economic

competitiveness and/or sustainability over other alternatives offered by the market." (Buzin, Heck & Vilela, 2017).

The composition also plays a factor on the processing of it, the following are important issues that should be considered when recycling or processing the EAF dust. Firstly, zinc plays a role in the economic process of the recycling of dust, the size and density of it also is a key issue, there are differing processes that can be done for EAF dust these are pyrometallurgical and hydrometallurgical. The Pyrometallurgical process is used when dealing with the particle sizes and density as it should have a low count of size and density which is done to not have dispersion, also done when iron is needed for recovery during this to ensure that the chemical elements do not contaminate the dust before zinc is extracted. It is seen as a treatment and is usually used to reuse the EAF dust into the EAF process.

There are techniques used for this process by injection into the slag or in agglomerate as pellets. Whereas, the hydrometallurgical is done as it has to separate solids from liquids which in cases is highly difficult and also in the separation of other metals that should be recovered before the recovering of zinc.

Yet, there are some disadvantages to this technique as it requires high levels of energy, and steel quality is sometimes not up to par, and zinc in limited quantities, it also is not a perfect procedure, it has some flaws including not all the zinc can be recovered and requires some gases The advantages of using the pyrometallurgical process is that it showcases the characteristics of holding a wider variation of raw materials, and as such the zinc holds great importance, it can hold against the chlorides, cost is much higher as the processors are of higher complication and as such need skill and detail orientation to the process.

This process occurs with high levels of fuming and condensing the metals in pure form. Most of this process is practiced in Mexico and the United States, after the processing occurs, the waste that is resided is delisted and disposed of in landfills (Rizescu, et al. 2010).

In the hydrometallurgical process, no reuse of iron is done, and sometimes it is found that the removal of small particles of lead or lead oxide is not easy. Therefore, one can say that this process is not always the most popular in most cases as some contamination can occur in light of the lead fallout (Rizescu, et al. 2010).

In the hydrometallurgical process is a less costly than the other procedures as they have lower transportation costs, this process basically attempts to extract zinc selectively. The type of waste produces a matrix and as such it has low particle sizes which is needed, quantities of water are needed for the process and is also used to wash remainders of waste, yet this leads to wastewater for treatment.

The waste produced also has high levels of moisture which in turn takes up more time to dry for final usage.

Finally, this method has the means to recover many more chemical elements and metals, all these lead to sufficient levels of economic feasibility in good conduct. These processes can be placed near the steel production in order to not have higher transportation costs. A problem with this process is that the metals that are found inside the dust are not found in normal state, yet in valence state, and as such this overly complicates the process of treatment of the EAF dust (Rizescu, et al. 2010).

The concept of reintroducing the EAF dust into other materials is of popular discussion amongst research, as it is said that the dust can be used in ceramic products and cement products. This can be done as the composition of dust has a basis to be used for the products that are needed yet certain aspects also play unfavorable matches for reuse.

The oxides in the dust could negate the process of incorporation into ceramics if temperatures are not efficient. The fact that zinc oxides occur also has a negative impact on the cement.

EAF Dust essentially has two options either disposing of it into landfills, which is of extreme severity to the environment if not placed or dealt with correctly, or to recycle the dust. These all come down to the treatment and transportation costs along with the environment aspect of law and regulations regarding the disposal of the EAF dust.

A case in the USA and Canada claims that overall 63% of companies tend to attempt to recycle the EAF dust, whereas 41% claim to bury it in a landfill, and only 5% use various types of recycling techniques (Liebman, 2000).

93% of the dust is chemical treated before placing into a landfill, also not all the plants have landfills on site, as such they transport it from 200 to 500 miles to a landfill or use a company that takes the responsibility of this disposal.

The processing of EAF dust in the United States ranged from 70$ to 150$ per tonne, which shows that this is higher than the landfills if the landfill is of close proximity (Liebman, 2000).

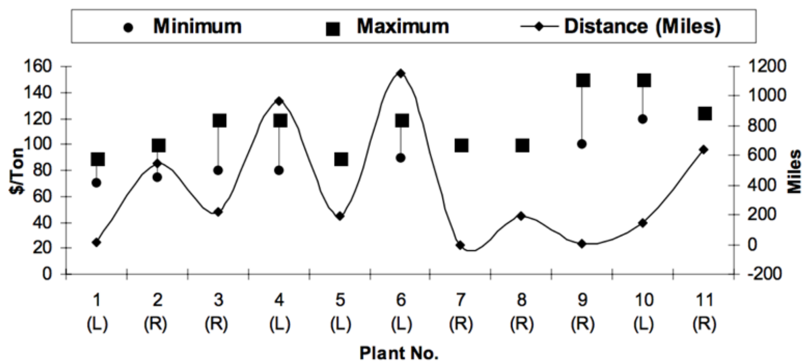

Figure 10 - Cost of EAF Dust Processing vs. Mileage to Site

Figure 10- Cost of EAF dust vs Mileage (Liebman, 2000)

The processes of the zinc and oxide extraction from the EAF dust can be done in a cost effective and highly efficient manner if employed in a proper way. The procedure needs controlling methods that are high in technology and strictness in order to ensure that the process is done correctly and efficiently.

The case in Thailand argues that if the proper measures are placed and that the pyrometallurgical and hydrometallurgical treatments are done in a proper manner then no emissions would be available to harm the environment or the surrounding areas.

There is a problem regarding the exporting of EAF dust to countries who require it, as there are many environmental regulations and treaties in placed that negate the means to do so (Wannakamb, 2013).

In the United States, it is estimated that around 0.5 to 0.6 million tonnes of EAF dust is produced containing zinc and lead. This shows a profound opportunity for the reuse of EAF dust after certain processing of extracting any elements that are hazardous to the environment.

The mitigation methods on dealing with EAF Dust have common practices, yet the most known after the Pyrometallurgical and hydrometallurgical are stabilization, which basically captures the toxic metals found in the EAF dust in order to not have it classified as hazardous, this process takes out lead and cadmium and as such the fixed waste is then proceeded to be placed into the landfills after delisting occurs.

Yet, if this process is done, no metal recovery is done, which means economically viable options are not of an option in this case which is not efficient and sustainable.
Another procedure would be the acid-based extraction, this is done to essentially dissolve metals that are wanted. This procedure requires abundant amounts of acid as the pH of the dust is high. This process is not usually exercised and if done it is not commercialized in general.

3.0 The Case of Egypt

Egypt is one of the highest manufacturers of steel in the Middle East, this is due to its extensive population growth which entails the need for more supply as demand has increased the past years.

The steel manufacturing industry in Egypt ranks the second largest in the MENA region from a production angle, and the third across the region from the consumption angle. In 2017 the total production of steel was around 6.8 million tonnes which showed an increase from the year before at around 35% (Flanders, 2017). Overall rank in the world, Egypt imports of steel rank 17th in the world, showing there is more room for improvement and production. Recently, the government has introduced a tax on imported steel in order to encourage more local production and the already present companies to start production at larger capacities or even introduce new companies that can higher the production levels in Egypt (Flanders Investment, 2017).

The consumption of steel as a whole has increased drastically in Egypt in the past years as the demand for it has increased. This is due to the extensive projects that Egypt has been undergoing the past four years and with a large number of projects forecasted to come in the near future, the demand is expected to increase drastically (Flanders Investment, 2017).

Table 4 - Evolution of Finished Steel Product Consumption in Egypt

Domestic Consumption in Egypt (Million Tons of Finished Steel Products)							
Year	2009	2010	2011	2012	2013	2014	2015
Consumption	11.1	9.3	7.8	9.5	9.2	10.2	10.9

(Flanders Investment,2017)

In Egypt the mostly used production process is the 'Electric Arc Furnace' with 89.5% as seen in Table 4. This is an indicator of how beneficial this process is and as such the research needed to view in what terms it can be enhanced or made more sustainable.

Table 5 - Steel Production by Technology in Egypt

Crude Steel Production by Process in 2015					
million tons	Oxygen%	Electric %	Open Hearth	Others	Total
5.5	10.5	89.5	0	0	100

(Flanders Investment, 2017)

Most of the top steel players in Egypt has now switched to the process of EAF which is found to emit less emissions which shows that it is more environmentally friendly as it consumes much less energy than the other methods.

The current waste materials generated from the steel industry in Egypt are as follows:

- Blast Furnace Slag
- Electrical Oxygen Furnace Slag
- Basic Oxygen Furnace Slag
- Blast Furnace Dust
- Blast Oxygen Furnace Dust
- Electrical Oxygen Furnace Slag
- Rolling Mill Scale and Sludge
- Blast Furnace Refractories
- Electrical Arc Furnace Refractory Bricks (Khunte & Mukuldev, 2015).

In 2016, the overall production of the steel industry in Egypt as per the numbers sent to the chamber of metallurgical industries and to each company that has reported is the below table 6 summarizing each months of approximate production.

This shows that overall in 2016 around 7.045 million tonnes of steel was produced throughout the Egyptian steel market. This number is a vast number as it shows the potential of the market and as such the percentages of waste that would have been generated.

In 2017, it shows that there was a slight increase in production capacity across the industry, whereby the total produced amount was around 7.169 million tonnes of steel (Youm7, March 2017).

Of these amounts, from conducting certain interviews and researching it was found that of the amounts of tonnes produced, around 5,86 million tonnes in 2017 are produced via DRI, iron ore, or scrap basis. These are all the production methods that would entail a generation of slag and dust from the Electric Arc Furnace (Chamber of Metallurgical Industries, Egypt).

Table 6 – Egyptian Steel Market Production

2016 Production	Tonnes
January	528,000
February	506,000
March	723,000
April	547,000
May	754,000
June	533,000
July	488,000
August	722,000
September	436,000
October	579,000
November	684,000
December	545,000
Total	***7,045,000***

2017 Production	Tonnes
January	476,000
February	431,000
March	594,000
April	465,000
May	613,000
June	499,000
July	610,000
August	764,000
September	581,000
October	767,000
November	656,000
December	713,000
Total	***7,169,000***

These numbers reflect the overall fluctuation in production, whereby a trend shows that in certain months more production capacity is reached, which is probably due to the overall production working at full capacity than in certain cases. Each plant has specific capacities and if working at full then the number of tonnes would be much more if it was measured by predicted or anticipated/forecasted production capacity.

Egypt falls in a category of production much less than that of the other mentioned countries, for example Germany producing annually around 42 million tonnes, which leaves Egypt at a lower ranking, yet a much higher percentage of slag is not used, whereas in Germany almost 65% of its road are made with steel slag (Personal communication with A. Moustafa, 2018).

In the EAF process, many plants in Egypt go through air granulation processes, which is the procedure that gas is blown into the slag as it is in the process of cooling down. It is still under research how to better efficiently recover heat loss in the cooling process. Overall, Egypt uses the accelerated method whereby high levels of steam is used, along with high levels of hot water and high pressure.
These are mostly the processes that are subject to the blast furnace steel process and not the electrical arc furnace.

