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“*The technopolitics between the Global North and the Global South: behind the smartphone’s Lithium-ion battery*”

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God is a Lobster, or a double pincer, a double bind.

Deleuze & Guattari (2014, p 40)

Abstract

The purpose of this thesis is to investigate lithium-ion batteries in the context of smart devices such as a smartphone. The central question refers to how lithium-ion batteries are constituted as an opaque and black-boxed technology against the backdrop of the relations between Global South (where the extraction of important materials such as cobalt takes place) and the Global North (where these materials are used for the production of smartphones). Particular attention is paid to how colonial practices of excavating cobalt are connected to the presentation of a device as smart in the North.

Contents

1. Introduction

The first part of this thesis discusses how lithium-ion batteries are represented in the public discourse. The second part investigates the relationship between lithium-ion batteries and mobile phones. How do the latter become smart-phones? This paper concludes with an analysis of This paper concludes by analysis of several technopolitical factors that determine the supply chain of cobalt – one of the most important components of lithium-ion batteries.

1.2. Anatomy of a Lithium-Ion Battery

In principle, a battery should better be thought of as an electrochemical cell, which is basically "a device that enables the energy liberated in a chemical reaction to be converted directly into electricity" (Scrosati, 2011, p. 1624). Given that every battery component has emerged through specific historical contingencies, there are numerous factors we need to take into consideration when addressing lithium-ion batteries.

Before moving on, let us talk briefly about the main constituent parts of a lithium-ion battery. These are the negative terminal, the positive terminal, the electrolyte and the separator. The first component has the tendency to give away electrons, while the second one has the capacity to attract electrons. The third part functions as a path, which allows electrons to flow from one terminal to another. Last but not least, we have the separator (Yoshino, 2014, p. 3). "During charge, the negative intercalation electrode acts as a 'lithium sink' and the positive one as 'lithium source'" (Scrosati, 2011, p. 1626).

