The Material Flow of a Smartphone: the Negative Impacts on the Countries of Origin and

THE BENEFITS OF A CIRCULAR ECONOMY APPROACH

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Abstract

This research has two main goals: firstly, to give an overview of the smartphone supply chain, with a special focus on five minerals that are fundamental to smartphone manufacturing; and secondly, to explore circular economy concepts and business models that can bring positive transformation to smartphone production.

Smartphones are now an essential part of life for billions of people, but the consequences of its production are rarely taken into account. With more than 150 different components necessary for its fabrication, the devices have an enormous environmental footprint. Moreover, the sourcing of the materials often generates negative social impacts on the countries in which they are extracted.

The first chapter of this research paper addresses the supply chains of copper, cobalt, gold, aluminum and lithium, and the role these materials play in the smartphone material flow. Furthermore, the consequences of their sourcing in the countries of origin will be presented.

The second chapter consists of solutions for the sourcing problem of raw materials needed to make these ubiquitous technological apparatuses, especially the ones that require mining. In a shift towards a circular economy, the researcher has chosen an approach in order to consider an effective alternative to the current model. As a result, innovative solutions are exposed through business models related to circular economy. At the end of this chapter, a case-study of a sustainable and responsible company based in the Netherlands is described.

The final section is the conclusion, in which solutions are given to the situations discussed in the two previous chapters.
Dedication

~To my beloved mother and grandmother - Patricia and Maria Regina~
For always believing in me, and for always encouraging me to chase my dreams

~To my brother, godmother and godson - Rodrigo, Giselle and Francisco~
For all the love, companionship and motivation given throughout my life
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Introduction

Overconsumption is a much debated issue nowadays. With the increase of awareness in sustainability, many of society’s problems are coming to light. The excessive and, sometimes, unnecessary use of disposable plastic, for instance, has been an inspiration for a change in production that is leading to a behavioral change. Nonetheless, plenty of other things are yet to be tackled, such as overproduction, and reuse of smartphones, and the side effects of sourcing and manufacturing in places like Africa, Asia and the Americas.

In 2017, more than 1.5 billion smartphones were produced in the world.1 This shows an exponential increase in relation to 2007, when the industry gained significant ground. The production of smartphones requires the extraction and use of enormous quantities of minerals and materials that are becoming scarce and detrimentally affecting biodiversity and communities. Copper, cobalt, aluminum, lithium and gold, for instance, are vital not only for smartphones, but for all of the devices of this kind.

The big players of the industry are concerned about their supply chain. Suppliers are seen as partners that are also responsible for the companies’s output. This change of mindset made corporations implement new policies, such as tracing the source of some of these materials, to avoid and prevent problems such as social exploitation and negative environmental impacts that were happening within their suppliers factories or mines. However, these measures are not enough to prevent social and environmental exploitation in the countries where the materials are extracted. Communities are being affected directly and indirectly by this kind of activity, threatening millions of people’s lives.

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To change this reality, it is necessary to look differently at the flow of material of a smartphone. The circular economy approach, for instance, posits that things should be built to last, and everything should be designed to keep the materials in the loop of usage for longer. This mindset is completely different from the current one that the smartphone industry has. At the moment, their business model has a few repetitive steps: extract, produce, sell and dispose. To make matters worse, the land from which these metals are sourced is not taken into account, which has been a major factor in creating or worsening environmental problems for the biodiversity and communities involved.

The goal of this research paper is to expose how the flow of copper, cobalt, aluminum, lithium and gold in the smartphone supply chain affect communities and ecosystems in the countries of origin. Moreover, this thesis aims to find sustainable and effective solutions for this problem by exploring the positive effects that a circular economy approach would have on the smartphone industry. The research will present circular economy business models that can be applied by the smartphone industry and, directly and indirectly, improve its supply chain. As a consequence, the minerals used in the smartphone can be positively affected too.

The thesis is structured in two parts: the first one exposes the flow of smartphone materials by giving an overview of the whole production process of a smartphone and presenting a concrete analysis of the current situation of the problems caused by mining copper, gold, aluminum, cobalt and lithium. The second part consists of solutions and opportunities that a circular economy approach would have in this supply chain, according to specialists in the field. In addition, in the second part a successful case of a sustainable phone will be presented, with suggestion of how the industry can use its example as a benchmark.
Methodological approach

There are two main questions that this research aims to answer: 1.) What is the material flow of a smartphone and its effects on the countries of origin? 2.) What would the benefits of a circular economy be in this material flow?

This thesis was written after careful analysis of data from a vast array of sources. The research was done from 15th of August to 30th of September, and to get a broad grasp on the current situation of the smartphone industry and its supply chain, different articles from various media outlets are used. The Guardian, The Washington Post, BBC, Recycling Nation and other specialized media outlets are used as sources. Furthermore, research papers and dissertations from other scholars are also taken into account.

The supply chain assessment compiled by the Fairphone Company is used as the framework for this research paper. The 2017 study gives an overview of each material used in a smartphone and its current impact on the origin country. The materials that were analyzed in this paper are copper, cobalt, aluminum, gold and lithium. Given the quantity of different materials, it was necessary to narrow down the research and focus on the five main ones.

The books “Circular Economy: a Wealth of Flows”, by Ken Webster, and “This Changes Everything”, by Naomi Klein, were also sources for this research. The first one because it presents all circular economy principles and the results of transformations towards this model. The last one because it exposes the reality behind the current system, showing how the current capitalist economic model of “take-make-dispose” is harming severely the environment and communities.

Interviews with a circular economy specialist, Prof. Laurent Maeder, were conducted in the months of August and September.
Chapter 1 - The material flow of a smartphone and its impact on the countries of origin.

1.1- The process

The process to make a smartphone consists of three steps: extracting materials, processing materials and manufacturing. These three steps are fundamental to producing a smartphone. They happen in different parts of the world and involve a lot of different people. The magnitude of these operations makes it difficult to regulate all the players associated with it. Additionally, it is very difficult to trace the source of these materials, since they travel through different places of the globe before arriving at the factory.

The extracting stage is the first one. To manufacture a smartphone, first raw materials need to be extracted from the earth. They are used to make the different components of a mobile phone: the circuit board, the liquid crystal display and the battery. Inside each device, many valuable components go inside it. The Economist reported:

“New phones are stuffed with pricier chips and displays. The total value of the parts inside the iPhone X and Samsung Galaxy S9 is 28% and 13% more, respectively, than in their predecessor models, according to IHS Markit.” (The global smartphone supply chain needs an upgrade. (2018, September 08). Retrieved September 20, 2018, from https://www.economist.com/business/2018/09/08/the-global-smartphone-supply-chain-needs-an-upgrade)

The circuit board requires crude oil to be transformed into plastic, silicon and other materials. Substances such as copper, gold, lead, nickel, zinc and beryllium are mined from the earth to be used as circuit boards parts. Many of these raw materials are potentially harmful to the environment and to humans. If they are extracted unsafely and improperly, they can harm the workers involved, contaminate the soil (if buried in landfills, for instance) and destroy the communities and the biodiversity in the surrounding areas of the mines.
To produce the liquid crystal display (LCD), different substances are used: plastic, glass, liquid crystalline and mercury. Mercury is known as a heavy-metal that can be potentially harmful to the environment and to people if it is not manipulated carefully or disposed of properly. Another flaw of the LCD manufacturing process is that sand, oil and liquid crystalline are non-renewable, which makes it impossible to reuse these materials after they have been disposed of.

Batteries are the third part that requires extraction of raw materials from the earth. It is probably the most debated component in smartphones in terms of recyclability and environmental damage. Smartphone batteries are powered by lithium-ion, but also contain different raw materials extracted from the earth such as cobalt, zinc and copper.

The second stage of smartphone production is the processing of materials extracted from the earth. This step turns the raw materials into parts and components that will be used in mobile phones. After the mining process, copper is ground, heated, and treated with chemicals and electricity to refine the pure metal and prepare it to be used as cables, circuit board components and batteries. This phase usually happens near the excavation site, although, sometimes it can happen in different countries.

The processing of raw materials requires a lot of energy and emits greenhouse gases. It can also be responsible for pollution and environmental damage such as soil contamination due to the usage of chemicals in order to treat pure metals. The workers can be potentially exposed to these materials and toxic chemicals during this phase, especially because treatment is not done in countries with strict labor laws that enforce a safe work environment.

The third and fourth phase are the production of the components (circuit board, battery...) with the raw the materials extracted, that after ready, are shipped to be assembled and manufactured into smartphones. After all the necessary materials have been extracted and processed, the manufacturer is ready to produce the components,
assemble and produce the phone. Each component of the phone is usually made in
different countries in Asia, like Malaysia, Taiwan, Vietnam or China. The assembly and
production is done in China, and then shipped to all over the world. The phones are
produced in China due to low cost labor and financial incentives from the Chinese
government. The Economist also exposed labour issues in the Chinese factories:

“Many observers worry about labour conditions in the supply chain; the
typical poorly paid assembly worker in China handles 1,700 phones a
day” (The global smartphone supply chain needs an upgrade. 2018, September 08. Retrieved
supply-chain-needs-an-upgrade)

Workers in China, Vietnam, Taiwan, India and Bangladesh face extensive work-
hours in order to meet the factories’s goals and deadlines. Many of them work for more
than 12 hours per day, what is more than what the International Labour Organization
recommends. On top of that, all of them are not paid well enough to compensate their
hard-work, what makes impossible for the majority of them to consume the same phones
they are producing everyday.