The main focus of this research must first take into consideration the actual production of the steel industry in Egypt by plant and locations this is done through the method of making the steel production end cycle in Egypt a more sustainable process with the focus on international methods that have already proven this theory.

This would entitle a more comprehensive look at the benefits of turning the production of the steel into cost. Each plant produces different amounts of steel that in turn have a market share in the industry. Yet, these plants as will be discussed are not conducting a sustainable cycle of business as most of the plants either dispose of the waste or place them into landfills.

Table 7 shows the capacity and actual production per plant and per company in Egypt that will give a wider scope of the problem at hand as the amounts are high. It also shows the approximate market share of each plant vs the total of the company in the year 2017. This is an indicator that there are more players in the market and as such a dire need for a sustainable approach is vital at this point of production.

As such the approximate production in year 2017 has a wider indicator that the amounts of slag that is generated and dust from these plants are high, if one takes the average yield of 10% - 12% of slag generation and 2% of dust, it shows that we have a major problem in Egypt and must be tackled effectively and efficiently if all these amounts of generated wastes are mismanaged in ways that harm the environment and the surrounding area.

Table 7 – Steel Producers Matrix in Egypt in 2017

Company - Plant	Total Tonnes Per Year (in Thousands)	Market Share
AL EZZ Steel Rebars Co.	**562**	**10.0%**
Al Ezz Rolling Mills	**261**	**4.7%**
Al Ezz Al Dekheila Co. (EZDK)	**1,899**	**33.9%**
EFS	**190**	**3.4%**
Total Ezz Steel	**2,912**	**52.0%**
Int'l Steel Rolling Mills	**46**	**1%**
Egyptian American Rolling Mills	**306**	**5%**
Total Beshay	**480**	**8.6%**
Misr National Steel Co. (Al Attal)	**95**	**1.7%**
Al Masreya For Steel (Al Garhi)	**109**	**1.9%**
Al Garhi For Steel (AL Ateya)	**37**	**0.7%**
Total Al Garhi	**241**	**4.3%**
Egyptian Steel (Port Saeid)	**218**	**3.9%**
Egyptian Steel (Alexandria)	**118**	**2.1%**
Egyptian Steel (Bany Swaif)	**266**	**4.7%**

Total Egyptian Steel	**601**	**10.7%**
Total Suez Steel	**289**	**5.2%**
Egyptian Lebanese Co. ELCO	**42**	**0.7%**
Al Delta Co. - Kouta Steel	**71**	**1.3%**
Egyptian Iron & Steel Co.	**19**	**0.3%**
Delta Steel Mills	**20**	**0.4%**
Estar Egypt (6 OctoberPlant)	**49**	**0.9%**
Maadi Steel Steel Co. (Menoufeya)	**10**	**0.2%**
Suez Co. For Steel Trading	**73**	**1.3%**
(Medi Trade Foe Industries (Al Said)	**31**	**0.6%**
Mitad Helwan (Ayyad)	**30**	**0.5%**
Arcosteel	**12**	**0.2%**
Bianco Steel	**31**	**0.6%**
El Ola Steel (Sarhan)	**44**	**0.8%**
Upper Egypt (Al Megharbel)	**33**	**0.6%**
Al Marakby	**103**	**1.8%**
EL Geyoushi Steel	**30**	**0.5%**
Antar Steel	**32**	**0.6%**
Misr Steel - (Smart)	**31**	**0.6%**
Total Other Companies	**659**	**11.8%**
Total Producers	**2,270**	**40.5%**
Total Local Suppliers	**5,182**	**92.5%**
Imports	**420**	**7.5%**
Market Consumption	***5,602***	***100.0%***

(Interviews with differing companies to reach production capacities, and research.)

4.0 Methodology

Many factors caused by the current production process and the management of the wastes have impacts on the sustainability of the business as well as on the environment. This research will tackle the three pillars of sustainability that would have direct or indirect effects on the environmental, social and economic impact of the steel industry.

Environmental hazards caused by steel production include mistreated waste products and emissions.

The economic effects include companies saving money in the long term through the reuse of byproducts, turning them into more competitive businesses that have more appeal to investors and by resale of these wastes instead of disposing of them.

The social issue that deals with the adverse health effects for factory workers that would either be reduced or eliminated. Job security and successful marketing campaigns that would add awareness and success of the company through showing the sustainability practice of the industry as a whole which would add a benefit to the company's image and way of practice and management.

4.1 Research Objective

To identify which sustainable management practice of byproducts in the steel industry can be adopted to Egypt, which methods regain the most reward to the industry in turning it from a normal production cycle to a sustainable cycle.

4.2 Research Problem:

This thesis aims to explore the challenges facing the sustainability of the steel industry in Egypt, in addition to examining methods that would improve the sustainability of this growing industry sector.

The objective of this research is to understand if the reuse of byproducts caused by steel companies in Egypt could contribute to the overall success and transition of the steel industry into a more sustainable production sector. By understanding possible solutions or process methods alterations, this thesis will make important suggestions as to how steel plants in Egypt can be turned into more sustainable businesses as current method practices are not seen as practical for the companies operating. A lack of management is in high occurrence and as such more practical solutions on direct dealing of the waste is needed.

4.3 Research Questions:

This research aims to tackle the following questions:

4.3.1 Major Question

- How can reusing byproducts that come out of the steel making process make the steel industry in Egypt a more sustainable industry sector?
- Is it viable to make an 'Electric Arc Furnace' using plant sustainable and environmentally friendly?
- How can byproducts be reused or recycled in Egypt, what is the potential for such products and how much profit can they generate for steel companies?

4.4 Research Hypothesis:

1) Reusing byproducts of steel plants will not only reduce the negative environmental impacts of these products,

2) Increase profit for the companies resulting from byproducts being left unused or untouched, be found profitable,

3) Have positive societal effects it has on the surrounding areas thus creating a fully-fledged efficient cycle of production while maintaining sustainable practices.

4.5 Research Methodology:

The study aims to utilize and focus mainly on the Qualitative approach as it is seemingly the most relevant in attaining information about the Egyptian market.

4.5.1 Qualitative Approach

The research adopted a case study approach. The reason behind this choice is that the definition of a case study is "an exploration of a bounded system or a case (or multiple cases) over time through detailed, in depth data collection involving multiple sources of information rich in context.” (Stake,1995). Furthermore, another definition goes as follows “concentrating on a single phenomenon or entity, the researcher aims to uncover the interaction of significant factors characteristics of this phenomenon.” (Merriam, 1998).

The choice of an approach that contains the above criteria ensures that the researcher has had more extensive research and data that entails a proper understanding of the research at hand. For this research the collection of data was ideal as it gave real life processes that took place globally and gave an insight into how it can be implemented in Egypt.

Furthermore, a case study aids the researcher in the findings that give out most of the assumptions in an unbiased matter. It is also beneficial as it’s a multifaceted and hence has the most comprehending point of view within the research, as well as collecting multiple data sources that enhance and enrich the perceptions and points of views of the research, as well as showing the limitations of previous case studies and fallbacks (Baxter, 2008).

Case studies that show the management practices of the steel industry across the globe have the upper hand in management and are a scenario to follow from the Egyptian side.

Accordingly, as the case studies were recent and focused on current modern practices, the case study approach proved to be more educational as contemporary events are deemed more appropriate than historical events in a case study realm (Yin, 2003).

The research questions meet the criteria of various perceptions of the phenomenon, and is a contemporary issue, while showcasing a what and how question investigation.

4.5.2 Quantitative Analysis:

This approach is done for the mathematical calculations that need to be done in order to prove the research questions viability. A forecasting model of the potential use of a processor for the EAF slag with certain assumptions which include the fluctuations in price of slag, fuel, diesel, and the capacity of the processor. Furthermore, the potential resale of EAF dust is done through the following equations:

4.5.2.1 Net present value (NPV):

It is an equation which explains the present value of any investments as expressed below;

$$NPV = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

Figure 11 – Net Present Value calculation (Net Present Value Formula and Calculator, 2017)

Ci = net cash inflow during the period t Co = total initial investment costs r = discount rate t = time periods NPV is required to anticipate the future profit of an investment.

If the NPV is negative, this means it is better to abandon the investment.
Therefore, the NPV
must be positive outcome (Net Present Value Formula and Calculator, 2017).

4.5.2.2 Internal rate of return (IRR):

It is a discount rate that turns the NPV into 0 to calculate the probable profits of an investment (Investopedia, 2017):

$$\text{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0$$

Figure 12 – Internal Rate of Return (Investopedia, 2017)

Where: Cn = net cash inflow
during the period n Co= total initial investment costs r = discount rate n = time in years

4.6 Research Technique:

The techniques used for this research were extensive interviews that were face to face, one on one. These are considered the most valid form of data collection, and well-informed respondents can provide important insights into a situation or phenomenon, as such become an essential source of case study evidence (Yin, 2003).

This research was based on extensive interviews with well-informed experts in the field, the high executives were selected based upon their knowledge of how the process works and their insights into what the current methods and potential methods are.

Interviews for this method was semi structured along with an interview guide in order to have a pathway of questions that are to be asked and giving space for more information to be attained if said questions were not sufficient.

4.7 Data Collection Methods:

4.7.1 Primary data:

Primary data are gathered by the researcher for particular research. Primary data are mainly collected through:

Interviews

4.7.2. Secondary data

- Mainly gathered from:

Published Data:

- Journals,
- Newspapers,
- Publications,
- Theses,
- Researches,
- Case studies,
- Official Government Reports:
- Statistical and census data.
- Websites.

4.7.3 Sample Selection:

The interviews were selected who are five senior executives working in the 5 largest producing steel organizations in Egypt. They represent around 78% of steel production in the steel industry in Egypt. This was done in accordance of Merriam's strategy of "reflecting the average person, situation, or instance of a phenomenon of interest."

The sample selection is of importance as it shows each company's current stance and since they represent the majority of the steel production in Egypt it showcases a valid feel and understanding of the industry in Egypt as a whole. The individuals interviewed all come from a technical background, working in high level of operation and production field of their companies, and have been with their corresponding companies for over 5 years plus on average.

4.8 Research Limitations:

As the study will be focusing on the steel businesses in Egypt, certain limitations might occur as the effects of the sustainability on the business will be tied to acquiring knowledge from the companies. This might prove to be an issue as not all companies will be open to participate in this level of interviewing. In addition to this issue, subjectivity due to biases also may be a limitation to this research, as each company might enhance its overall procedures of dealing with by-products in the realm of not showing negative practices of dealing with them as a protective measure for the company's image.

Another limitation could be the possibility of quantitative errors that occur when quantifying the waste and acquiring costs of each by-product which, in turn, might change monthly as steel prices are ever-changing, this has also proven to be a limitation as reaching a correct set price for the byproducts was difficult.