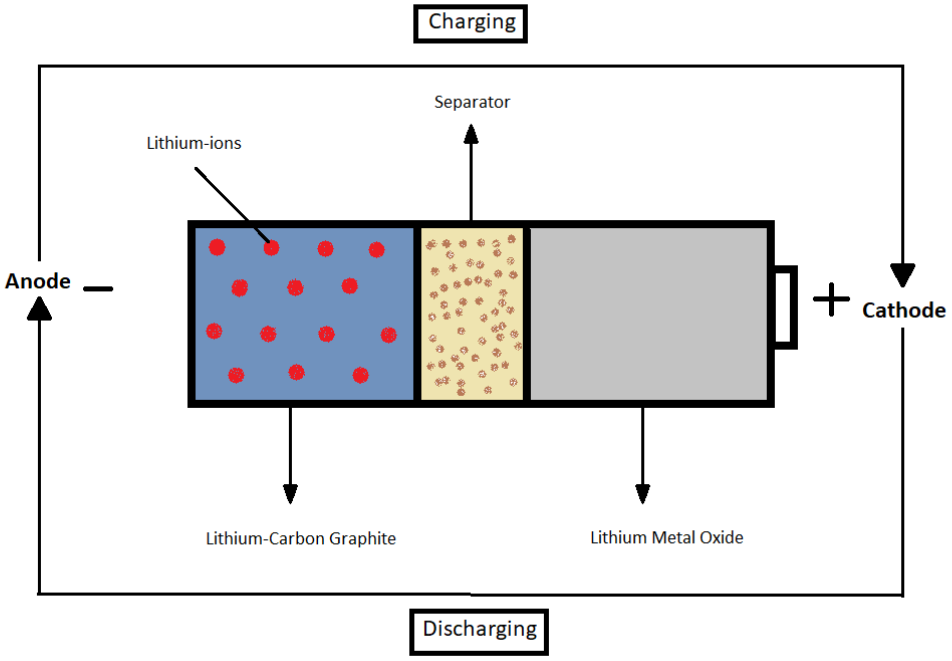

Figure 1: Parts of a Lithium-ion battery: Created by the Author

The negative terminal (also known as the “anode”) consists of lithium (Li), which is a silver-grey alkali metal.[1] Lithium has become a very popular anodic material due to its electrochemical profile (Reddy et al., 2020, p. 1). Nevertheless, lithium is a highly reactive metal and has to be captured within layers of graphite in order to remain in a stable state (Reddy et al., 2020, p. 2). Once there is an available path, lithium gradually releases its atoms, which are now positively charged. These atoms (called “lithium-ions”) start to flow from the negative terminal to the cathode.

The role of the electrolyte, as mentioned above, is to provide a path for the Li ions from one terminal to another. This means that the material which is going to be used needs to have a high dielectric constant and a low viscosity. For this reason, a combination of cyclic and linear carbonate esters is used, with the addition of an electrolyte salt (Yoshino, 2014, p. 13). The separator is basically a filter that allows the Li ions to pass through, while, at the same time, it prevents any contact between the anode and the cathode—which is crucial because the mixing of the anode and the cathode could potentially lead to an aggressive chemical reaction.

The positive terminal of a battery contains cobalt (Co), a silver-grey, hard metal[2]. When cobalt loses electrons due to oxidation it becomes positively charged and “demands” electrons. The flow of electrons which are migrating from the anode to the cathode creates the electricity that powers our devices. Cobalt, due to the morphology of its crystal structure, is able to store and diffuse freely the lithium-ions. Therefore, by regulating the flow of Li ions in such a manner, cobalt has the capacity to optimize the battery’s electrochemical potential better than other materials (Yoshino, 2014; Scrosati 2011, p. 1627).

Batteries come in various shapes and sizes, each one carrying a different electric potential depending on its components. Furthermore, batteries are categorised as primary or secondary electrochemical cells. The main difference between primary and secondary batteries is that the electrochemical process of discharging is irreversible in primary batteries, whereas in secondary batteries the intercalation is reversible. The

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[1] Lithium is the third element on the periodic table and has excellent physical properties. This element was discovered in 1817 by Arfwedson and Berzelius as they were studying an ore called petalite. Brand and Davy managed to isolate lithium oxide in 1821.

[2] Cobalt comprises almost 0.002% of the earth’s crust and is similar to iron and nickel. Hence, these three elements are “neighbours” on the periodic table.

chemical elements in the cathode and the anode allow lithium-ions to be transferred from one terminal to the other and vice versa, giving secondary batteries the capacity to dis-charge multiple times. This is why they are also known as rocking chair cells (Julien et al., 2015, p. 32).

According to Bruno Scrosati, the first battery can be traced back to the 18th century. Both Luigi Galvani (at the University of Bologna) and Alessandro Volta (at the University of Pavia) contributed greatly to the field of electrochemistry with their ideas and experiments. In 1895, the French chemist Gaston Planté invented the first rechargeable battery. A few years later, in 1901, the Swedish scientist Waldemar Jungner made the discovery of the rechargeable nickel-cadmium battery.

During the subsequent years, pressing demands from numerous fields accelerated the technological advancements of batteries. Medical devices that would rely on high energy density and long-lasting energy sources as well as high energy and high-power sources for military purposes (Eisler, 2016b, p. 32)—combined with the explosive expansion of the electronic market—led to the prevalence of lithium-ion batteries (Scrosati, 2011, p. 1624).

In 2019, the Nobel Prize in Chemistry went to Akira Yoshino**,** M. Stanley Whittingham and John B. Goodenough for the development of lithium-ion batteries**.** Belharouak & Passerini mention that: **“**Lithium-ion batteries have revolutionised our lives since they first entered the market in 1991. They have laid the foundation of a wireless, fossil fuel-free society, and are of the greatest benefit to humankind” (2020). The development of lithium-ion batteries cannot be pinpointed to a single occasion, as it was a rather layered process that involved interdisciplinary collaboration, public policy and lots of experimentation. In fact, one of the most important tasks that scientists had to engage with, while developing new techniques and materials for lithium-ion batteries, was “ransacking the periodic table of elements to find combinations of materials that produced a cheap, durable, and safe battery" (Eisler, 2019).