Once the mobile phone is ready, it is shipped to other countries to be sold. These
long-distance shipments increase the carbon and environmental footprint of the
product, that is already extremely high since all the parts and components come from
different parts of the world.

Scientists from McMaster University in Canada have found that smartphones are
the most damaging products of the tech industry in terms of carbon emissions, with the
bulk of its emissions coming from the production chain. They have calculated the carbon
footprint of laptops, desktop computers, tablets and mobiles, and all these gadgets have
supply chains that are responsible for the majority of the emissions. While the devices
require low energy to operate, 85% of the emissions come from the supply chain and
manufacturing.
Canadian scientists also analyzed energy consumption of the mobile phone industry supply chain. According to their research, by 2020 the energy consumption of a smartphone will be more than that of laptops and PCs. This is due to the value chain, but also because the data centers involved in maintaining data and cell phone service of the devices, which requires a lot of energy in order to operate twenty-four hours per day, 365 days a year:

“For every text message, for every phone call, every video you upload or download, there’s a data centre making this happen.” (How our smartphones are hurting the environment. 2018, March 02. Retrieved September 10, 2018, from https://www.irishnews.com/magazine/science/2018/03/02/news/how-our-smartphones-are-hurting-the-environment-1268849/)

In addition to the carbon footprint, smartphones also generate vast economic footprints. A study by the International Monetary Fund shows that smartphone components accounted for 33% of exports from Taiwan, 17% of exports from Malaysia and 16% from Singapore. In China, smartphones comprise of 6% of the country’s exports. The Economist assessed the supply chain and discovered that memory chips come from South Korea and Vietnam; system chips from Malaysia and Taiwan; displays from Japan and South Korea. The parts are mostly assembled in China by “armies of Chinese workers”, according to the publication.²

It is difficult for a company to trace back the source of the materials involved in their products due to the broad network of people and companies involved. Almost every smartphone contains at least one mineral that is financing social and environmental problems in the country of origin. Mapping out every material of the supply chain gives an opportunity for improvement of the companies involved in many ways, and this topic will be addressed in the second chapter of this research paper.

1.2 - Cobalt

In a common smartphone one can find at least eight different minerals that are mined in a vast array of different countries and regions around the world. For instance, Cobalt (Co) is mined in the United States, Chile, Peru, Russia, Mexico, Zambia, Poland, Kazakhstan, Canada and Congo (DCR).

Cobalt is used to build rechargeable lithium-ion batteries – a mandatory component of the tech industry that has become very common in recent years. Companies like Apple, Samsung, Tesla, General Motors and BMW have an increasing demand for cobalt, since they produce mass-scale products that require the mineral. The demand is expected to increase sharply in the coming years.

The metal comes from countries where social and working conditions are better than others. For instance, cobalt from Canada is mined more responsibly in the Democratic Republic of Congo. This disparity regarding the impacts of mining activity has created the expression “conflict minerals.” These minerals are given this title because they are used to finance wars, dictatorships, social exploitation and environmental degradation. In 2016 approximately 60% of the cobalt mined was a by-product of copper, 38% a by-product of nickel, and the remaining 2% from primary cobalt mines.
More than 51% of the world’s Cobalt came from the Democratic Republic of Congo in 2017. This means that companies like Apple, Samsung andMotorola, as the biggest competitors of the industry, purchase the mineral from this region, either directly or indirectly. When a smartphone arrives at a retail store, the customer holds it and tests it, ask the salesperson for specific information. It is unlikely that the customer will ask about where the cobalt used in the batteries comes from. Regardless, it is inevitably there, and it is not likely to come from a responsible source. The demand for cobalt has increased a lot in the past two decades, especially with the advent of the computer and smartphone industry. Production is keeping pace with the demand, but still maintaining poorly managed work conditions.

The Cobalt Supply Chain

Since the 1990s, cobalt production has gone almost straight up to meet demand:

Cobalt production per year - Source: www.visualcapitalist.com

Many different players are involved in the mining process alone. From the miners themselves to the transportation companies, many different people play a role in this first phase. There are a great number of people participating from the very beginning, and all of them are affected in some way or another. With the current model in place by the
industry, it is almost impossible to track the source of cobalt that is arriving to be manufactured in countries like China and India.

Other countries are experiencing detrimental impacts from cobalt mining as well. In China, for instance, cobalt mining is related to heavy-metal and radioactive contamination of water and soil. In addition, it is also responsible for groundwater and public health problems associated with industrial pollution. In Canada, cobalt is related to long-term environmental and biodiversity degradation and contamination. In Russia, cobalt is responsible for damaging protected areas and affecting local communities and the traditions of pastoral indigenous groups. In Zambia, cobalt mining is compromising water quality in some regions and negatively affecting local aquatic ecosystems.

Small-scale and unregulated mining practices also contribute to cobalt’s hazardous role. In the DCR, cobalt is linked to human rights abuse and the exploitation of the working class. Lower classes are forced to work in the mines against their own will. This forced labor fuels and finances the civil war currently thwarting the country. Most of the time, the mining is done by child labor, which increases the social problems of the country and destroys families. The Washington Post did an investigative report on the coal roadmap, from the tunnel mines in Congo to the devices used daily by millions of people. They posit:

“The world’s soaring demand for cobalt is at times met by workers, including children, who labor in harsh and dangerous conditions. An estimated 100,000 cobalt miners in Congo use hand tools to dig hundreds of feet underground with little oversight and few safety measures, according to workers, government officials and evidence found by The Washington Post during visits to remote mines. Deaths and injuries are common. And the mining activity exposes local communities to levels of toxic metals that appear to be linked to ailments that include breathing problems and birth defects, health officials say.” (The cobalt pipeline: From dangerous tunnels in Congo to consumers’ mobile tech. (2016, September 30). Retrieved September 14, 2018, from https://
Even if big companies make a concerted effort to better the situation, the DCR will continue to play an important role in cobalt production for many years. Production is forecasted to increase gradually year by year, reaching almost 80 tons in 2020. An increase of more than 10% in relation to 2018. However, if done responsibly and according to international standards and laws, the result from small scale mining is not always bad. In the second chapter of this master’s thesis, small-scale mining will be analyzed, and its positive effects will be explored.

Besides financing conflicts and labor exploitation, a number of other negative side effects are caused by cobalt mining. Excessive untreated waste, radioactive waste, greenhouse gas emissions, water and soil pollution and biodiversity damage. Water contamination due to mining waste is a serious issue in all cobalt-producing countries.
In addition, air pollution from pulverized dust causes breathing problems for the workers involved and communities near the mines.

1.3 - Aluminum

Aluminum is present in almost everything nowadays. It has important and unique characteristics that make it the right choice to be used in a big range of products. It is strong, light, impermeable, highly resistant to corrosion, odorless, non-combustible and easy to recycle. This material can be found not only in vehicles and airplanes, but also in small objects such as aluminum foil, antiperspirants and smartphones. Nonetheless, aluminum creates a series of social and environmental issues that will be addressed below.

Aluminum comes from the separation of bauxite ores via electrolysis. This method was discovered almost two hundred years ago, and since then, it has become an essential material in many industries, playing an important role in the GDP of many countries. China, Russia, Canada and Brazil are the four largest producers of aluminum in the world.
Some of the biggest companies in the smartphone industry make their products with aluminum. Apple utilizes it in all of its iPhones which makes them durable and good-looking for consumers. Samsung also started to use aluminum in their mobile phone protective cases. The journey of aluminum to a finished product is long and arduous, consisting of four main steps: 1.) primary production or extraction 2.) melting and solidification/processing 3.) fabrication 4.) usage in finished products.

Aluminum is extracted in a process called open-pit mining (also known as strip-mining), in which large areas of the earth are excavated relatively close to the surface, enabling workers to remove bauxite from the ground. In order for this to happen, all native vegetation must be extirpated, drastically impacting local biodiversity. According to the website *Recycle Nation*, which specializes in recycling:

“The strip-mining process removes all native vegetation in the mining region, resulting in a loss of habitat and food for local wildlife as well as significant soil erosion. The caustic red sludge and toxic mine tailings that remain are commonly deposited into excavated mine pits where they ultimately seep into aquifers, contaminating local water sources.” ([RecycleNation. (2012, February 21). What Aluminum Extraction Really Does to the Environment. Retrieved September 14, 2018, from https://recyclenation.com/2010/11/aluminum-extraction-recycling-environment/)"
Moreover, after the extraction phase, the rest of aluminum production is incredibly energy-consuming. Often, power plants are built solely to support the aluminum industry. Depending on the source of the energy used, this can increase the environmental and social damage of the aluminum extraction process. For instance, in countries like China, with low levels of clean energy sources and usage, aluminum extraction contributes significantly to greenhouse gas emissions and the deterioration of air quality.