5.0 The Current Management Practices in Egypt and Effect on Sustainability

5.1 Current Management Techniques of Slag Utilization in Egypt:

In conducting interviews, in a form of an academic elite and specialized method, with senior executives in the five major steel producing companies in Egypt. Each company was asked in details their production cycle along with the specific methods of dealing with the EAF slag and dust.

A clear understanding was needed and a detailed breakdown of the current practices as well as the current production capacity of each company. This was done for the purpose of the comprehension of the quantities generated of slag and dust.

Looking at the entirety of the companies in Egypt, an average tonnes produced from the main companies were around 5.86 million tonnes, and it is said that around 10-15% of slag is generated from a tonne of steel, and 1-2% of dust (Khunte & Mukuldev, 2015).

This would imply that around 586,000 tonnes of slag is produced yearly by the main steel companies in Egypt, as such would entail a great economic viability and opportunity for reuse or resale.

Subsequently to the interviews, the following was observed:

Company A – The only company that has taken an investment into a slag processor in order to utilize it within other industries. They have invested close to 3.5 million euros prior to the fluctuation in the processor. This processor's usage is mainly to change the EAF slag into an aggregate in construction materials including pavement. This was done for many reasons and paved the way for the company to reduce its overhead costs as by using the processed slag, they have managed to pave the surrounding areas of the plants which are vast in space. This has affected the costs as by this method, the need to buy ready-made construction material for pavement was unneeded. The essential investment was done in a realm of knowing the long-term profitability of this would be impactful on the company not only financially but from a commercial, and social side. This investment has saved for the company an amount of money; this is including the maintenance costs; and as such has diminished the concept of non-optimization, unsustainability, and waste of money of not using the slag.

The company has since done feasibility studies of the reuse of slag that was done, and has shown the amount of direct contribution this has had as well as the overall image and finances that was glorified due to this practice.

They have used this processor as a sort of 'Corporate Social Responsibility', as by paving the surrounding areas and villages across Egypt they have seen this as a way to give back to the community. This is important as this was not only done in the cities they operate in, yet, in a lot of remote areas around Egypt, furthermore, they have not publicized this act and as such not many individuals in Egypt know of this. The practice of such has also helped employment of individuals around the area (Personal communication with M. Abdallah, 2018).

According to Eng. Abdallah, the placement of slag into landfills is of grave importance to be focused on in Egypt. Most plants in Egypt use this as a way to facilitate manners with almost 90% of all steel slag produced ending up in landfills.

Dust is another process completely, certain practices are either paying the Ministry of Environment the transportation and certification costs which go up to 600 EGP per tonne for certification and 5,000 EGP per 30-40 tonnes of dust in a specialized truck, or by getting certifications from the Ministry to sell the dust to other industrial factories that require dust as their raw material for their production cycle. Both methods are of extreme costs, yet it is better than attempting to deal with the dust on their own.

Dust plays a big role in illnesses, including lung, eye, throat, and skin diseases. The process of removing zinc from dust if of great potential as if the zinc content is more than 20% one can sell a tonne for 5 USD and start the exporting of this material as it is a natural resource that is depleting.

Company B – This company has stated that certain processing occurs for slag to end up in the scrap yard. A scrap yard is an area next to the plant that is used basically as a warehouse for the initial input into the EAF – scrap. This requires zero processing of slag.

As mentioned with this interview, it is seen as a great potential for reuse, and as such they have signed research grants with Egypt's top universities to identify alternative uses of slag along with its implementation becoming a reality if possible. The current method entails a segregation of slag into direct and indirect, the indirect is sold, and as such shows that there is poor management of the slag. The remaining slag is always placed into landfills, with no means of reuse. The selling of slag currently falls around 17-25 EGP per tonne in unprocessed slag (Personal Communication with L.Beshay, 2018).

Dust is another matter that is of high importance as it is very costly in disposing of. Firstly, a certificate is to be obtained from the Ministry of Environment for 550-650 EGP per tonne. Secondly, a truck must be paid for to transport the dust which falls around 5,000 EGP per 30 tonnes of dust only. By minor calculations you can reach to know that this falls as a huge bucket of money that is spent disposing of a waste that must have other procedures done with.

Company C – Claimed that they pay governmental entities to come and take away the slag from their possession, as opposed to dealing with it themselves. The alternative is placing the slag in landfills, or leaving it left unattended to near the plant. Some selling of slag is done but in an unprocessed form which is around 22 EGP per tonne, this does not really make profit for the company, but aids in the disposing of slag.

As for dust, Company C pays around 550 EGP per tonne to the Ministry of Environment in order to transport the dust away from their plants. The current hazardous state of dust is affecting the company direly as many employees go through health scares due to the close contact with dust. Currently they are unaware of any procedures to facilitate dust removal, yet are very interested in finding alternatives as the current cost of management is extensively high (Personal Communication with N.Khalifa, 2018).

Company D – This company has claimed that the reason behind not utilizing the slag in Egypt is due to a lack of vision, although there is a high possibility of reuse, most plants in Egypt take a facilitated path and simply place their slag into landfills. This lack of vision can entail many negative profits in the long run, as seen globally there is a leaning towards a more sustainable cleaner production method. The process of landfills is no exception to them as they proceed with the same methods. They have claimed that they are aware of the potential reuses and are very interested in these methods and especially that they are well informed that countries abroad including Germany have found the highest possibilities of reuse and as such are gaining profit from this method and decreasing costs.

As dust is a hazardous waste material, the specificity of management is vital for the organization to remain intact and in good relations with the Ministry of Environment. The company pays money to the Ministry to take off the responsibility from their hands as they do not have the equipment needed or the facilities to correctly manage the hazardous dust from the EAF. They are aware that some companies actually place the dust into landfills by their own selves but this method is neither wise nor sustainable in their points of views (Personal Communication with M. Zada, 2018).

Company E – Currently they place the slag into landfills, and the slag remains unused. The claim is that there is a lack of education and awareness in the country. They have also stated that as long as everything is working correctly, the overall attitude is that if the current method is functioning effectively, then there is no need for a more dynamic method.

Yet, they have started investing in foreign companies to come and educate and train their employees on the circular benefits of the reuse of slag. This is also a way of highlighting their company's efforts into making better decisions for the society and decreasing the environmental harm.

The process of dealing with dust has an immense amount of administrative paperwork, as the Ministry of Environment entails specific documentations that must be signed and dealt with properly for each tonne of dust produced. This document places the amounts of crude steel produced along with the amounts of dust generated, furthermore the amounts must correspond to the quantity given to the Ministry. If any deviation occurs within the quantities special fines are done in order to discourage this behavior. The fines are placed for reasons pertaining to unethical conduct or resale in the black market (Personal Communication with G. Nagdy, 2018).

A breakdown of each pillar is now needed with current analysis of each of the pillars along with the current management techniques of slag and dust internationally and in Egypt.

5.2 Impacts of The Current Practices on Sustainability

5.2.1 The Environmental Pillar:

Slag, as mentioned, is a non-hazardous waste, yet, when placed into landfills in an improper way it loses its beneficial potential to the environment and can end up polluting the environment. With the triple bottom line in thought, burying of EAF slag into landfill falls under the sub category of the environment as land use. Increase use of land in an unnecessary manner entails that the pillar is not being fully achieved. Globally, the reuse of slag into concrete as the example of Germany and Turkey and the other countries listed in the cases above, is a valid example of the current mitigation efforts the countries are undergoing to not further harm the environment. As also the natural resources are depleting across the globe in a rapid manner, it is also of importance to see that the globe response to the issue is that of moving forward and finding new and innovative ways to deal with the waste generated.

In the steel industry abroad, the main reuse of EAF slag is into concrete and pavements. This is a key indicator that the world is moving towards saving natural resources as the current uses in concrete and pavements use the natural aggregates which consumes many of earth's natural resources. Furthermore, the extraction of zinc from the EAF dust is another concept that in a way is attempting to salvage the environment. By this extraction one is making sure that the environment is not negatively harmed by the corrosive substances that could be emitted into the environment in the case of putting the EAF dust into landfills. This process not only plays a factor in this realm but in all the other pillars also. The other indicator would be the decrease in the greenhouse gases emitted into the environment which is of importance as this is an ongoing trending topic across the globe.

The byproducts generated all have methods to be disposed of, the question is whether the industry is looking to just dispose of the waste or to find better uses and reuses of this waste in order to better help the environment.

The current management techniques show that industries are not abiding by the environmental pillar as the burial into landfills is not sustainable, nor is it beneficial to the environment in the long term. Arguments that EAF slag is non-hazardous and as such does not pose threat to the environment are negligible because it would entail proper conduct of dealing with the landfill and ensuring that no gases or leaks occur and ruin the landfill.

Accordingly, around 60% of the world still disposes the EAF dust via dumping (Bakkar et al. 2016).

Whereas arguments that EAF dust are not considered viable as in all cases before extraction of harmful components, it is considered an extremely high hazardous waste and must be dealt with in an efficient and effective manner. Waste management is of extreme importance when dealing with industries that produce in a large scale, which is the case in the Egyptian steel industry.

EAF dust is an extremely hazardous waste due to the containment of some elements including chromium, lead, and cadmium. These elements automatically ensure that since EAF dust contains them they are a liability to the environment and this is why from an environmental aspect it is necessary for the recycling or reuse of the EAF dust, and essentially treat the dust before placing it into a landfill or store the dust in areas that would not directly impact the surrounding atmosphere or areas (Bakkar et al. 2016).

When off gas occurs in the EAF process, the components include CO, CO2, hydrogen, nitrogen and argon due to the burning of coke and steel decarburization, along with those there are other amounts of dioxins which are highly toxic to the environment. These gases are also a threat as they are considered greenhouse gases (Jones et al. 1998).

From an environmental perspective recycling and reuse of waste materials can aid in many issues as there is an overall lack of supply of natural aggregates in certain construction sites and the fact that these aggregates are found through certain mining also plays a factor in the environmental realm of the process (Ouda & Abdelgawwad, 2015).

These types of uses of waste materials can solve problems of lack of aggregates in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. The use of waste aggregates can also reduce the cost of concrete production. Due to the face that aggregates can significantly affect the properties of concrete, consequently, a thorough evaluation is necessary before using any waste material as aggregate in concrete

5.2.2 Social Pillar:

When looking from the social perspective, one must see all the aspects that directly affect this pillar. EAF dust pertains many elements that have health adverse effects on the human body. These dusts can cause multiple skin, eye, ingestion, and inhalation diseases.

All these diseases a factor in many employment issues that occurs across the steel plants around the world, most notably in Egypt, as these health risks are high, it causes the company to have a highly categorized medical insurance scheme in order for the employee to agree to work in the plant. Whereas, if clear health and safety measures are taken and dealt with professionally, individuals would have clear tasks and limitations to abide by when dealing with any hazardous wastes inside the plant.