In 1952, Goodenough was participating in an engineering research project named “Whirlwind” at the MIT Lincoln Laboratory. This program was part of the first U.S. air defence early-warning system and focused on radars, computers and telecommunications. There, Goodenough (who specializes in solid state physics) had the chance to investigate the electrical properties of electronics and metal oxides. "It was the heyday of Big Science, a time when undirected research was thought to be the secret sauce for technological innovation and economic growth" (Eisler, 2016b, p. 31). Once the "Whirlwind" program ended, the Lincoln laboratory carried on its research activity until 1967–1969, when pressures from the anti-war movement led congress to sever the military's ties to academic science. Additionally, the idea of long-term undirected research was no longer compatible with the pressing economic demands (Eisler, 2019).

The oil crises that occurred during the 1960s and the 1970s led car companies to gravitate towards electric vehicles, as the price of oil had increased dramatically. At the time, Whittingham was working for Exxon as a chemist and was experimenting with low temperature nonaqueous electrolytes. Whittingham managed to demonstrate "that lithium ions could be reversible inserted into the spaces between the sheet-like layers of the titanium disulfide cathode" (Eisler, 2016b, p. 32). However, the practical and commercial use of the lithium-ion battery was still not achieved because the lithium which was used in the cathode is highly reactive. Therefore, the intercalation process was unstable and could lead to potential aggressive chemical reactions. As Goodenough mentioned: "After Exxon blew up a couple labs, they got out of the advanced battery industry" (Eisler, 2019).

In 1985, Sony's Energytec division wanted to find a suitable replacement for nickel-cadmium battery. Yoshino, who is the third member that won the 2019 Nobel Prize in Chemistry, participated in research aimed at assembling a lithium oxide cobalt cathode with a graphite anode. Identifying graphite as a stable and non-reactive material proved to be fruitful and ensured the safety of the intercalation process. As a result, in 1991 Sony released the first commercial lithium-ion battery, which managed to utilize "graphite as the 'lithium sink' anode and in lithium cobalt oxide as the 'lithium source' cathode" (Scrosati, 2011, p. 1627).

Lithium-ion batteries have multiple applications and can easily be incorporated into new technological advances. Suffice it to say that nowadays, almost every wireless technological device contains a lithium-ion battery—from laptops and mobile phones to cars and aeroplanes. This type of electrochemical cell is paradoxically *"obvious when it is most hidden"* (Feenberg, 2010, p. 6). As a result, we tend to notice it only whenever we need to recharge our device or if the battery reaches its life expectancy (Eisler, 2017, p. 369).

In addition to lithium-ion batteries being rechargeable, their resilience is equally important, as it allows engineers to optimize their shape and size according to the demands of the market. As one of the battery's creators Akira Yoshino has stated:

> This technological revolution led to a growing need for rechargeable batteries with greater capacity or with reduced size and weight for a given capacity. Conventional rechargeable batteries available or under development at that time such as lead-acid, nickel-cadmium, and nickel-metal hydride batteries used aqueous electrolytes, which posed limitations on increasing the energy density and reducing the size and weight (2014, p. 2).

Lithium-ion batteries have dominated the field of electronics and portable devices due to their resilience and their capacity to achieve optimal electrochemical density. It is very hard to imagine a smartphone not being powered by a lithium-ion battery. The popularity of these batteries becomes apparent when we consider that "there were 1.41 billion smartphone devices sold in 2018 (out of 1.86 billion mobile phones), and a total number of 7.42 billion smartphones were sold from 2012 to 2017" (Bookhagen et al., 2020, p. 2).