Subsequently the mining process, smelting and processing phases start. These procedures release plumes of toxic vapors into the air, that include some greenhouse gases, such as carbon dioxide, per-fluorocarbons (PFC), sodium fluoride, sulfur dioxide, polycyclic aromatic hydrocarbon and more. These substances are problematic and harmful to human beings and animals, and in the long-term, they contribute to the deterioration of the quality in the regions involved.
The Environmental Literacy Council concluded in a 2015 study that greenhouse gas emissions are the major environmental impact caused by aluminum extraction and production. In the United States, for instance, aluminum processing is the leading source of per-fluorocarbons emissions. PFC’s that originate from metal smelting are the most potent of all the greenhouse gases.

Aluminum cans can be found anywhere on the streets since the metal takes up to five hundred years to decompose. With a vast variety of products utilizing the material, the industry is also responsible for urban pollution and ocean pollution, leading to biodiversity degradation. Demand for aluminum is increasing sharply over the years (5.7% in 2017) and more and more bauxite is being mined to supply a wide range of industries. Some specialists believe that if the demand keeps increasing at this pace, one day aluminum will become scarce and companies will need to rely solely on recycling.

Luckily, aluminum has good recycling properties, such as a low energy consumption and low greenhouse gas emission during the recycling process. In addition, the resulting product is almost the same quality as the original, and it can be recycled almost indefinitely. Aluminum is one the has the biggest potential for the smartphone industry, and this topic will be addressed with further detail in chapter two.

1.4 - Gold

The amount of gold used in a smartphone has boosted over the past four years. From 2016 to 2017, the tech industry consumed 2% more gold. Even though the gold demand has reached a record low in the last few years, the demand for gold has seen a continuous increase in terms of the tech industry. Around 84.2 tons of gold was used for electrical wiring and in smartphones and LEDs, according to an article by The Telegraph.3

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The tech industry is responsible for 8% of the gold used worldwide, which amounts to 375 tons of gold per year. This puts the industry just behind central banks with regard to gold purchase. According to Alistair Hewitt, head of market intelligence at the World Gold Council: Gold has certain features that means it lends itself really well to tech. It’s highly conductive, it doesn’t corrode or tarnish, and it’s highly malleable. The metal, for instance, is used in LED displays and 3D sensors such as facial recognition software used by Apple in iPhones and MacBooks.\(^5\)

As an important material for smartphone manufacturing, gold it is also considered a “conflict mineral” and its extraction and processing generate awful social and environmental impacts. The biggest gold producers of the world are China, Australia, Russia, United States, Mexico, Peru, South Africa and Ghana. Combined, they are responsible for 58% of the global gold production. More than 100 million people rely on gold for their livelihoods.

Irresponsible gold mining is to blame for numerous problems such as habitat destruction, water pollution and social degradation. The South-American country of Peru, for instance, relies on gold mining, which represents 6.2% of the country’s GDP. Artisanal and small-scale mining are predominant in the region, and the gold that comes from Peru helps finance human rights abuse, such as child labor, sexual exploitation and trafficking. Moreover, artisanal and small-scale mining is also responsible for environmental degradation and deforestation, destroying local biodiversity, polluting water and damaging local indigenous communities that rely on different activities.

In the Democratic Republic of Congo and Rwanda, gold mining is done rudimentarily, with workers using hand tools. These artisanal and small-scale miners make up the majority of the work force of the country, and are often brutally exploited by local, corrupt and violent governments. Besides the violence, the governments do not

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provide health safeguards, good wages or any kind of safety regulations. Child labor is also an issue, with thousands of kids being put to work to finance the system. Environmental issues also arise, such soil and water contamination, that directly affect biodiversity there, and indirectly in the DCR’s population.

Informal gold mining in Mexico and Ghana are also linked with human rights abuses. Child labor, sexual exploitation, trafficking and violent extortion are employed by the cartels in Mexico and by the volatile Ghanaian government. In both countries, gold mining also causes health issues to the workers involved due to poor workplace conditions and safety. Workers are constantly exposed to mercury and other kinds of heavy-metals. Water and soil contamination due to gold mining in Mexico and Ghana are also a factor. Inconsistent work supervisions combined with the usage of chemical materials results in a serious environmental problem that hits farmers.
South Africa faces similar problems from informal gold mining. Fairphone, an Amsterdam-based company that produces modular smartphones from responsibly sourced materials, made an study about the material profile of smartphones reports:


Mercury, cyanide and other substances are regularly released into the environment as a result of dirty gold mining practices. Many gold mines dump their waste directly into water bodies, contaminating completely the ecosystem in the region. The sustainability-specialized website Brilliant Earth states:

“To limit the environmental damage, mines often construct dams and place the toxic waste inside it. To limit the environmental damage, mines often construct dams and place the toxic waste inside. But these dams do not necessarily prevent contamination of the surrounding environment. Toxic waste can easily seep into soil and groundwater, or be released in catastrophic spills. At the world’s estimated 3,500 dams built to hold mine waste, one or two major spills occur every year.” (Gold Mining and the Environment. (n.d.). Retrieved September 16, 2018, from https://www.brilliantearth.com/gold-mining-environment/)

In addition to toxic waste and water and soil pollution, gold mining is also responsible for high levels of carbon dioxide emissions. Large amounts of rocks must be crushed to extract small amounts of ore, and this is a very energy-intensive process. The nature intrusive mining process is usually a source for greenhouse gases emissions, but some more than others. The gold one is specially intense and requires more energy. And for being a valuable metal, with high economic value, it is sourced everywhere, even in
small mines. It adds more emission into account, since it is done all the time and in many different places.

1.5 - Lithium

The lithium-ion battery has been used for more than two decades. In 1991, Sony started and developed the manufacturing process of lithium-ion batteries, and the battery itself has changed very little since then. Nowadays, products like smartphones, laptops, smartwatches, tablets and electric cars are powered by such batteries. The soaring demand for lithium is one of the reasons this metal has been having negative side effects on the countries in which it is mined. Between 2016 and 2018, the mineral price doubled due to a spike in demand.

There are two main ways to produce lithium: from brine water and from rock mining. The first one is the most efficient and cost effective process, with 87% of global lithium production coming from this method. The places with highest concentrations of
brine waters are found in the South American countries of Bolivia, Argentina and Chile. Lithium is obtained from briny lakes called salars, and the production process is very straightforward: it requires only natural evaporation. Brine water evaporation results in lithium carbonate, the raw material that is used in lithium-ion batteries, magnesium, potassium, calcium and sodium. This is a long process that takes up to three years.

Of the remaining lithium reserves, 13% can be found in traditional mines. The mineral concentration in hard rock is higher than in the briny lakes. However, rock mining is a more expensive process with a bigger environmental footprint, so the industry is focusing mainly in the evaporation process described above. Still, at least nine traditional lithium mines are still in operation.

Salar de Uyuni, Bolivia. Brine is pumped out of a nearby lake into a series of evaporation ponds and left for 12 to 18 months. Various salts crystallize at different times as the solution becomes more concentrated. It is also treated with lime to remove traces of magnesium. When the minerals are ready for processing, they are taken to the nearby Planta Li lithium factory to produce the ions that will go into batteries. In 2017, the factory produced 20 tonnes of lithium carbonate.
Unlike the other minerals cited in this master’s thesis, lithium does not create social impacts like labor exploitation. However, it does harm the environment. First, lithium mining requires a lot of water - approximately 500,000 gallons per ton of lithium. The amount of water used for mining, causes a shortage of water in other parts for different things, such as agriculture, and it also impacts flora and fauna. In Atacama, Chile, lithium mining consumes 65% of the region’s water.

On top of that, contamination from the harmful chemicals that are used for leaching, is also a reality. Those chemicals require proper waste treatment but, unfortunately, there have been problems with waste spills related to lithium mining, like is common to see in other mining operations around the world. Mishandling of waste is also a major problem when it comes to lithium waste treatment. The tech-oriented website Wired did an assessment on lithium dependence in the industry and its environmental cost. They discovered problems in unexpected places, like Tibet:

“In May 2016, hundreds of protestors threw dead fish onto the streets of Tagong, a town on the eastern edge of the Tibetan plateau. They had plucked them from the waters of the Liqi river, where a toxic chemical leak from the Ganzizhou Rongda Lithium mine had wreaked havoc with the local ecosystem. There are pictures of masses of dead fish on the surface of the stream. Some eyewitnesses reported seeing cow and yak carcasses floating downstream, dead from drinking contaminated water. It was the third such incident in the space of seven years in an area which has seen a sharp rise in mining activity, including operations run by BYD, the world’s biggest supplier of lithium-ion batteries for smartphones and electric cars. After the second incident, in 2013, officials closed the mine, but when it reopened in April 2016, the fish started dying again.” [Katwala, A. (2018, August 03). The spiraling environmental cost of our lithium battery addiction. Retrieved September 16, 2018, from https://www.wired.co.uk/article/lithium-batteries-environment-impact]
Argentina has also suffered lithium mining. Streams and rivers used by humans, livestock and crop irrigation have been contaminated. Chile has experienced clashes between mining companies and local communities, who disagree about the change of the landscape of the region, which is now filled with discarded salt.