A common practice related to EAF slag and its current management shows that the more developed countries are the ones who are managing it efficiently in compliance with laws and regulations regarding the reuse management. Currently, Turkey and Germany are leading in managing the EAF slag into aggregate to reuse in the process (Ouda & Abdelgawwad, 2015).

As the population growth in the globe is increasing drastically, one must take into consideration that the demand for commodities increase with it, and the supply must be enough to cover the demand. By ensuring the correct management of EAF slag one can ensure the various uses of natural resources, the reuse of slag also extends to the decrease of use of other natural resources that are depleting exponentially across the globe. It is the responsibility of the industry to find new and innovative ways to ensure that they are protecting the society in efficient ways and that development of the process is ongoing to salvage more than the resources being depleted, but also, the other factors including human health and increasing employment.

Institutions across the globe should all agree on various methods of generalizing the scope of management of these waste products in order to be an efficient neighbor to its surrounding environment and community. An efficiently working supply chain is a key indicator for the social pillar as it shows the amounts and regulations of the wastes and how the industry is handling this for the best interest of the employee and its shareholders.

A new concept of the reuse of EAF slag and dust in Egypt can entail multiple new job offerings and will directly affect the unemployment rate in Egypt.

By issuing a new processing facility that will turn EAF slag into aggregate for multiple uses and resale, this would open the doors for immense possibilities of acquiring new employees and would give back to the society as a whole.

The reuse of EAF slag and dust plays different roles for the social pillar as both are different in their implementation and meaning. EAF slag being managed in its reuse or resale, shows that the industry is moving towards a cleaner production trail. This is vital for the company's image as it highlights its management in attempting to deal correctly with the waste and not have it harm the environment that it is working in.

5.2.3 Economic Pillar:

Zinc as an element is an extremely important type, it is consumed in many various production cycles and industries and is needed in around the world direly. Zinc is a highly consumable metal, it ranks 4th globally, which is high enough to make it a vital consumable that is needed to be protected. As EAF dust contains around 46% of zinc, this makes the recycling of zinc an important issue. It is also said that zinc is slowly depleting from the earth and as such making it vital to find any ways of recycling zinc and not disposing of it in a matter whereby the reuse is lost (Bakkar et al, 2016).

From an economic perspective, the current management of slag and dust seems to be hazardous to the company and industry as it requires a lot of costs of dealing with these wastes.

Certain use of waste aggregates including EAF slag is helpful in the decreasing of costs related to production (Ouda & Abdelgawwad, 2015).

This also takes into consideration the industries norm of wanting to decrease the amounts of natural resources used and electricity used, alongside decreasing the needed lands and uses of landfills.

Also, by introducing new management of wastes to the industry this would entail that new employment is needed, and further training of current manpower.
Another aspect would be that by finding sustainable management processes for slag and dust, one can reduce the costs of differing things, including the disposal costs which entail a big burden on the industry. This is also not only measured by cost in an aspect of money, but also by the cost to the environment and the cost to the resources itself. By disposal, one is foregoing the right to recycle and make use of a secondary raw material which in fact be more beneficial to the environment and economy if dealt with otherwise. Furthermore, the usage of a secondary raw material contributes to the generation of another source of income, which entails that the industry will be contributing more to the country it is operating in.
All these factors play a role in the building of the economic pillar of sustainability and contribute to the overall look of the industry and how it fits into the sustainable development realm.

Table 8 – Benefits of reuse of byproducts through the sustainability pillars

Benefits of Reuse of Byproducts through the Sustainability Pillars
Environment
Decrease Spills
Decrease Accidents
Decrease Emergencies
Reduce use of Landfills
Reduce Creation of Landfills
Reduce amounts of raw materials used
Cleaner Production
Economic
Decrease Waste disposal costs
Decrease Operational costs
Generate another source of income
Decrease cost of raw materials used
Decrease amounts of lawsuits
Social
Protect Workers
Reduce Accidents
Reduce Risks of Lawsuits
Reduce Risks
Increase Employment Rate
Training of Employees
Reduce Health Risks
Technology
New Technology
Innovative
Less Energy Consumed
Up to Date Methods

Table 8 was conducted to showcase the benefits of the reuse of byproducts through the sustainability pillars and how they can help promote the sustainable development of the steel industry in Egypt.

6.0 Utilization of byproducts

6.1 Management for Sustainability:

A 'Sustainable Business Strategy' can be defined as "one that creates profit for its shareholders while protecting the environment and improving the lives of those with whom it interacts. It operates so that its business interests and the interests of the environment and society intersect. A sustainable business stands an excellent chance of being more successful tomorrow than it is today, and remaining successful, not just for months or even years, but for decades or generations." (Savitz, 2014). Having understood the management of steel waste and the potential of its reuse from case studies found outside of Egypt, it is the time to focus on the implementation of this concept in Egypt. Firstly, the industry needs to comprehend what it is to have a

The concept of the triple bottom line corresponds and is directly linked with the sustainability pillars, as it takes into consideration the environment, society, and the economy.

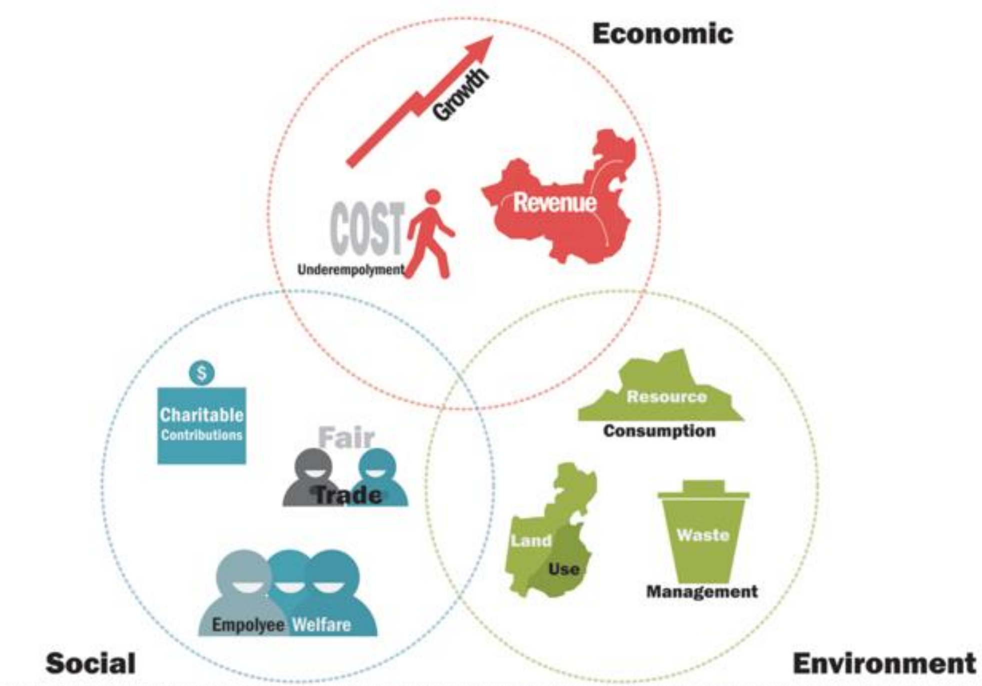

Figure 13 – The sustainability Triple Bottom Line model (Savitz, 2014)

As shown in Figure 13, it is vital for an organization's growth to be linear and ongoing, with decrease of costs and an increase in revenue. Resources consumption and unnecessary land use must decrease, and waste management efforts should be increased. Finally, from a social point of view, employee's welfare and charitable contribution are of vital importance for this model to work.

6.2 Qualitative Analysis

The five major producing steel companies in Egypt having been interviewed give a valid and structured indication as to what the current effect of their management practices is doing to the society, economy, and the environment.

Breaking down each interview to comprehend more of their practices gives an overall look to what can be analyzed as the following:

- 5 out of the 5 interviews have all claimed that the most common practice in Egypt for slag management is Landfills.
  This indicates that there is a great market opportunity for slag reuse in Egypt, which also predicts that other industrial companies would be benefiting from the slag in their construction cycle, or their application.
  The fact that the price of slag jumps from an average of 20 EGP to 150 EGP after processing indicates a major advantage for companies that invest in a processor to have a secondary raw material. The processing of slag is important for the company's image and their profitability.
  The case studies abroad should also be studied well to see the beneficial aspects of reuse of slag and the disadvantages of using landfills which is costly and entails land deterioration.
  It also shows potentially profitability for the industry which will be shown throughout the mathematical calculations in the next section.

- 1 out of the 5 companies have invested in a slag processor.
  The success story of this one company should be an indicator for the rest to follow in their footsteps. Also, the dealing of slag in such a way is vital in the economical realm of the company from a social and environmental side. The profitability of being environmentally conscious is more satisfying for a company as they can position themselves in another aspect of the business scope especially in Egypt which is leaning towards becoming sustainably aware.

  With correct positioning one can argue that these companies can last longer, especially with the globe transitioning towards a more sustainable life cycle of businesses and production. This reuse of byproducts is an opportunity for the Egyptian steel industry to join the world in a more sustainable life cycle.

  'Corporate Social Responsibility' is another major issue that must be tackled sufficiently in Egypt, so far, the steel companies in Egypt except company A do not have a valid CSR program that falls under the scope of pure CSR. Company A does not publicize their methods of reusing the slag in villages across Egypt.

  What is needed currently, is a follow of the example set in Company A whereby companies start their reuse in a more dynamic and socially conscious way and not by harming the environment or even have the potential of harm in their scope.

- 5 out of the 5 companies have claimed that they would be very interested in investing in a slag processor for reuse or resale.
  The benefits of reuse will be seen in the next section from a profitability point of view. Yet, an interest for the company will greatly impact the industry as a whole from a sustainable point of view. The management of slag to be redirected to beneficial aspects can greatly impact the company's image. It would also match Egypt's path of turning sustainable and help in the awareness of being more aware of its production habits. Egypt's focus on the sustainable goals impact each industry, however, when an industry decides to replicate and mirror the goals of the country they are operating in, it gives a positive image of the industry not only to the Egyptians, yet across the globe. The focus on the success of the case studies found globally is vital for now to find new innovative

ways of dealing with slag, and would also encourage the employees to better understand the importance of turning sustainable especially in the production realm.

Lastly, the fact that the five highest producers in Egypt are interested in investment of a slag processor shows that there is great potential for this project to succeed.

Over the past years, Egypt's unemployment rate has slowly started to decrease showing that there is progress in the society in Egypt and that the economic infrastructure is on its way to recovery. With this comes the need for innovation and sustainability. As sustainability is not only a key in business practices but in the country, it is much needed. The roles of the companies of implementing this sustainable practice of management of the steel wastes is a key factor in showing the society that the company is taking a path to being entrepreneurial in its management styles and practices.

- 5 out of 5 companies claim EAF dust holds major health adverse effects that affect their employees and overall health.