2. Theoretical Framework and Research Questions

The approach we are going to follow in this chapter is known as 'technopolitics'. It focusses on the way technological assemblages re-distribute agency within different environments. Technopolitics can be understood as "hybrids of technical systems and political practices that produced new forms of power and agency" (Edwards & Hecht, 2010, p. 619). Hence, technology is not exogenous of our social relations, but, rather, it is entangled with the organisation of society.

Hecht, in her article *"Political designs",* illustrated how although "the French government had decided not to build an atom bomb" (Hecht, 1994, p. 663), scientific practices and politics paved the way for the production of nuclear weapons. Here, multiple catalysts, such as institutions, access to natural resources, politicians, engineers and different political agendas influenced the way that nuclear energy was developed in France. The role of catalysts is very important, as they illustrate the contingencies of a technology's emergence. In other words, they help us to avoid the trap of reductionism by treating the relations of technological systems and society a as a product of multifactorial causation.

Furthermore, in her book *Being Nuclear: Africans and the Global Uranium Trade*, Hecht showcases how technological artefacts and other materials can become either banal or exceptional entities, depending on the technopolitics and the environment. For instance, "yellowcake from Niger made Iraq nuclear in 2003. But in 1995 yellowcake didn't make Niger itself nuclear" (Hecth, 2011, p. 13). Technologies emerge with different forms in different scales and environments. For example, the production of nuclear bombs "split into nuclear and non-nuclear states, nuclear and conventional technologies, nuclear and non-nuclear dangers, pro- and anti-nuclear politics" (Hecht, 2003, p. 2).

Given these points, technological assemblages do not always comply with the linear and deterministic terms as we might expect them to. To elaborate, determinism dictates a linear and direct link between cause and effect, while the final and "stable" state of technological devices can be linked with multiple paths and is therefore open-ended—also known as *equifinality*. According to Hecht:

> Technologies can also, however, exceed or escape the intentions of system designers. Material things can be more flexible—and more unpredictable—than

> their builders realize. The allure of technopolitical strategies is the displacement of power onto technical things; a displacement that designers and politicians sometimes hope to make permanent. But the very material properties of technopolitical assemblages—the way they reshape landscapes, for example, or their capacity to give or take life—sometimes offers other actors an unforeseen purchase on power by providing unexpected means for them to act (2011, p. 3).

Likewise, lithium-ion batteries constitute different conditions in different scales and locations, as technopolitics can be understood as a centralization and decentralization of environments, narratives and actions (Kurban et al., 2017, p. 14). The Global South is perceived as a place with no development, while the Global North is perceived as a forefront of development. The production of rechargeable batteries becomes imperative Global North's development and sustainability, whereas the Global South takes the role of providing natural resources and is perceived as a destination for discarded technologies.

The following diagram attempts to describe how the lithium-ion's battery supply chain functions as a black boxed circuit. "The word black box is used by cyberneticians whenever a piece of machinery or a set of commands is too complex. In its place they draw a little box about which they need to know nothing but its input and output" (Latour, 1987, pp. 2–3). The circuit has two different terminals and the natural resources flow from one negative terminal towards another positive terminal.

To be more explicit, starting from the bottom, the material resources needed for the production of lithium-ion batteries are excavated from the Global South and, then, enter the black box. It is well known that excavation activities can cause environmental hazards and are often linked with other social and economic ramifications. Hence, this terminal slowly becomes wasted. Once the natural resources exit the black box, they are introduced in the Global North as lithium-ion batteries. In this context, lithium-ion batteries add more value to the Global North, since they are presented as a technological innovation that translates the ideology of development into narratives of sustainability and smartness. As soon as these batteries become spent, they travel back to the Global South in the form of waste.