Not being able to be reused is a problem of this material. Lithium-ion batteries cannot be recycled or used again as batteries. Although the it is recyclable can be used in glass and different materials, the recycling rate of lithium is less than 10% worldwide, with the majority of batteries ending up in landfills and contaminating the soil. Furthermore, the life cycle of the batteries is very short, and is becoming shorter due to high usage of devices such smartphones and laptops, that are pushing batteries to their limits more and more. Even though a lot of different research is being done to figure out a solution for lithium recycling, researchers are still in the developing stage without significant results.

1.6 - Copper

Copper is a mineral used in circuit boards of a smartphone. It is obtained from the earth’s crust and the oceans. It is usually found in the combination with sulphur, iron, carbon and oxygen. Many different techniques are used to separate one source of copper to the other. For instance, 80% of the world’s metal comes from Chalcocite and Chalcopyrite ores. To mine copper, first ore needs to be ground in order to separate the copper particles from the rock. This phase involves a series of chemical, electrochemical and physical processes.

After extraction, it is necessary to start the smelting phase, which results in 99% pure copper. It is necessary to use different chemicals in this phase. This is a complex and energy-intensive process. When this step is finished, the mineral is then refined by other chemical process that increase the purity level even more. This step takes up to a
week to be completed, and after that, the copper is ready to be used in manufactured products.

The top six producers of copper are Chile, China, Peru, USA, Australia and the Democratic Republic of Congo. Chile produces 30% of the world’s copper production, with over six million tons extracted in 2017. This is almost three times more than China, which only produced two million tons of the mineral during the same year. The mining sector has a significant impact on the country’s GDP, representing 14.2% of it. Furthermore, the DCR depends on mining as an important economic factor much like Chile. In the DCR, the industry represents 20.3% of their GDP. Among other metals, Copper contributes a lot to these figures, since it is one of the most needed minerals in a large variety of industries.6

Just like all mining activities, copper impacts the landscape of the place in which it is mined, the health of the workers involved, the communities close to the mines, water

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storage, the soil and the air. It also requires a lot of energy which has other impacts, such as greenhouse gas emissions directly and indirectly. The metal can be recycled through a melting process, but the numbers so far are still very low. In Europe for instance, only 41% of copper is being recycled annually. A large part of the copper waste goes to landfills, which contributes to the contamination of soil and groundwater tables.

In the Democratic Republic of Congo, copper mining is linked directly and indirectly to the support of armed militants that are currently waging war in the country. Just like what happens with cobalt mining, copper mining is done in unregulated, small-scale mines. This means it is done by poor families, including children, who are forced to extract the mineral without any safety or health protection, and without any financial compensation. They are threatened by local armed militias and coerced to do what they are told. These people are exposed to considerable health risks, including inhalation of heavy metal dusts. Recently, China has signed a deal with the DCR’s state copper company to exchange infrastructure knowledge for resources, but no changes have occurred so far.

Peru has also experienced armed conflicts because of copper-mining. Local communities and mining companies have been clashing against each other because of the negative impacts the practice creates in mining regions of the country. The ongoing situation has already resulted in the death of multiple mine protesters. Other top copper producers are facing different problems. China is coping with extensive water contamination in the Ting River that was caused by copper smelting. On top of that, mining was discovered as the root of cancer in Yueyang’s villages. The long-term exposure to toxic air pollution and water contamination by heavy metals is harming the local population. Chile, United States and Australia are also being socially and environmentally harmed by copper mining. Mining is responsible for the depletion of water resources and soil pollution.
According to the US Geological Survey in 2015, the second largest producer of copper in Africa is Zambia, just behind the DRC. This country has extensive natural resources and has been an attractive place for companies to explore. In the past ten years, enormous projects have been implemented by different companies promising to bring work and development to many regions in the country. However, it has never happened, with all these projects having very little positive effects in the life of the local population. One of the reasons for this is tax abuse. Companies manipulate, avoid or evade taxes of the country, that would result in billions of dollars for the Zambian government in revenue. The problem is complex and involves the rampant corruption thwarting Zambia.

According to an investigative article written by Danish website DanWatch,

“Tax abuse is one reason. Tax avoidance or manipulation by multinational mining companies is draining the country of billions of dollars in resources meant for development. On the other hand, systematic tax abuse is only possible because of a lack of regulation and enforcement, which means that the state is again failing to protect its people’s human rights. Tax abuse, poverty and violation of human rights are deeply entwined, because tax abuses deprive governments of the resources required to ensure the economic, social and cultural rights, according to the report “Tax Abuses, Poverty and Human Rights” (2013) issued by the International Bar Association’s Human Rights Institute (IBAHRI).” (Overgaard, A. G., Voller, L., Andersen, M., Xavier, G., Kyndesen, N., Christensen, A. B., . . . Larsen, P. (n.d.). Broken Promises. Retrieved September 18, 2018, from https://old.danwatch.dk/en/undersogelse/broken-promises/)

Despite the fact that Zambia’s government does no auditing and does not inspect companies properly, it also demonstrates a reprehensible lack of commitment to the country’s development facilitated by the mining companies. It is a generalized problem that should be confronted not only by government agencies and officials, but also by the corporate social responsibility and compliance departments of the companies. If these
companies sell the idea that they will bring positive transformation, they should be the first one to endorse this mindset. Corruption amongst government officials and company executives should be investigated by the local government and international organizations in order to hold all those that are involved accountable.

Chapter 2 - What are the benefits of a circular economy for this material flow?

2.1 - The Current Scenario and the Principles of Circular Economy

2.1.1 - The Current Scenario

To understand what a circular economy is, first is necessary to understand the current system. After the Industrial Revolution, and the advent of large scale product manufacturing, the consumption of goods increased like never before in the history of human kind. This resulted in societal changes for the better, and helped mankind thrive against all odds, conquering nature and using it as tool for technological improvements. It brought widespread progress and raw materials found in nature started to be used indiscriminately for more than two centuries in order to foster social and economic growth.

Products were not, and still are not, designed to last, creating a so-called “make-use-dispose” system that generates huge amounts of waste and uses more resources than the planet can provide. Throughout the 20th century, the negative symptoms started to appear. Year after year, the global economy has exhausted Earth’s natural resources faster than it can regenerate. On August 2nd, 2017 for instance, mankind had used more than the planet could give, making a need for almost 1.5 earths every year to supply the demand of raw materials and resources. Furthermore, since 1971, the global population has used more than what the Earth produces. Every year, 55 billion tons of bio-mass, fossil energy, metals and minerals are extracted from the earth. This is almost 10 tons for every person in the world. For people in the Western world, this number is much higher.
Ken Webster reported the following in his book “A Circular Economy: a Wealth of Flows”:

“The linear ‘take, make and dispose’ model relies on large quantities of easily accessible resources and energy, and as such is increasingly unfit for the reality it operates.” (Webster, K. (2017). The circular economy: A wealth of flows. Cowes, Isle of Wight, United Kingdom: Ellen MacArthur Foundation Publishing.)

In addition, overconsumption has brought about the enhanced greenhouse effect, which is the leading cause of climate change. Human activities – particularly burning fossil fuels (coal, oil and natural gas), agriculture and land clearing – are increasing the concentration of greenhouse gases, mainly carbon dioxide in a way that is impossible for the planet to keep up. This enhanced effect is warming the atmosphere resulting in an increase of its average temperature, and changing climate patterns in many ways. All these changes are affecting nature and people’s lives: from forests and oceans, to farming activities and urban life. The polar regions are melting, sea levels are rising, species are being eradicated, weather is getting more extreme, and oceans are getting warmer. According to the National Aeronautics and Space Administration (NASA), climate change will increase continuously in the coming years:

“Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time. Scientists have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gases produced by human activities. The Intergovernmental Panel on Climate Change (IPCC), which includes more than 1,300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century. According to the IPCC, the extent of climate change effects on individual regions will vary
over time.” (Global Climate Change: Effects. [2018, July 16]. Retrieved September 18, 2018, from https://climate.nasa.gov/effects/)

On top of that, one major issue of the make-use-dispose system is the huge amount of waste it generates. In 2017, cities around the world generated over 1.3 billion tons of waste. Due to urbanization and population growth, this number is estimated to rise to 2.2 billion tons by 2025. According to a study by The World Counts, 99% of the products bought by one person, are trashed after six months, and if all this waste was put on trucks they would go around the world twenty-four times. Excessive consumerism is the main cause of waste generation. Every day, an enormous amount of good things are thrown away, ending up in landfills. The Washington Post reported in November 2017 that:

“The world generates at least 3.5 million tons of solid waste a day, 10 times the amount a century ago, according to World Bank researchers. If nothing is done, that figure will grow to 11 million tons by the end of the century, the researchers estimate.” (Drowning in garbage. (n.d.). Retrieved September 19, 2018, from https://www.washingtonpost.com/graphics/2017/world/global-waste/?noredirect=on&utm_term=.ac36492be094)
With more people having access to goods and services, more waste is being generated. Europe and the United States are the biggest producers of refuse, but it is often invisible once it is tossed out. In Europe, for instance, to export waste is a common practice for companies that want to be in accordance to new regulations. The New York Times reported:

“Rotterdam, the busiest port in Europe, has unwittingly become Europe’s main external garbage chute, a gateway for trash bound for places like China, Indonesia, India and Africa. There, electronic waste and construction debris containing toxic chemicals are often dismantled by children at great cost to their health. Other garbage that is supposed to be recycled according to European law may be simply burned or left to rot, polluting air and water and releasing the heat-trapping gases linked to global warming.” (Rosenthal, E. (2009, September 26). Smuggling Europe’s Waste to Poorer Countries. Retrieved September 23, 2018, from https://www.nytimes.com/2009/09/27/science/earth/27waste.html)
However, in other parts of the world it is more obvious: landfills, waste dumps or pollution all around can be easily found in the middle of the cities. Waste management is difficult and the current solutions, so far, are not good. It is a complex and broad network, involving many service providers and governments.