  The five companies have all agreed that these diseases are a source of worry and must be looked into ways of mitigation or decreasing the amounts of accidents that occur due to the EAF dust and the components that are hazardous in it. These sorts of diseases are a grave indicator and should not be taken lightly, remedies and mitigation methods are vital to be researched. This also shows the fatality of not investing in the right procedure to deal with dust and as such poses a threat to the overall health of the employee and as such the sustainability of the industry. As most of the diseases that are incurred due to dust are fatal and affects the ability of the employee to work, one must invest in ways to fix this issue and find better alternatives to this hazardous waste.

  The adverse effects of dust on employees also is costly on the company, and if methods are placed to manage the dust in a more practical way, this could impact the company's image as well as the industry as a whole. With the globe following into the sustainable development goals, Egypt's aim is to start implementing the goals is also an indicator that the steel industry should consider when attempting to deal with the dust. The social aspect of attempting to find other methodologies of dealing with the dust is important as it directly impacts the sustainability pillars.

- 5 out of the 5 companies pay the Ministry of Environment to manage their dust with high cost on the company.
  The cost of this certification and transportation is extremely high which shows that this is not costly sustainable.
  There are advantages and disadvantages of this method, looking at the pros one could see that this would take off any legal repercussions on the company as they would not be the ones emitting hazardous waste by attempting to dispose of it. If the company decides to start placing it into landfills, wrongfully doing so can have a grave impact and as such legal action can be taken. The overall impact of having a company place the dust into landfills in a wrongful way can direly affect the reputation and the image of it, which shows that this is of extreme importance. However, though the cost is high, the mere hassle of it would be reduced as companies would leave it all in the hands of the Ministry.
  The cons of this method can be argued to be unsustainable as the company is not investing in a closed loop method by finding alternative ways to reuse the dust as a secondary raw material. With the overall depletion of natural resources each company should not take the easy route of just disposing of it through the Ministry but find alternative innovative solutions to deal with the problem at its source as they are the ones who are emitting this hazardous waste. Furthermore, the cons of this method is the cost. The cost this high can actually negate the potential profit which will be shown in the next section.
- 1 out of the 5 companies resells dust to other industrial cycles.
  Zinc is an extremely economically viable product which should grab the attention of the producers in finding alternative methods and solutions in extracting it as it is considered as a secondary raw material. This is important as a sustainable method that guides the industry into becoming a closed loop method instead of just disposing of the dust.
  The concept of selling the dust to other industries is also beneficial as though it is still costly, one does not dispose of it on their own, and gives other industries the means to use a material that would otherwise be thrown out. This would give an edge to the industry as a sustainable business in their practices and methods.

6.2.1 Quantitative Analysis

For an efficient cost comparison of the EAF slag being reused or recycled in pavements or concrete, one must remove the logistics and the cost of proximity from any equation related to the cost effectiveness of substituting the natural or coarse aggregate by the EAF slag.

Research has shown that in order to implement the slag into the mix of concrete or pavements, the dimensions of the raw materials need to be adjusted to meet the standards. The most potentially useful substitute is that of dolomite. The process of substituting the dolomite by the slag or 'expandable slag' is of the best interest of the industry. Reason being that expandable slag can be compared one to one to the dolomite that it would be replacing. Having this information is of a key indicator that must take into consideration the cost of both materials and how that through case studies it shows that the substitutions are of actual better results and durability than use of natural aggregates.

To implement this sort of byproduct management in Egypt, the prices of the aggregates versus the expandable slag were researched to figure out which one would ensure better profit and long-term sustainability.

According to experts interviews, average price of slag has been said to range from 17 EGP to around 25 EGP depending on the quality and dimensions of it and where it has come out from as unprocessed slag.

Processing the slag into making it more economically rich in its reuses, will make the cost of it jump significantly and reach a range of 100 EGP to 150 EGP (Personal communication with G. El Nagdy, 2018). This price is an indicator of the cost effectiveness of the processed product and as such the feasibility study of that follows.

The way around this processing is through a processor called a 'Gravel'. This processor manages to change unprocessed slag into a one that has the ability to be used in road construction and is right in its durability.

The benefit of this 'Gravel' is several prospects. Firstly, As the steel plant is already manufacturing steel and currently handling slag in a matter, the need for extra labor is uncalled for, except for a small amount. The proximity of the gravel to the plant is also vital as this negates the idea of transportation cost. After the slag is processed one would sell it directly to the concrete industry as there is a surplus of supply and as such needed demand. Research regarding the actual processor was done to essentially get the initial investment price of the processor as a machine with the required data on how to physically maintain the machine.

Taking the pillars of sustainability and synchronizing it with the processor it shows that there are environmental and economic benefits.

From an environmental point of view, as natural aggregate is deteriorating, the high environmental impact is high, which in turn also shows that the demand of construction aggregate is needed and growing immensely, hence the reason behind finding the raw materials that are not depleting and are in abundant supply and misused. The slag after processing turns into an industrial aggregate. This also means the saving of natural resources and energy as a whole.

From the economic side, the natural aggregates and their actual performance are costlier than slag, also the opportunity cost is high as instead of disposing of the slag in non-economical ways there occurs a reuse in a matter that saves differing resources. Segregating slag is another economical viable way of ensuring recycling measures are to take place. The major problem in Egypt are that most plants do not segregate the slag yet leave it to cool down together then handling measures take it all in one bulk together. This management style goes against the process of sustainability and recycling. On the other hand, by adjusting and having clear parameters with differing sections for the slag and not mixing them together, the slag does not get contaminated. This is important as when slag is contaminated the important elements found inside cannot be recycled or reused, hence leaving it useless. Segregation can aid in the process of having clear dimensions of the slag that have the proper elements and can be reused in other methods including aggregate.

6.3 Forecasting

6.3.1 Conservative vs Aggressive Model:

The assumptions that were chosen to calculate the profitability of the processing of slag are vital in the forecasting model and each were chosen based on certain criteria.

For correct forecasting, the research has looked at the governmental decisions that have entailed the cutting of electricity subsidies throughout the years to come (The Official Newspaper, 2017).

Currently with the International Monetary Fund's loan to Egypt, diversions of projections have occurred on consumable goods, which has shown that the anticipated plan of the prices of electricity will be ever changing.

For the Conservative model, the price of electricity has assumed that the growth in rate will be only 15% next year whereas after this subsidy being taken off it will reach a sort of consensus and stabilize. Whereas, the aggressive model will show a current rate of growth of 15% for the first year yet remain on a 15% increment to showcase potential setbacks in the removal of subsidies.

Below is a list of assumptions that were conducted in order to have a sufficient forecasting model, they are divided into revenue assumptions and cost assumptions.

Revenues:

1) Maximum Capacity of the machine to be operating on average 100,000 tonnes of slag.
2) 1st year operating on 80% utilization then bumping up to 100%.
3) Slag price of 117 EGP per tonne (conservative method)
4) Slag price of 150 EGP per tonne (aggressive method)
5) Slag price growth rate at 8% average (based on historical average of price of slag)
6) 3% of recovered scrap is decreased from the amount of slag produced

Costs:

1) Price of Energy KWh is 0.433 (El Youm el 7, 2018).

2) Increment of energy is 15% for the first year,

3) Energy prices to stabilize and increments only 10% growth after year 1 as subsidies in Egypt are being taken off.

4) Diesel fuel increment as 15% for the first year and also increases by 10% after year 1.

5) Set prices of consumables and incrementing by 10% in the conservative realm, yet 15% in the aggressive model.

6) Labor as minimum wage of 1,200 EGP and inflating only by 11% each year and 15% in the aggressive model.

6.3.1.1 Conservative Forecasting

For the conservative forecasting as mentioned the assumptions were vital in conducting the projected cash flow. The conservative model comes from assuming that prices are not to fluctuate drastically and that inflation affecting the costs are also minor. Finally the slag price was given the minimum amount in order to keep the model conservative.

Table 9 – Conservative NPV & IRR calculation

Year	2018	2019	2020	2021	2022	2023
Total Revenues	-	9,079,200.00	12,256,920.00	13,237,473.60	14,296,471.49	15,440,189.21
Total Cost	-	(456,264.00)	(647,032.50)	(713,267.55)	(784,668.23)	(863,217.11)
Total Cash Inflow	-	8,622,936.00	11,609,887.50	12,524,206.05	13,511,803.26	14,576,972.10
Initial Investment	(35,000,000)	8,622,936	11,609,888	12,524,206	13,511,803	14,576,972
IRR	20%					
NPV	$9,203,180.62					
Payback Perid	3.8					

As seen in Table 9 the years following the initial investment show an increase in revenue along with costs yet balancing out that the total cash inflow is positive and increases until year 5. A summary of the FCF was placed to show that the NPV is positive and the IRR rate is at a 20% which is efficient. These are with the conservative prices of slag and conservative rates of inflation for the costs. The payback period of the initial investment is 3.8 years which shows a promising result efficiency.

The assumptions that were chosen to calculate the profitability of the processing of slag are vital in the forecasting model and each were chosen based on the above criteria.

6.3.1.2 Aggressive Forecasting

For the Aggressive forecasting as mentioned the assumptions were vital in conducting the projected cash flow. The aggressive model comes from assuming that prices are to fluctuate drastically and that inflation affecting the costs are also somewhat major. Finally, the slag price was given the maximum amount in order to keep the model aggressive.

Table 10 – Aggressive NPV and IRR Calculations

Year	2018	2019	2020	2021	2022	2023
Total Revenues		9,079,200.00	12,256,920.00	13,237,473.60	14,296,471.49	15,440,189.21
Total Cost		(456,264.00)	(647,032.50)	(713,267.55)	(784,668.23)	(863,217.11)
Total Cash Inflow		8,622,936.00	11,609,887.50	12,524,206.05	13,511,803.26	14,576,972.10
	(35,000,000)	12,501,153	14,954,276	16,095,850	17,322,249	18,637,570
IRR	33%					
NPV	$22,018,575.95					
Payback Perid	1.6					

As seen in Table 10 the years following the initial investment show an increase in revenue along with costs yet balancing out that the total cash inflow is positive and increases until year 5. These are much higher than the conservative model. A summary of the FCF was placed to show that the NPV is positive and the IRR rate is at a 33% which is exemplary. The payback period of the initial investment is 1.6 years which shows a very short period.

6.4 The Current Cost of Managing EAF Slag in Egypt

With personal communications with senior executives in the top manufacturers of steel in Egypt, most of the companies have claimed that for now they leave the slag lying around near the plant, or by building a scrap yard to use as a warehouse for materials outdoors.

Currently, there is no concise price of the current method of management, yet one can measure it from another perspective in an environmental, social, and economic. The opportunity cost is higher by leaving the slag unmanaged as you forego the potential profits from the reuse of slag, and the cost of utilizing more of the natural resources. Other foregone profits include that of marketing oneself as a top green player in the industry that reuses most of its wastes in a conduct that better helps the environment and society. This shows that one must find efficient ways of reusing the slag.

Certain companies break the slag and take out potential parts that can be reinitiated into the process, yet the majority is used into scrap yards or left untouched. These actually take up place and space in the area and as such is an opportunity cost of what could be used with this taken up space.

6.5 The Current Cost of Managing EAF Dust in Egypt

Currently, the cost of managing EAF dust is extremely high. There are two scenarios that occur when dealing with EAF dust. Firstly, is the burying of the dust in Environmental landfills through the Ministry of Environment. This is very costly as one truck that holds around 25-30 tonnes costs 5,000 EGP. These trucks are not ordinary and are closed off in specific dimensions to ensure that no emission or waste is emitted outside as dust is of extreme hazard to the health and population of the area. In addition to that, one must obtain a certificate stating that they have disposed of the EAF dust in an orderly manner and environmentally friendly way to ensure that the hazardous waste was not let go into the surrounding environment.

The table 11 shows the total cost for only **30 tonnes** of dust to be transported to a governmentally accepted location and buried.

Table 11 – 30 Tonne carrying Truck of EAF Dust

1 Truck - carrying 30 Tonnes	
Price of Truck	5,000
Certificate	19,500
Total	***24,500***

To understand the scale and impact of this, an example was conducted by table 12 assuming the following:

- Taking an average of just one company that produces around 700,000 tonnes
- One can generate the approximate EAF dust that is produced of around 2% being 14,000.

By applying the same methodology of how much transportation and certificate costs would be needed an abundantly high number is retrieved.

Table 12 –EAF Dust Estimated Costs

Cost of 14,000 Tonnes of EAF Dust	
Certificate	9,100,000
Trucks for tonnes	2,333,333
Total	***11,433,333***

Table 12 shows that around 11 million EGP is needed to dispose of just 14,000 tonnes of dust produced from the EAF.

A senior executive from a firm operating in Egypt has also stated that currently Egypt does not find any alternatives to the focusing of reuse of EAF dust and as such this money is being paid

either way as one is entitled by the law to rid of it in an efficient manner.
Currently what occurs is that steel companies give away their dust to the Cement companies for free as they need it in the clinker in their process. This methodology proves to be the most efficient currently as it shows that the industry will not pay money, yet the other industries are gaining the secondary raw material for free in their process.

The opportunity cost is zinc extraction, when zinc is extracted the waste becomes an expensive one to sell as if the zinc metal content is more than 20% can be sold up to 150 EGP. In cases that have more than 30% of zinc metal content, the price for it changes and as such is a great potential for exportation to other countries. Yet, the processor is said to have a high maintenance cost and as an initial investment is also of high costs.

7.0 Conclusions and Recommendations

After referencing the case studies of differing countries around the globe in the literature review, it can be concluded that there are multiple ways of handling the wastes generated from the steel industry. Yet, each method of handling has specific advantages and disadvantages. One might believe that leaving the wastes managed as it is beneficial as they are operating efficiently, yet when looking at the alternatives feel that there are other beneficial substitutes of the current management style of wastes. This can be related to the welfare in an economic and social perspective, and the environment as the most important of what is deteriorating quite quickly and how the alternatives play a role in the dynamic synergizing of these pillars together to gain a more sustainable cycle.

Current legislations and strategies are placed to ensure proper handling of hazardous wastes occur globally, yet as slag is deemed non-hazardous many countries do not see the need to manage it in a different manner. As seen in the examples abroad as depicted in the literature review, certain countries have placed efficient manners of management of the wastes by finding alternative methods instead of disposing of the slag. This is most apparent in cases such as Germany and the United States who have contributed more than half of their wastes into different processes and have utilized the sustainable management method. This has helped in their overall sustainability and contribute to the image of the country. It is also seen for the dust handling that even though costs of handling are extremely high, certain examples show that through the hydrometallurgical and pyrometallurgical practice, one may attain the highest return on natural resources extraction and even export to countries that are low in supply of these resources. The methods that have been placed in other countries whereby they use landfills for dust is of vital importance for Egypt to learn from their mistakes or mismanagement for optimum results. The literature review essentially is important as it gives grounds for discussion for the Egyptian industry to focus on past examples, learn from their sustainable management practices, and finally to learn new methods of handling especially if they are attempting to develop various other methods of management.

In Egypt the current legislation is needed for more policy makers to implement certain laws and regulations that entail some policy interventions along with long term planning strategies that encourage the industry to put more effort in dealing with the wastes that are produced.

Accordingly, new measures are needed to be reinstated in Egypt, that being a clear objective and beneficial scenarios for all stakeholders involved, considering the sustainability and the utilization of these benefits for the three pillars.

There is an advantage for Egypt as it has many examples abroad to study and learn from.
The beneficial aspect of investment in this processor shows that slag can be sold to the construction industry for a good price as well as maintain the three pillars of sustainability by decreasing costs across all aspects and saving some of the depleting natural resources. This would also entail better image for the company and would show that there is an attempt to decrease the mishap against the environment and produce job opportunities for potential employees. Though both scenarios are of high initial costs, the mathematical aspect shows that it is promising if implemented correctly and would profit the industry money wise as well as environmentally and socially also.

The mere image of each company when applying a specified and clear waste management cycle will aid in their image and as such potentially boost sales in addition to positioning of the company as one that is environmentally aware of its hazardous management procedures and its willingness to change that.

Furthermore, internally it plays a factor with the employees, as employees who see that the practice of the company is changing in favor of a more aware process will essentially have more appreciation for the company, which in such will promote the industry to act as a whole and attract employment and attractiveness of the potential employees to the industry.

The suggested methods of dealing with the waste must take into consideration some recommendations that will entail a smoother and more profitable outcome along with the correct navigation with governmental entities that will facilitate the manner and even provide incentive for the companies with the correct practice methodologies.

7.1 Recommendations:

The most crucial recommendations are the ones linked to attempting to synergize the process of the steel making process in Egypt.

Currently, we lack multiple infrastructures that coordinate together in order to come up with the best practice and most efficient one.

In order to efficiently start implementation of a more dynamic and sustainable production cycle, these are the major points that need to be tackled and implemented and as such are the recommendations:

1) Defining the Major stakeholders involved in the process

This is vital as it shows clear and defined people involved that will have a clear and direct impact on the profitability and successfulness of the implementation of this cycle.

By defining the stakeholders involved it will also entail that there are people held responsible for when no implementation is done. It will also show the companies that there are individuals involved in following up.

Most importantly it will show the companies how their current actions are affecting not only the environment, yet the other factors that they would not have seen otherwise. This is an eye opener and would show certain stakeholders differing opinions and points of views.

2) Defining clear objectives and frameworks

This point is also a major factor as having clear set guidelines and objectives along with a framework will ensure that operations go smoothly without complications. Furthermore, in the case of any complications or objections, there will be a clear matrix on how to handle and why it is needed to have objectives so that everyone involved knows the end goal and the benefits of having these in place and finally what the end goal is.

This concept here can be implemented to the steel industry in Egypt as a whole as all the factors stated above have direct relation to the management methods currently in place and the potential strategy to be implemented for the steel industry.

3) Corporate Social Responsibility

The reuse of slag and dust can be used for CSR purposes for companies in the steel industry in Egypt. This is an efficient gateway for companies to begin doing good for the country as a whole with the added benefit of not throwing away their waste or more essentially having good waste management practices. CSR is vital for a company to keep its reputation in the industry a positive one.

4) Revisiting the current waste management pathway

By focusing on the flowchart of what is actually done with waste and how it is handled, one can spot the bottlenecks and reissue the flow of how it is handled. By having a different strategy on how to handle the waste, one can diversify the pathway and show the most efficient route that it should take.

More training and knowledge are required for the companies also to invest in, this would entitle them to have a wider understanding of the benefits of the reuse of these by products and as such would encourage the companies to make generous investments in the machinery needed. Trainings of the employees is also vital as it would educate the individual as to why this processing is happening, to further let the employee comprehend the benefits of recycling and then the prior negative impacts the burial into landfills would have done if this process keeps on going.

5) Reduce amounts of landfills used

The fact that all the waste is placed into landfills is another reason why the recommendations must ensure that one should reduce the number of landfills and put into consideration the cost to the environment it is causing by using the landfills, especially the cost of the actual land, the opportunity cost needs to be taken into consideration to justify and see the bigger problem.

6) **Investment in Research**

The reuse of EAF slag and dust must be researched in various implementation scenarios and see which technologies are available for use in Egypt. The industry should invest in differing Universities in Egypt and see what can be implemented and see if students have different ideas or theories that can be implemented. Hence, the industry needs to keep an open mind to the various reuse methods.

7) **Incorporating Expertise advice**

The field needs to take ahold of expertise in waste management and consult with them on how to make better decisions and reuse of their wastes. To consult with experts in the waste management field in Egypt will enable better pathways and would entail that the steel industry would see issues that have been caused with their current management practices.

8) **Governmental Involvement**

With having someone held accountable, this would entail the industry to attempt to make an effort in having better procedures on handling the waste. It would also give some incentives for the companies that started to invest in better waste management processes and have easier tax regulations or even better relations across all stakeholders.

7.2 Further Needed Investigation:

- More intensive look and further studies in finding more solutions to the waste management problem in the steel industry in Egypt.
- This is vital in overcoming the high costs of management and the depletion of natural resources that are occurring rapidly.
- There is also a need to find more processor types used globally and compare the costs with the proposed solution.

- More research on the successful uses of slag in types of material,
- Stakeholders to be involved in the decision making for the implementation of a more sustainable steel industrial cycle.

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%D8%A7%D9%84%D8%AA%D8%B3%D9%88%D9%8A%D9%82-
%D8%A8%D8%AD%D8%AF%D9%8A%D8%AF-%D8%B9%D8%B2-100-
%D9%85%D9%84%D9%8A%D8%A7%D8%B1-%D8%AC%D9%86%D9%8A%D9%87-
%D8%A7%D8%B3%D8%AA%D8%AB%D9%85%D8%A7%D8%B1%D8%A7%D8%AA-
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Appendices:

A. IRB Approval

CASE #2017-2018-180

THE AMERICAN UNIVERSITY IN CAIRO
INSTITUTIONAL REVIEW BOARD

To: Amina Mahmoud

Cc: Muhammad Khaled

From: Atta Gebril, Chair of the IRB

Date: August 28, 2018

Re: Approval of study

This is to inform you that I reviewed your revised research proposal entitled "**Sustainability analysis of Steel industry in Egypt: Reusing the byproducts of Steel Making Plants in Egypt**" and determined that it required consultation with the IRB under the "expedited" category. As you are aware, the members of the IRB suggested certain revisions to the original proposal, but your new version addresses these concerns successfully. The revised proposal used appropriate procedures to minimize risks to human subjects and that adequate provision was made for confidentiality and data anonymity of participants in any published record. I believe you will also make adequate provision for obtaining informed consent of the participants.