When it comes to smartphone waste, the numbers are astonishing. Once they are discarded, they go to landfills, leaching toxic chemicals into the soil. The United Nations reported in 2017 that discarded laptops, mobile phones and electronic goods are now the world’s fastest growing waste problem. Electronic devices account for up to 70% of toxic waste in landfills. With as many 1.5 billion new phones being manufactured every year, specialists believe that, at least, the same quantity is being discarded. Sometimes discarded in the regular trash, other times into recycling bins or, simply stored away in an empty drawer.

The study also found that forty-three million tons of electronic waste was generated in 2016, a rise of eight percent in comparison to 2014. This is double the rate of plastic refuse, another major waste problem but only it has more visibility. Within this huge amount of refuse, people are inadvertently throwing away precious metals such as gold, silver, platinum, copper, aluminum and more. The United Nations report estimates that more than forty billion pounds worth of recoverable materials is binned or mothballed every year.

There are also dire economic consequences of the current “take-make-dispose” system. With the demand of all natural resources increasing, scarcity is becoming a common word. But not only the population growth is responsible for the lack of resources, another issue is the way this resources are managed. Nowadays, most of the resources are not efficiently managed, what results in more unnecessary waste. Population growth, overconsumption of raw materials and not well-managed supply chains create a risk that in the near future, resources prices will raise and many business will struggle to adapt to the new reality. Some materials are already causing this
transformations, such as the aluminum. To avoid this uncertain scenario a circular economy approach would be very beneficial, making easier and less risky to predict such prices.

### 2.1.2 - Principles of a Circular Economy

A circular economy is a concept that aims at redesigning the “take-make-dispose” industrial model. With the global population predicted to reach nine billion people by 2030, the world’s natural resources to supply this demand are being put at risk. The current “linear economy” model requires more and more of the planet, unbalancing ecosystems, damaging biodiversity and generating colossal amounts of waste. The goal of a circular economy is to design restorative and regenerative industrial systems, avoiding waste and decreasing the amount of natural resources we consume. Furthermore, the circular economy attempts to keep products and materials in the loop of usage for longer. According to the European Commission:

“A circular economy is explained as an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized.” *(Circular economy - Growth - European Commission. [n.d.].)*


This concept is in accordance with the United Nations agenda for sustainable development. To achieve some of the United Nation’s Sustainable Development Goals, a move towards a circular economy is necessary. As a creativity-driven concept, it creates a fertile ground for innovation. In order to surmount the main problems that society faces today, it its necessary to come up with innovative approaches. The development of waste and industrial ecology solutions in factories, for instance, is one of the opportunities that
would be possible with this new approach. The seventeen Sustainable Development Goals (SDG’s) are grappling with issues such as the eradication of hunger and climate action. For example, with more than half of the food produced being thrown away in good condition, it is clear that the current system in operation needs to be redesigned.

The notion of circularity is not new and it has appeared many times during human history. Building things to last and using resources properly were also characteristics of society until the Industrial Revolution and the advent of mass production, when the current “take-make-dispose” system started to be implemented. Non-linear systems were in place before this period, keeping humans and nature in balance with each other. Human interference was not so extreme, and therefore, it did not result in the overwhelming harm mankind is inflicting on nature today.

After World War II, computer-based studies of non-linear systems revealed the complex, interrelated and unpredictable nature of the planet. It was discovered that it behaved more like metabolism, rather than a machine. During the 1980’s, the Swiss architect Walter Stahel, co-founder of Geneva-based Product-Life Institute, was one of the first to promote the idea of a circular economy. Recently, he defined the concept in 2016:

A circular economy would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. It would change economic logic because it replaces production with sufficiency: reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired (Stahel 2016, 435).

This explanation makes it very clear that a circular economy seeks to redesign the current system. To reuse products, extending their life cycle, or when it is not possible to reuse, to recycle this products and make them good to be used as source for other products are the main objectives of a circular economy approach. Manufacturing new goods is a last resort, only to be used when the two aforementioned options are not
possible. This is in direct confrontation with the market-driven society that encourages consumers to buy new smartphones every year to keep up with the latest technologies, without providing efficient and transparent recycling or reuse programs as an alternative. In a linear-economy the value of goods are built to fade and decrease quickly so that consumers are impelled to buy “the latest and greatest”. On the contrary, the circular model encourages the production of goods with a long-lasting life cycle, in which this quality is one of the key elements for the product’s value.

The Ellen MacArthur Foundation, one of the top research institutes in circular economy, states that the transition to a circular economy does not only amount to adjustments that reduce the negative impacts of the linear economy. Instead, it represents a shift that builds long-term durability, generates business and economic opportunities, and as a result, also provides environmental and societal benefits. A
circular economy allows businesses to separate economic growth from resource consumption by focusing on value retention. As described by the Ellen MacArthur Foundation:

“the model distinguishes between technical and biological cycles. Consumption happens only in biological cycles, where food and biologically-based materials (such as cotton or wood) are designed to feed back into the system through processes like composting and anaerobic digestion. These cycles regenerate living systems, such as soil, which provide renewable resources for the economy. Technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture or (in the last resort) recycling.” [E. (n.d.). The Circular Economy Concept - Regenerative Economy. Retrieved September 20, 2018, from https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept]

A circular economy requires system thinking and integration of everyone involved: business, people, organizations, environment and so on. Combined, they create a network in which the actions of each one involved, impact others and their actions. The consequences are taken into account as are key factors for the decision-making processes. Measuring the impacts of the value chain of products and its impacts on the short-term and long-term with the objective of creating long-lasting, resilient systems, for instance, are part of this integrated system thinking approach.

This model, in theory, has the potential to save more than 70% of the materials that have been extracted today. This massive transformation would have positive economic influence on companies in different business fields. The potential amount of savings is calculated as $630 billion in the sector of consumer goods, by increasing longevity of products such as smartphones.

The transition to a circular economy would also positively affect employment growth. It would generate an increase in labor related to recycling and repair, at all levels, from specialized to generalized jobs. In addition, it would foment the logistics sector with

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a new network of suppliers for returning products. At the very least, it would increase new business through innovation, a key principle of the circularity model. New ideas are necessary and encouraged to bring innovative solutions for problems that a circular economy could fix, but are not yet viable or scalable, in the sense of not yet being able to be implemented in broad range of situations.

Transitioning to a circular model would be beneficial and create opportunities for entrepreneurs. The Elle MacArthur Foundation has summarized four main opportunities: new chances for profit, better security and resilience of supply, demand for service models and enhanced customer relationships. Keeping materials in the loop will make it easier to assure the continuity of supply, that would facilitate the way businesses forecast their supply and demand, for instance. Furthermore, it would decrease the overall costs of a business through energy optimization and waste reduction. As this research paper has previously argued, innovative business would thrive as demand for new service models grow. These new opportunities create a fertile ground for new jobs in all sectors. Reverse logistics companies, that would be responsible for picking up old products at the costumers’ homes or stores, taking them to be remanufactured or reused as another product would play an essential role. Sales platforms that facilitate longer service life and higher utilization of products would also be vital. This would help companies create long-term relationships with their customers, better understanding their needs and desires, bringing insights to business and generating innovation through that. Due to new business models and opportunities, the transition to service, leasing and rental models would create a long-lasting relationship with customers, enhancing continuous contact between the factions involved. Furthermore, if the supplier remains responsible for a given product, customer satisfaction and customer loyalty would increase through

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good communication and frequent intermediate contact and service for maintenance and repair.

2.1.3 - Circular economy business models and the smartphone industry

A circular economy has the potential to bring positive transformation to the smartphone industry, and in turn, to the mining sector. This model praises for resource effectiveness what is a direct contrast to the current one of “take-make-dispose”. Companies are already parting ways with scarce or harmful resources and developing new revenue streams that add customer value with circular business models.

Mining is a predatory activity with detrimental impacts on the world, and by definition it is part of the linear model. Nonetheless, it is crucial for many different sectors all over the world, and has an important economic impact. The shift to a less exploitative business model is a sign of movement towards a circular economy. For instance, sustainable sourcing is one of the key characteristics of all school of thoughts in circular economy, such as “Cradle to Cradle.”

Another matter that could be improved in the mining sector is the amount of waste generated by the entire process of this activity. From extraction to processing, huge quantities of waste are created that contribute to soil and water pollution and many health issues for the workers and communities. In addition, the metals are easily discarded with manufactured products, such as smartphones, which contributes to harmful waste impact. So far, very little has been done by the major players in the mining industry to ameliorate this situation, however there is a big potential for change and innovation.