This approval letter was issued under the assumption that you have not started data collection for your research project. Any data collected before receiving this letter could not be used since this is a violation of the IRB policy.

Please note that IRB approval does not automatically ensure approval by CAPMAS, an Egyptian government agency responsible for approving some types of off-campus research. CAPMAS issues are handled at AUC by the office of the University Counsellor, Dr. Ashraf Hatem. The IRB is not in a position to offer any opinion on CAPMAS issues, and takes no responsibility for obtaining CAPMAS approval.

This approval is valid for only one year. In case you have not finished data collection within a year, you need to apply for an extension.

Thank you and good luck.

Atta Gebril

Dr. Atta Gebril
IRB chair, The American University in Cairo
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T: 02-26151919
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Institutional Review Board
The American University in Cairo
AUC Avenue, P.O. Box 74
New Cairo 11835, Egypt.

B. Interviews transcribed

M. Abdallah

1. **What is the current technology used in your plants:**

   Would you like me to go into detail of flag sheet production?

   Currently, we are using the eclectic arc furnace technology. It is the most cost efficient method and is highly effective.

2. **What is the production capacity?**

   More than 2 million tonnes but I will send you the full excel sheet. The approximation at least as billets and rebars and like you said, I will disregard the flag sheet production.

3. **What are the major current byproducts generated?**

   The two major byproducts are slag and dust. These are byproducts that are a result of EAF production line.

4. **The volumes of these byproducts?**

   Again, I will send them to you as a concept. It is approximately 10-12% of slag and 2% of dust.

5. **Is Slag reused? How?**

   Currently, we reuse slag through our slag processor in paving the plant premises and we also use this for CSR reasons by paving villages nationwide. However, for the rest, are usually thrown into the scrap yard or placed into landfills.

6. **Is dust reused? How?**

   No, we are entitled by the ministry of environment to certify any amount of dust generated and we pay a sum of 650EGP per ton for one certificate. Otherwise, we would be fined a large amount. As you know, dust is a very hazardous waste that we cannot place ourselves into landfills. The other option in this case would be to extract the zinc but we have not invested in a processor yet but overall, managing dust waste is extremely expensive for us and we are actively searching for different ways to deal with this.

7. **What are the technologies used? What are the costs?**
   We have invested around 2 million euros in a processor for the slag and this excludes maintenance or anything else. (Prior to the floatation of the Egyptian pound). This has proven to be very efficient for us not only cost wise, but also, from a sustainability perspective.

8. **How much is currently reused (if any)? What are the current barriers to reusing more/all materials?**
   We aim to reuse any and all slag generated as a byproduct but of course, sometimes, we leave the slag for purposes out of our hands on the scrap yard.

9. **Is your company interested in investing in better waste management technologies?**
   Yes, we are looking for other ways to better manage our slag waste and most importantly our dust waste.

10. **If reuse is done, do you think this would benefit your company's CSR?**
    From what we have done, it has. Especially if you consult our marketing department, they have seen great results whereby not only do buyers trust us more, "please see market share," our employees build a sense of loyalty to the company.

11. **What is the maximum amount your company would pay for investing in the reuse of the byproducts?**
    That is confidential however we are willing to explore various options.

12. **What profit amount or payback period would be needed for you to invest in the reuse of byproducts?**
    our payback period for the slag processor was around 3 years which is great but we would be willing to wait for more years to come for new technology.
13. **What additional know-how will be needed?**
    You need to train your employees and invest time and energy in growing a difference within the company which all comes down to the employee's skills and belief in the cause.

14. What are the most common diseases related to dust and slag?

Lung problems may arise along with eye-sight issues. This is causing us huge amounts in medical expenses (how much?) – sorry I am not able to disclose this information but let's just assume that it is a big amount that needs to be looked after and hence why, we are looking into investing into a new processor for dust.

15. How does your company respond to adverse health effects of your production?

We fully cover our employees' medical expenses. We care a lot about our employees' well-being and morale.

16. Do you know about any technologies used in other countries? How do you see them applicable in Egypt? Are you aware of any research done in Egypt?

We know that in Germany there are great methods dealing with the slag but most notably, in Turkey, this case study is to be looked at because they are one of the few countries that operate mainly with EAF technologies like Egypt and have started investing in more technologies that seem to be more attractive and suitable to use.

17. Are there any regulations regarding the byproducts?

Yes, for dust especially. Like I mentioned, the certificates from the ministry of environment have to be signed by the ministry otherwise huge fines are emitted on any misuse of management.

18. Are there tax benefits for better environmental management in your sector?

Not that I am aware of.

19. Have you tried selling your products to other heavy industries that require the same material?

Because we do not have the blast furnace technology we cannot sell to the cement industry. Yet, we can sell to the concrete / construction material industry which is at a very high price as pavement with slag is of high durability and strength. It is also needed so there is high demand for it.

M. ZADA

1) **What is the current technology used in your plants:**

We use the electric arc furnace technology in our plants as per most of the plants in Egypt. Currently the only plant in Egypt that uses the blast furnace technology is the National Steel company in Egypt. We find that this technology is a bit old and as such it is more cost efficient and environmentally friendly to use the EAF technology.

2) **What is the production capacity?**

We produce around 300,000 tonnes of steel annually. This number has significantly differed over the past years as we reached full capacity.

3) **What are the major current byproducts generated?**

There are a lot of byproducts produced, these include slag, dust, sludge, and refractories. The most of byproducts generated are slag.

4) **The volumes of these byproducts?**

From the annual amounts of steel produced around 30,000 tonnes of slag is generated as a byproduct. These might not seem like a significate number but for a small scale plant is causes some issues of where to place it. s

5) **Is Slag reused? How?**

We would love to reuse slag as a secondary raw material, but currently we tend to leave it or place them into our scrap yard. We know one company in Egypt has a processor. We have also looked at case studies abroad and found there are multiple places that reuses slag, yet we need to study it more to find how we can actually implement it in Egypt.

The cost of slag differs from processed to unprocessed. As a byproduct it is set at around 25 EGP per tonne. Yet, if you process the slag it goes up to 150 EGP. This is a significant increase in the price and shows great potential, we just need to have the mentality to invest into new technologies to reuse

6) **Is dust reused? How?**

We would love to reuse dust, yet we have not invested in this. Currently we pay around 600 EGP per tonne of dust to the Ministry of Environment. We also pay around 5,000 EGP per 30 Tonnes for a special truck that takes the dust into the landfills. This is a huge amount we end up paying every year and as such would love to find alternatives.

7) **What are the technologies used? What are the costs?**
N/A

8) **How much is currently reused (if any)? What are the current barriers to reusing more/all materials?**
we don't reuse many of our materials, its expensive and honestly I would say Egypt is lacking the vision in doing so. But, if we could have reuse potential we would definitely do it. It's a profitable amount that would be reached if reuse is done. The resale of dust is around 150 EGP per tonne atleast it would carry the amount of the certification and the transportation. The non-reuse of slag is a waste of money, concept and it is behind optimization

9) **Is your company interested in investing in better waste management technologies?**
Turkey should be focused on – most country in the world that imports the scrap 21 million tonnes of scrap annually. 1.7 million tonnes monthly – Egypt is importing max 1.5 million annually. 100,000 tonnes monthly. We should look at turkey as an indicator.

10) **If reuse is done, do you think this would benefit your company's CSR?**
Immensely, our companies CSR would sky rocket.

11) **What are the most common diseases related to dust and slag?**
Lung diseases and eyes. These are very costly

12) How does your company respond to adverse health effects of your production?
Try to have clear guidelines for health and safety in order to not have more effects on the health of our employees.

13) **Do you know about any technologies used in other countries? How do you see them applicable in Egypt? Are you aware of any research done in Egypt**?
Turkey, please look into it.

14) **Are there any regulations regarding the byproducts?**
Yes, for dust especially. Like I mentioned, the certificates from the ministry of environment have to be signed, also we need more governmental regulations.

15) Are there tax benefits for better environmental management in your sector?
No.

16) **Have you tried selling your products to other heavy industries that require the same material?**

If we can process the slag we can sell it for 150 EGP, especially when the FEO is low. Also, dust can be resold. Slag foaming is also important as it makes electrodes safe and does not break.

L. Beshay

1) What is the capacity of your SMP production line?

We have 3 SMP production lines with the following nameplate capacities;

- SMP(EA): 1,200,000 MTPY.
- SMP(ES1): 1,500,000 MTPY.
- SMP(ES2): 1,500,000 MTPY.

2) How do you deal with the byproducts currently?

Byproducts are split into two types, direct and indirect.

Direct products are treated and then either sold or are reused internally, indirect byproducts are usually sold.

3) What are the technologies used? What are the costs?

We segregate the metallic and non-metallics found in slag and treat the slag and segregate them by size.

4) What are the volumes of byproducts generated?

Byproduct
Lime Fines
Slag
Scale
ZnO Dust
Wood
Light Plastic
Used Refractory Bricks
Paper Bags
Woven Plastic Bags
Copper
Lead
Lawn & Landscape Byproducts
Used Oil Filters
Aluminum

Nickel
Heavy Plastic
Plastic Barrels
Metal Barrels
Carton
Used Graphite Electrodes
Used Cables
Used Lubricants
Used Oil

5) **How much is currently reused (if any)? What are the current barriers to reusing more/all materials?**

6) **Is your company interested in reusing byproducts?**

   Yes, we aim to reuse 100% of our byproducts and to be an environmentally sustainable producer.

7) **Is your company interested in investing in better waste management technologies?**
8) **If reuse is done, do you think this would benefit your company's CSR?**
9) **What is the maximum amount your company would pay for investing in the reuse of the byproducts?**
10) **What profit amount or payback period would be needed for you to invest in the reuse of byproducts?**

ROI < 1year.

11) **What additional know-how will be needed?**
12) **What are the most common diseases related to dust and slag?**

Mainly lung diseases and eye infections.

13) **How does your company respond to adverse health effects of your production?**

Periodical medical check-ups are carried out and the personnel that

14) **Do you know about any technologies used in other countries? How do you see them applicable in Egypt? Are you aware of any research done in Egypt?**

We are members of the “Bureau of International Recyclers” and they regularly share the new technologies and research being carried out in the field of dealing with recycled materials generally. Additionally, we are involved locally with a university in Egypt in researching alternative uses for treated slag.

15) Are there any regulations regarding the byproducts?

Only for indirect byproducts, specifically, the used lubricants and oils.

16) Are there tax benefits for better environmental management in your sector?

No.

17) Do you have a carbon footprint and environmental impact analysis for your company? How far does it affect your management decisions?

We do not measure our carbon footprint, but we do analyze our environmental impact and are ISO 14001:2015 accredited and we comply to the local and regional standards, in the process as well as to the decision-making procedures.

18) Have you tried reusing slag/dust from the steel industry?

Yes, treated slag, mainly with the aggregate and ready-mix producers.