Each mineral is extracted differently and its supply chain creates its own set of environmental complications. The AustIMM Bulletin exposed some of the differences in a 2016 report:
Each waste stream along the metal value chain has its own set of environmental issues. For example, the concerns around tailings dams differ from those related to electronic waste. The opportunity to create value and reduce environmental liability from waste streams along the value chain is potentially one way that the mining and metals industry could make substantial contributions to the circular economy and, in doing so, improve sustainable development. (The contribution of mining to the emerging circular economy. (2016, October 06). Retrieved September 22, 2018, from https://www.australianBulletin.com/feature/the-contribution-of-mining-to-the-emerging-circular-economy/)

There are numerous opportunities to implement a circular flow at the mine site level, which would result in enhancing mineral extraction, reducing mineral loss to mining waste and mitigating some of the environmental impacts related to mine waste disposal. Recovering these minerals or stockpiling mineralized waste material in a way that enables future recovery while controlling leakage may contribute to improvement of the site’s environmental health and result in economic gain. In addition, stockpiling mineral waste would also enhance the overall resource extraction at a mine site. As a result, this would reduce the need for new mines to some degree. Preparing for the future of a mining site after extraction is very important. This is not only important in terms of economics, but also in environmental terms. Mining done for a long period in a certain area is likely to create long-term problems for it. One has to remember that the after-life of these regions is also part of a circular economy approach.

A system perspective approach of waste elimination can help different industries that use mined minerals to redesign processes and products in partnership with all the stakeholders involved – from consumers to suppliers. This holistic method is beneficial because it helps to find flaws easier and come up with durable results. The economic significance of the value chain is enhanced through disruptive and innovative business models that aim to move the whole business system towards a circular, sustainable one. Material retention and multiple cycles of usage, down-cycling, up-cycling, industrial
symbiosis and collection services are some of the business models that can have a positive impact on the smartphone industry, and as a result, the mining industry.

The table below shows challenges and opportunities. Some of the business models proposed above are already being implemented in non-circular business. One of the opportunities is to explore the entire potential of these models, leading business towards full circularity. This transformation is gradual and requires financial commitment from the companies’ part, that are usually concerned only with short-term results. The main challenge is to create profitable short-term investments in companies that are willing to implement this models.

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Upstream mining-related examples</th>
<th>Downstream examples</th>
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</thead>
<tbody>
<tr>
<td>Closed-loop recycling</td>
<td>Retain material and its quality for multiple cycles of use-recycling</td>
<td>Waste lubricants recycling; mining equipment refurbishment and recycling</td>
<td>HP’s cartridge recycling program</td>
</tr>
<tr>
<td>Downcycling</td>
<td>Alternative area and/or form of use, lower value, loss for future recovery, savings on landfill</td>
<td>The use of mine waste for backfilling</td>
<td>Nike’s ‘Reuse a shoe’ (recycling into rubber for playgrounds)</td>
</tr>
<tr>
<td>Upcycling</td>
<td>Turning material into new product of higher value and/or quality</td>
<td>Metal (and by-product) recovery from waste rock and tailings; reuse as a soil additive and for road construction</td>
<td>Worn Again (textile recycling); REDcycle (plastic bags and packaging recycling)</td>
</tr>
<tr>
<td>Industrial symbiosis</td>
<td>Waste and by-product exchanges, sharing of services and utilities</td>
<td>Alternative raw materials for cement production</td>
<td>Timberland Tire (old tires for shoes)</td>
</tr>
<tr>
<td>Collection services</td>
<td>Collection of old or used products (for further recycling elsewhere)</td>
<td>Old tyres collection</td>
<td>Teracycle (multiple collection programs); Nespresso’s coffee capsules collection</td>
</tr>
</tbody>
</table>

Table 1 - Business models for a circular economy

The closed-loop, up-cycling, down-cycling and collection service models can be easily applied to smartphones. The collection service, for instance, would encourage companies like Apple, Samsung and Motorola to focus on retrieving previous models.
from their customers. This would save billions every year, since many of the minerals used in the devices can be efficiently recycled and used in new devices, preventing the companies from buying new minerals from bad sources and decreasing the impact of the mining sector on the environment and communities. Keeping the phones in closed loops is a challenge, especially when consumers expect new models with new features every year. The Fairphone Company, a Dutch smartphone company, is a good example of how phones can be up-to-date and at the same time, lessen the amount of waste they produce. The Fairphone Company case study will be addressed in the following chapter of this research paper.

Up-cycling is a model that has already been implemented in other industries, such as the automobile industry, that could serve as an inspiration for the smartphone industry as well. This model consists in reusing a material or product without degrading its quality and material composition for the next uses. Plastic is a good example of up-cycling. For instance, when PET bottles are recycled they lose quality, so turning them in different things become a viable option. As a result, companies rather put the “up-cycling” model into practice, turning these discarded bottles into carpets, toys, clothes and more. This allows the plastic to stay in the loop for longer, and at the same time keeping the quality expected by consumers. In addition, up-cycling can keep some materials in the loop indefinitely without changing the original purpose of it. Aluminum is a good example of this:

Our treatment of soda cans is closer to a true up-cycling model. These aluminum containers can be melted down and made into brand new cans and in the process save over 90% of the energy required to make new ones from scratch. This cycle can continue in perpetuity, reducing energy consumption and effectively removing certain materials from the waste stream. (Recycling vs. Upcycling: What is the difference? (2015, October 19). Retrieved October 01, 2018, from https://intercongreen.com/2010/02/17/recycling-vs-upcycling-what-is-the-difference/)
Moreover, up-cycling has good direct and indirect effect on the entire business process. Firstly, this practice reduces the amount of waste that is produced, avoiding negative repercussions, such as the contamination of soils, water and communities. Secondly, it reduces the need for the acquisition of new raw and virgin materials. This has a positive environmental impact in the sense that the earth would suffer less from mining, for instance. Finally, up-cycling foments innovation, creating a fertile ground for new specialized companies to appear, and at the same time instigating product development within the original companies that produced the specific material that is being up-cycled.

The smartphone industry is already aware of that benefits of up-cycling. Samsung is calling its program "Galaxy Up-cycling." Since February 2018, Samsung has been working on this issue by teaching customers ways to give a new purpose to their old phones. As stated on the Samsung website:


The South Korean company created a tutorial video in 2018 teaching many ways to reuse the Samsung Galaxy phones, without decreasing the quality of it. One of the suggestions, for example, is to transform the phone into an internet router or a new computer terminal in the consumer’s home, avoiding the necessity to buy another apparatus. This is an interesting initiative, specially because it does not cost anything to Samsung to up-cycle these old phones. By educating their customers in the new alternatives, people can make the necessary changes, if any is required, at their own
houses. Furthermore, it enhances customer relationship by developing new ways of dialogue between the company and customers.\(^{10}\)

Another recycling practice used in business that are moving towards a circular economy model is called down-cycling. This method involves breaking down products, and once the constituent elements or materials are recovered, they are usually reused as products of lower-value. Only the elements that cannot be reused are discarded. Down-cycling helps businesses to reduce production costs. Moreover, it helps companies to decrease their environmental footprint since this method attempts to improve efficiency of resource use, preventing components and material parts to reach landfills. Today, many products are already down-cycled and reused. One good example of this is paper, which starts as a good print quality paper, and finishes its life-cycle as toilet paper. Nonetheless, down-cycling requires energy and water to happen, usually in lesser quantities than common recycling, but it still is not totally free environmental impacts.

Another different circular-economy business model is closed-loop recycling. This kind of process is developed in order to recycle all the materials and elements of a product, usually to be used again in the same type of product. In order for closed-loop recycling to happen, it is necessary to design the manufacturing process with recycling in mind. This is directly related to the types of components that will be chosen. For instance, product developers do not choose an element that cannot be reused efficiently if they are planning to create something that will be closed-loop recycled. Dell, the British tech-manufacturer, is designing products with recyclability in mind. The company is well-known for their closed-loop recycling processes. Dell focuses on designing their products to minimize the use of glue which reduces loss and allows for less degradation of materials during the recycling process.

Closed-loop recycling is a good option for the smartphone industry because it allows minerals used in a mobile phone, such as gold and copper, to be used again. With a simple take-back program, companies would be able to save billions of dollars in sourcing and investments, because they would be able to collect the old metals from previous phone models, that would be usable in new models without losing quality. Furthermore, the demand for new raw materials would not increase exponentially over the years if closed-loop recycling were a reality in the tech industry.

The development of a more integrated economy in past decades has created a necessity for companies and industries to work together. Now, more than common suppliers, companies are perceived as partners of each other. Collaborative partnerships help companies to save money, while increasing productivity and making circularity more accessible. The Ellen MacArthur Foundation delved into this kind of model and presented a report that delineates the advantages of what is called “industrial symbiosis.” This term was first used in 1989 and was applied to a Danish industrial zone that had been working together with partners to minimize waste, resource usage and exchange energy and materials in closed loops. The name of the area is Kalundborg and the process is known as the “Kalundborg Symbiosis.” The Ellen MacArthur Foundation describes it as:

“One such example is Kalundborg Symbiosis, the world’s first functioning example of industrial symbiosis. Situated in Kalundborg, Denmark, the symbiosis is based on public-private partnerships, with exchanges of energy, water and materials in closed loops. The vision of Kalundborg Symbiosis is to be the world’s leading industrial symbiosis with a circular approach to production. An industrial symbiosis constitutes a local partnership where, partners provide, share and reuse resources to create shared value. The purpose of industrial symbiosis is to create loops of technical or biological materials while minimizing the leakage and waste in the loops - demonstrating some key parts of a circular economy, at a local

Industrial symbiosis is a way to improve business practices continuously. Innovation and cooperation are key characteristics of this model, therefore it is fertile ground for start-ups. In Kalundborg, for instance, new business ventures have established themselves there. From algae production facilities to bio-ethanol production, these industries take advantage of the cooperative nature of the place and its innovative mindset. Five core values make Industrial symbiosis partnerships possible: trust, confidentiality, transparency, equality and cooperation. With these values, creating a flow of energy and materials becomes easier, at the same time of implementing a system thinking perspective that will allow this cycle to keep working without unnecessary interference.

This model challenges the business world to operate in unison with the ecosystem where everything has a place and function, and nothing goes to waste. Surplus resources generated by an industrial process can be used as a source of energy by one or
more companies, providing mutual benefit. In the smartphone industry, this can be easily incorporated when it comes to the manufacturing. Because production occurs mainly in industrial areas of China, factories could apply the industrial symbiosis model in order to be more energy efficient, less environmentally harmful and to save costs. It could be also an opportunity for the phone companies to expand their business operations to other areas, since the rethinking process requires innovative ideas. For instance, the carbon dioxide emitted during manufacturing could be channeled and reassigned as an element for the production of new things, helping companies profit from a by-product. Instead of simply polluting, companies could turn it into an opportunity to develop new products and processes.

Furthermore, industrial symbiosis helps to keep resources in use for longer, reducing the overwhelming stress on the planet’s natural resources. It would be beneficial for the smartphone industry to move towards this model because it would be less predatory for the environment and the communities involved in the mining of the metals that go into the phones.

All the models cited in this part of the research have three main characteristics in common: to utilize resources efficiently, to limit the amount of final waste to be disposed of and to reduce the loss of valuable materials. These three principles, if taken into account during the planning of all business models, would start moving the economy towards a circularity.

2.2 - The Fairphone Case Study

In 2013 an Amsterdam-based company decided to create an ethical, modular phone, that wouldn’t be as harmful as the ones we find all around the world in every

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store. This phone is called Fairphone and what is really interesting, is that it opens its supply chain, allowing buyers to know where the elements that make up their phone come from. The sustainable sourcing mindset and the long-lasting modular phone are a groundbreaking combination that could change the way the smartphone industry does business.

Before the idea of a modular phone came into popularity, Fairphone started as an awareness campaign about conflict minerals. From this campaign, a crowdfunding project started, and in 2013 the first phone was ready to go to the market. Currently, Fairphone has more than fifty employees from 25 different countries and has sold over 100,000 phones. More than a smartphone manufacturer, Fairphone sees itself as a movement that wishes to change the way the electronics business is done. They want to move the industry towards a more sustainable model, creating partnerships with suppliers. Fairphone believes suppliers should go hand-in-hand to help each other and show commitment to environmental and social issues. Through responsible sourcing, it wishes to decrease the negative side effects of mining operations and increase product value and customer relationships with a more sustainable product.

The company is working on four major factors: a long-lasting design, fair materials, good work conditions and reuse and recycling. To develop a long-lasting phone, it was necessary to design it having in mind that it should be as easy as possible to be opened and manipulated by non-experts. From the original design to the repair designing, all steps are thought to be simple and with reparability as a key concept. Fairphone is fighting against a global market trend where the average phone is replaced every eighteen months. This quick turnaround creates huge environmental impacts especially because customers want to keep up-to-date with the new technology, but cannot upgrade the phones themselves and feel the necessity of buying a new one. From its modular design, to easily replaceable parts which extends the longevity of the product while keeping it up-to-date, allowing customers to replace specific features, Fairphone
has introduced an innovative way to design a product that is essential in people’s lives. For instance, if a new type of camera is launched, they only need to replace this specific component, which is sold on Fairphone’s website. The company replaces it for you and takes back the old piece, reusing it in other phones.

The phone is now in its second generation, which is called Fairphone 2. A community of Fairphone owners was created in order to help the company work out the bugs and mistakes, improving the circular model. From technical problems to software bugs, users give feedback to assist the manufacturer to improve this long-lasting system. Thanks to collaboration with their clientelle, many improvements were made from the first model to the second one.

Using fair materials is of upmost importance for Fairphone. As stated on the company’s website:

“We care about what we’re putting in our phones. That’s why we’re tracing where our phone’s parts come from and creating demand for materials that are good for

The idea of creating a sustainable modular phone emerged from “conflict minerals” and mining activities that harm the environment and people in different parts of the world. As stated before in this research paper, mining is a predatory activity that inevitably generates environmental footprints. In addition, many of the main metals that go into the phones are sourced from places with poor working conditions by people that do not have any healthcare. Moreover, mining activity is directly related to social exploitation and child labor. Fairphone traces back all the elements used to make their smartphones and makes sure none of these elements come from bad sources. The table below exposes the quantity of materials that go into a phone. This chart was compiled by Fairphone in one of its reports done about material sourcing. It is really detailed and lets the consumers know the importance of some metals and the amount of problems that they create when mined.

38 materials found in a Smartphone - Source: www.fairphone.com
Moreover, the company is developing a framework to better understand the issues of the supply chain and help other companies to source responsibly as well. On its website, many different studies are available for download. They explore specific problems, such as work conditions, environmental impacts and more. Fairphone carefully assess these problems and create reports to facilitate the understanding of this complex value chain. The reports entitled “Smartphone Material Profile - Opportunity for improvement in 10 supply chains” and “Understanding the materials in mobile phones - Understanding Issues and Opportunities for improving material supply chain” were used as frameworks for the first part of this research. Another objective of these studies on the supply chain is to raise awareness to consumers to what a smartphone really is and what it really costs to produce the device which is more and more part of people’s everyday lives.

Fairphone’s fair materials goal works overseeing three main objectives: 1.) source materials that are less hazardous/toxic 2.) source materials that empower vulnerable communities or have better sustainable performance 3.) increase the use of recycled and/or renewable resources. The first two relate to more sustainable practices that consequently reduce the negative environmental and social footprints of the phone. The third one is directly related to circular economy as it helps materials to be kept longer in the loop.

Intrinsically linked to the fair materials area, is good work conditions. These factors are interconnected because in order for a mineral to be sourced fairly, it needs to come from mines that have good work conditions for their employees. One of the most problematic issues in mining sites, and even in factories in China, where 774.1 million phones were produced in 2015\(^\text{12}\), is the poor work conditions people face on a daily basis. From toxic environments to exploitative hours, millions of people directly and indirectly

\(^{12}\text{Social work values & good working conditions. (n.d.)}.\text{ Retrieved}\ September\ 28,\ 2018,\ \text{from}\ https://www.fairphone.com/en/our-goals/social-work-values/\)
related to the smartphone supply chain are working in unsafe conditions. Fairphone opens its supply chain and works close to suppliers, assessing them, to avoid doing business with suppliers that are involved this kind of immoral practice.

The company wants go beyond the traditional compliance model adopted by the majority of the industry. Through the “working together”\textsuperscript{13} approach the company collaborates with production partners, labor rights experts, NGO’s and researchers to develop innovative solutions to be implemented in order to increase worker representation and to enhance worker satisfaction. In addition, Fairphone is a member of Clean Electronics Production Network (CEPN), a multi-stakeholder initiative that aims to move the electronic industry towards zero exposure to toxic chemicals in the manufacturing process.

One of Fairphone’s initiatives is “Making a positive impact on working conditions.” It started in 2014 with the desire to give managers at the factories the necessary skills to improve human resources, health and safety. This initiative is happening with some selected Chinese suppliers and the goal is to empower those managers so that they can help transform the rest of the work environment. The company describes the way they are collaborating with these selected suppliers:

“Starting with selected suppliers (like our manufacturing partner), we’re assessing working conditions in the factory and collaboratively working towards improvements to jointly track progress. We want to build lasting relationships in order to advise and support our suppliers in creating better, safer workplace.” (Fairphone. [n.d.]. Making a positive impact on working conditions. Retrieved September 28, 2018, from https://www.fairphone.com/en/project/improving-working-conditions/)

In general, one of the major challenges has been substandard labor law in China. Due to the country’s exponential growth, factories need to achieve certain goals that

affect workers both directly and indirectly. Nonetheless, a thorough assessment inspired by the UN Global Compact, Ethical Trading Initiative and the International Labour Organization Fundamental Principles and Rights at Work is being used by Fairphone to work collaboratively with the suppliers.\textsuperscript{14}

The improvement of worker representation, such as the number of women in managerial positions, and the enhancement of employee/manager communication are other issues addressed by the company. Factory workers know better than anyone what needs to be improved in their routine but they lack the power to make their voices heard and create productive dialogues with management teams. This initiative increases worker satisfaction and increases transparency at factories.