19) Have you tried selling your products to other heavy industries that require the same material?

Yes.

G. ElNagdy

1) What is the current technology used in your plants:

EAF technology, especially in our new plants that don’t only have rolling mill but continuous casting which and the actual EAF Furnace.

2) What is the production capacity?

I have sent you our capacities, yet we expect to reach 2.3 million tonnes if we work on full capacity.

3) What are the major current byproducts generated?

Most of the byproducts generated are in small amounts, but the most amounts of byproducts are slag and dust which we are interested in seeing a reuse for.

4) The volumes of these byproducts?

You can always have a set rule of a yield of around 12% of slag, and 1-2% of dust. This is a known fact across the industry.

5) Is Slag reused? How?

Yes we reuse it in our scrap yards. We don't have the technology to entail us to reuse it like we would like. This is costly but we would love to have it. Slag can be resold at around 120 EGP if it is processed which makes it an attractive investment. We are looking into it.

6) Is dust reused? How?

Dust is a very hazardous waste and as such to be able to reuse it it is very sensitive. The current management of it is very expensive around 550 EGP per certificate and transportation of around 10,000 EGP per 60 tonnes. It is very expensive.

7) What are the technologies used? What are the costs?

none yet

8) How much is currently reused (if any)? What are the current barriers to reusing more/all materials?

We aren't using it efficiently. There are barrier of course of the reuse of this like governmental regulations that have to be looked it. Even trying to have them go into the process with us.

9) Is your company interested in investing in better waste management technologies?

yes of course and we hold competitions here to see if anyone comes up with waste management technologies.

10) If reuse is done, do you think this would benefit your company's CSR?

We are very interested in our CSR. Like you know you cannot market steel, so CSR is as much as you can do.

11) **What are the most common diseases related to dust and slag?**

Lung diseases and eye infections are the most common cases due to dust. Slag does not bare any diseases.

12) **How does your company respond to adverse health effects of your production?**

HSE is very important, and ofcourse medical insurance to be up to par.

13) **Do you know about any technologies used in other countries? How do you see them applicable in Egypt? Are you aware of any research done in Egypt?**

I know that Germany and USA have great things done with slag, we would look into that.

14) **Are there any regulations regarding the byproducts?**

As mentioned we need to look into the governmental regulations and have them promote the reuse of byproducts of the industry.

15) **Are there tax benefits for better environmental management in your sector?**

No.

16) **Have you tried selling your products to other heavy industries that require the same material?**

Not yet, but if we invest into this processor it would be very likely to go to the construction material industry to have them buy slag from us.

C. Detailed NPV calculations of each scenario

Conservative Forecasting

Revenues	Year 1	Year 2	Year 3	Year 4	Year 5
Quantity	100,000	100,000	100,000	100,000	100,000
Capacity	80%	100%	100%	100%	100%
Slag	97%	97%	97%	97%	97%
Slag	77,600	97,000	97,000	97,000	97,000

Slag Price	117.0	126.4	136.5	147.4	159.2
Increment	8%	8%	8%	8%	8%
Scrap Price	6800	7276	7785.32	8330.2924	8913.412868
Increment	7%	7%	7%	7%	7%
Total Revenues	9,079,200	12,256,920	13,237,474	14,296,471	15,440,189
Energy					
Quantity KWh/t	5.1	5.1	5.1	5.1	5.1
Energy Price	0.4	0.5	0.5	0.6	0.7
Increment	15%	10%	10%	10%	10%
Total Electricity Cost	(176,664)	(253,955)	(279,350)	(307,285)	(338,013)
Diesel Fuel					
Quantityl/t	0.3	0.3	0.3	0.3	0.3
Energy Price	5.5	6.3	7.0	7.7	8.4
Increment	15%	10%	10%	10%	10%
Total Diesel Fuel Cost	(132,000)	(189,750)	(208,725)	(229,598)	(252,557)
Consumables					
EGP/t	18.0	19.8	21.8	24.0	26.4
Increment	10%	10%	10%	10%	10%
Total Consumables Cost	(144,000)	(198,000)	(217,800)	(239,580)	(263,538)

Labor					
Quantity	3.0	4.0	5.0	5.0	5.0
Wage	1,200.0	1,332.0	1,478.5	1,641.2	1,821.7
Increment	11%	11%	11%	11%	11%
Total Labor Cost	(3,600)	(5,328)	(7,393)	(8,206)	(9,108)
Total Cost	(456,264)	(647,033)	(713,268)	(784,668)	(863,217)
Total Cash Inflow	8,622,936	11,609,888	12,524,206	13,511,803	14,576,972

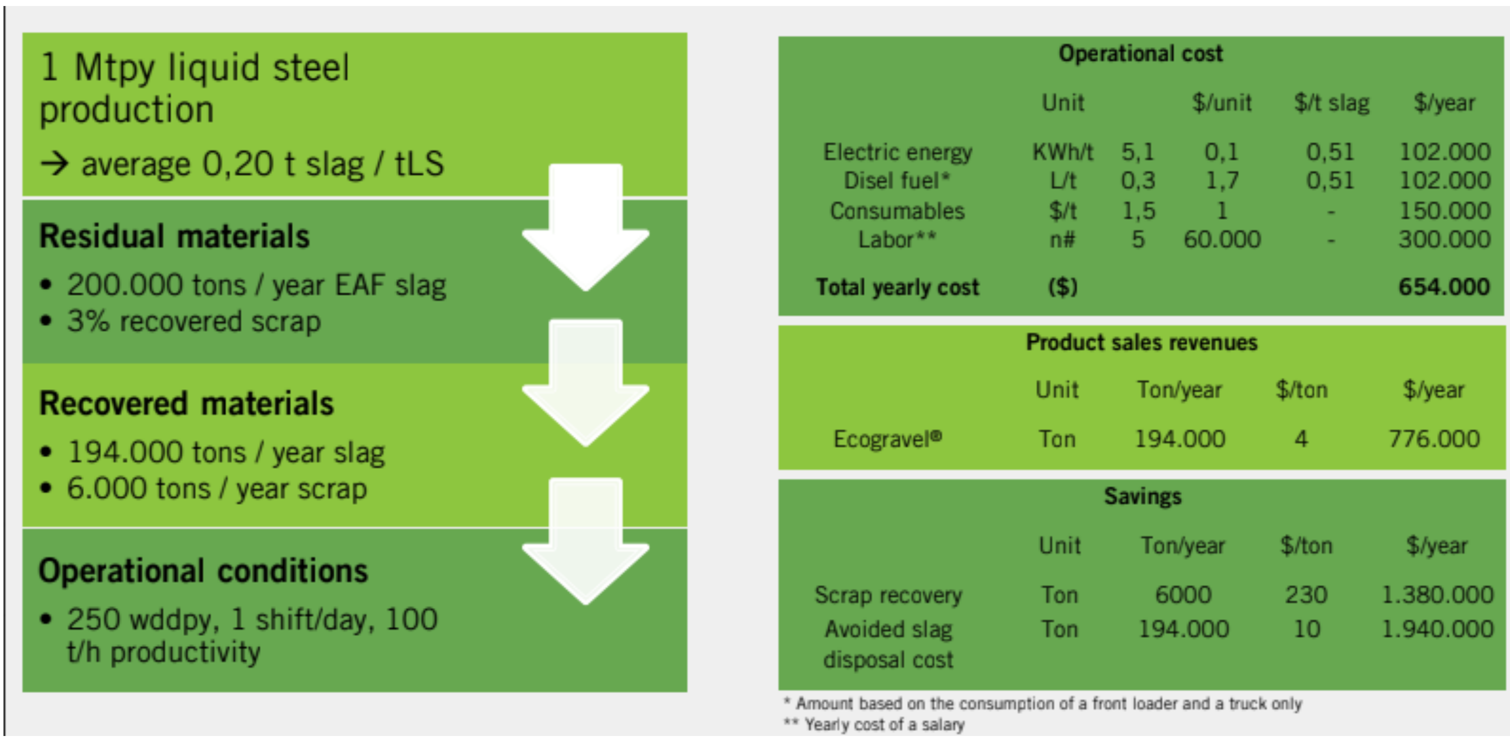
Aggressive Forecasting

Revenues	Year 1	Year 2	Year 3	Year 4	Year 5
Quantity	100,000	100,000	100,000	100,000	100,000
Capacity	90%	100%	100%	100%	100%
Slag	97%	97%	97%	97%	97%
Slag	87,300	97,000	97,000	97,000	97,000
Slag Price	150.0	162.0	175.0	189.0	204.1
Increment	8%	8%	8%	8%	8%
Scrap Price	6800	7276	7785.32	8330.2924	8913.412868
Increment	7%	7%	7%	7%	7%
Total Revenues	13,095,000	15,714,000	16,971,120	18,328,810	19,795,114

Energy					
Quantity KWh/t	5.1	5.1	5.1	5.1	5.1
Energy Price	0.4	0.5	0.6	0.7	0.8
Increment	15%	15%	15%	15%	15%
Total Electricity Cost	(198,747)	(253,955)	(292,048)	(335,855)	(386,233)
Diesel Fuel					
QuantityL/t	0.3	0.3	0.3	0.3	0.3
Energy Price	5.5	6.3	7.3	8.4	9.6
Increment	15%	15%	15%	15%	15%
Total Diesel Fuel Cost	(148,500)	(189,750)	(218,213)	(250,944)	(288,586)
Consumables					
EGP/t	18.0	20.7	23.8	27.4	31.5
Increment	15%	15%	15%	15%	15%
Total Consumables Cost	(243,000)	(310,500)	(357,075)	(410,636)	(472,232)
Labor					
Qauntity	3.0	4.0	5.0	5.0	5.0
Wage	1,200.0	1,380.0	1,587.0	1,825.1	2,098.8
Increment	15%	15%	15%	15%	15%
Total Labor Cost	(3,600)	(5,520)	(7,935)	(9,125)	(10,494)

Total Cost	(593,847)	(759,725)	(875,270)	(1,006,561)	(1,157,545)
Total Cash Inflow	12,501,153	14,954,276	16,095,850	17,322,249	18,637,570

D. Eco Gravel Model:



Operational cost					
	Unit		$/unit	$/t slag	$/year
Electric energy	KWh/t	5,1	0,1	0,51	102.000
Disel fuel*	L/t	0,3	1,7	0,51	102.000
Consumables	$/t	1,5	1	-	150.000
Labor**	n#	5	60.000	-	300.000
Total yearly cost	**($)**				**654.000**

Product sales revenues				
	Unit	Ton/year	$/ton	$/year
Ecogravel®	Ton	194.000	4	776.000

Savings				
	Unit	Ton/year	$/ton	$/year
Scrap recovery	Ton	6000	230	1.380.000
Avoided slag disposal cost	Ton	194.000	10	1.940.000

* Amount based on the consumption of a front loader and a truck only
** Yearly cost of a salary