The last main area revamped by Fairphone is the “reuse and recycle.” The company is heading in the opposite direction of the rest of the industry, and is encouraging consumers to repair and reuse their phones, instead of acquiring a new one. This is a large step towards the circular economy model. In addition, Fairphone is devoted to foment research about electronics recycling options and ways to reduce electronic waste worldwide. To deter the “take-make-dispose” mindset is a very difficult task, especially when customers are encouraged every year to buy the newest version of their favorite phone. Spreading the message that things should be built to last is a good initiative. The modular phone made by Fairphone allows the company to show a concrete example that change is possible. The company describes its approach as follows:

“We sell spare parts and offer repair tutorials to help make your phone useful for as long as possible. Our take back program supports the reuse and recycling of your old phones, and we’re also researching the best way to recycle the Fairphone 2 by making it easier to dismantle. Finally, we’re working with partners to improve local collection efforts in countries struggling with electronic waste.” (Recycling and

The “Take Back” program done by the company allows every person to ship their old phone to Fairphone for free and receive a €45 discount on the latest model, Fairphone 2. They accept any kind of phone, from Apple iPhones to Motorolas, the intent is to avoid having these phones ending up in landfills. It is a good source of materials as well, since every phone received contains materials that can be recycled indefinitely in other phones or in other things, as explained previously in this research paper.

The three objectives in Fairphone’s “reuse and recycle” initiatives are the following: 1.) encourage the Fairphone community to donate old phones through recycling programs 2.) support collection in developing countries with local partners 3.) research smartphone recycling to optimize the recyclability of current and future products. These initiatives help to reduce electronic waste and the fomentation of the predatory supply-chain behind the smartphone industry. Keeping materials in the loop for as long as possible, is currently the best solution to decrease our dependence on rapidly dwindling raw materials.

Interestingly, Fairphone’s website provides innumerable reports, studies and assessments about the smartphone industry and its supply chain. Everywhere you click, you can find links which redirect you to one of the pages that inform customers about the impacts of smartphone production. This initiative to educate smartphone users about sourcing is an advantage that Fairphone has over its competitors. To change people’s mind about a more sustainable future is a long-term investment. Fairphone’s partnerships are a good example of private-public cooperation. All the reports are elaborated in partnership with non-profit organizations or governments.

In order to engage customers in sustainability events and practices, Fairphone created the “Fairiphone Community.” Everyone that owns and uses a Fairphone can join
this community. Through it, members can discuss sustainability-related topics, be educated in new sustainability practices and raise awareness about Fairphone to people outside the community. Everyone that has a Fairphone, for instance, can organize workshops to talk about the company, the phone and the goals that the company hopes to reach. Fairphone provides informational resources and support for these events to happen. While the phone is promoted, people are also educated in new ways to consume technological devices.

One of the problems that Fairphone faces is the competitive scenario of the smartphone segment. With giant corporations like Samsung, Apple, Motorola and Huawei, it is difficult to compete and make the product viable competitor. Since its foundation, Fairphone has sold over 100,000 phones all over the world. This is a nominal amount when compared to the big players, especially considering that over 1.5 billion new phones were produced around the world in 2017. Besides the fact that Fairphone does not heavily invest in advertising like the others, the modular phone also has a high price in comparison to the majority of the other models. The Fairphone 2, for instance, costs €529, which is more than many Samsung and Motorola models, and almost the same price as an iPhone. Due to a carefully chosen supply chain, the manufacturing costs are higher than of an average phone, which decreases Fairphone competitiveness in the market.

Moreover, all of Fairphone’s efforts to change the industry’s mindset will only have minor results in the medium and long-terms. That said, the company has had some significant achievements recently. The crowdfunding campaign, created with the intention of increasing the company’s impact, raised €2.5 million this year. These numbers say a lot and represent 250% of what was previously expected. Furthermore, in 2018 Fairphone reached over 10 tons of electronic waste collected to be recycled. These accomplishments are real milestones for Fairphone, and they show how people are starting to engage with the company.
Conclusion

This study aimed at exploring, exposing and analyzing the smartphone supply chain with focus on copper, cobalt, gold, aluminum and lithium. After all the discoveries, it is evident that the smartphone industry is creating major environmental problems, and contributing to serious social issues. The impetus of this research was to expose the other side of what looks like a bright and shiny world of innovation. With annual new releases, this industry foments overconsumption that is exhausting the materials and workers involved. This overconsumption comes with a cost.

Furthermore, it is surprising that an industry driven by innovation (and usually led by young executives) is outdated in their business practices. From the predatory mining behind material sourcing to the lack of commitment to new environment and social standards set by various international organizations, smartphone companies are still doing business as they were in the 20th century. All the problems that society faces currently, seem unimportant to them.

This lack of commitment to society’s expectations is masked by massive advertising and well-designed, efficient and beautiful products. The constant launching of new models, with tiny differences from the previous ones, create the sensation of progress and constant innovation, but as a matter of fact, it is not innovative at all and is just a traditional method applied for years in many industries, such as automobiles. The encouragement to buy new models all the time created a system that, on average, a smartphone is only used for maximum eighteen months. After that, they are discarded, and more than 80% of the time, improperly.

The way recycling is currently seen and done by the industry is also a major issue. Take-back programs have the opportunity to decrease the problems caused by predatory sourcing. Furthermore, they are an efficient way for the companies to save manufacturing costs. Keeping materials in the usage loop for longer is not a primary concern when
smartphones are designed. Nonetheless, it has great opportunities to be reused as other things, such as portable computers and internet routers.

The restorative system of a circular economy, designed to reduce waste and pollution, keeps materials in the circuit for longer and regenerates natural systems. This is an incredible opportunity for the smartphone industry. It provides a range of business models that would be an extraordinary advantage for companies to improve efficiency, reduce operating costs and encourage innovation. As described in the second chapter of this research paper, sustainable business models could provide solutions to serious challenges that these companies are currently facing, such as the waste of precious minerals in previous smartphone models. With these concepts in mind, big corporations, such as Apple and Samsung, would be able to revolutionize the industry.

Another issue that has been addressed in this thesis is the fact that for a business to start being more resource-efficient and waste-free, system thinking is necessary. The absence of this approach in their supply chain and manufacturing processes is a waste of potential. The “industrial symbiosis” model described in the second chapter is an example of how different companies can work together to be more productive, cost-effective and energy-efficient. With smartphone components being produced in manufacturing hubs like China, Taiwan and Bangladesh and assembled in China, it is fertile ground for cooperation between players of this industry. Redesigning the production system would be faster in state-run factories in China, where decision making is more centralized and, if change is necessary, it usually takes place quickly. Creating systems that aim at improvement is a viable option that has not been taken into account yet.

Astonishingly, smartphone companies do not have control of what happens to their supply chain. Suppliers, who are obliged to comply to certain requirements, simply do not follow them. It infests the smartphones with “conflict minerals”, that are harming the environment (more than the ones that are responsibly sourced) and financing serious
social problems, like the war in the Democratic Republic of Congo, where 51% of the cobalt comes from. Traceability of materials should be the norm of the industry, but unfortunately it is a rare exception. If customers knew from where things inside their phones came from, they would have additional characteristics to differentiate players within the competition, besides the regular ones of price, color, brand and so on. More competitive features would lead to improvements in this supply chain.

Moreover, responsible sourcing makes it easier to track the origin of the component/material than the irresponsible method. To rework the way suppliers are doing things should be the number one priority of these companies. By doing that, many of the problems caused by irresponsible sourcing would be avoided, or at least, decreased. Responsible sourcing also means extracting a better quality material, which means to increase the quality of the final product. Sourcing responsibly is an obligation, and in many different categories, customers tend to boycott products that do not comply with regulations. Nonetheless, the difficulty to assess the steps and components behind the phones create a situation in which consumers are unaware of what they are really buying. Behind these devices that facilitate life and connect people, there is a myriad of consequences.

The introduction of sustainability and circular economy principles in the manufacturing and extracting processes would generate positive labor impacts. For instance, better work conditions would lead to better overall satisfaction at work, increasing productivity. Furthermore, the top-down management strategy currently adopted also delays certain adjustments that need to be made to keep the work environment level at factories as the best working practices recommended by the International Labour Organization, for instance. Also the number of women in managerial positions would rise, as circular economy praises diversity.

From reutilizing raw-materials, recycling components, protecting the environment, improving labour quality standards, to push innovation, save costs and increase
productivity, a move towards a circular economy would be one hundred percent beneficial for the smartphone industry. More and more companies are aware of the necessity of being sustainable, and there is no way better to be sustainable than implement a model that praises and approaches sustainability in a thorough way. This change would require long-term investment and commitment, what can halt short-term results. Nonetheless, the long-term results would be incredibly positive, culminating in cost savings, since the entire operation would be redesigned to be more systematic, efficient, making easier to predict things, such as sales and sourcing, which would make simpler for companies to maximize the entire process while investing only the strict necessary to keep things going.
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Websites