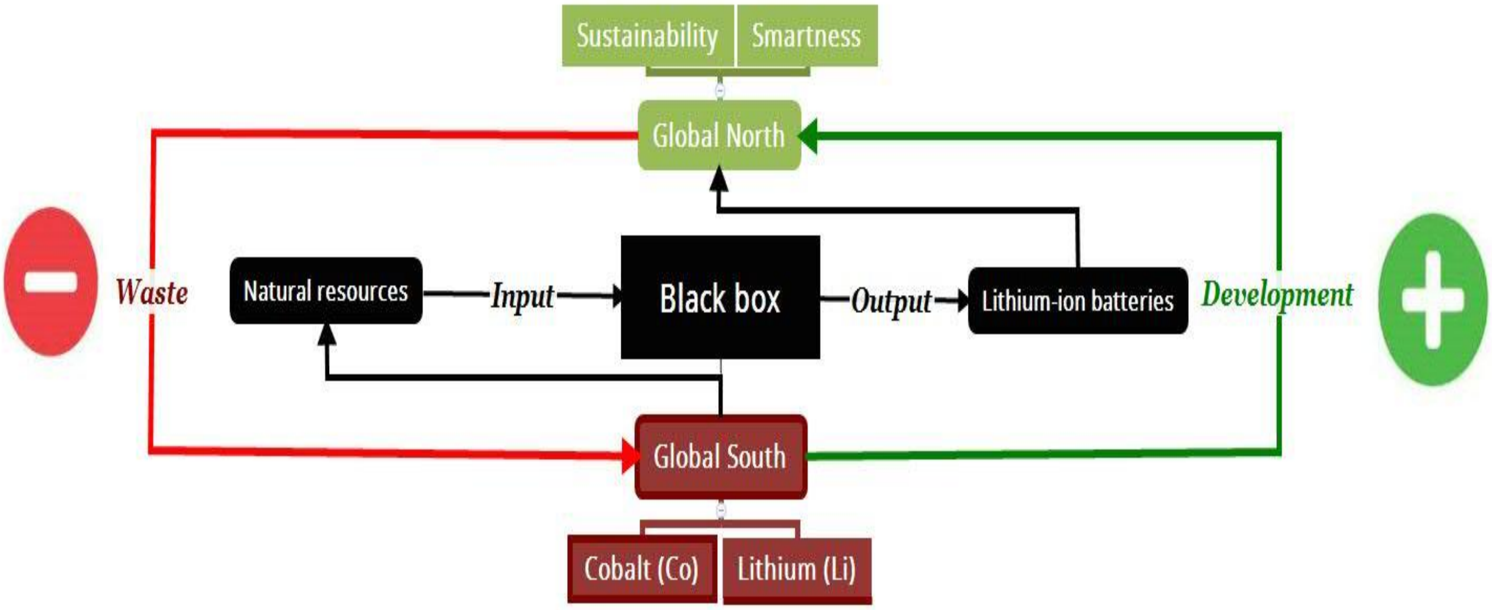

Figure 2: Representation of the lithium-ion battery's supply chain between the Global South and the Global North: Created by the Author

The material flows between the Global South and the Global North create a circuit feedback loop, where one terminal is steadily giving away its value, whereas the other one is steadily accumulating value. Therefore, the global configuration of battery production functions as a battery itself. Nonetheless, as expected, the relevant black box obscures certain aspects of how lithium-ion batteries are produced. We can see the input and the output, but, still, it is not completely clear under which conditions the extraction of natural resources takes place and, therefore, what kind of relations are established between the Global South and the Global North. How are lithium-ion batteries represented in the public sphere? Where does smartness emerge from? How does a phone become a smartphone? How is development and waste distributed between the Global South and the Global North?

3. Methodology

This thesis’s primary material comes from leading international science journals. The sampled material amounts to 60 articles in total. Given that the purpose of the ensuing discourse analysis is to investigate how lithium-ion batteries are represented in the public sphere, it was deemed appropriate that the samples should be principally derived from scientific magazines, scientific journals and newspapers. Thus, ten articles were selected from the scientific magazines *Scientific American and New Scientist*. Correspondingly, ten articles were selected from the very popular scientific journals, *Nature* and *Science*. Lastly, ten articles were selected from the influential international newspapers, *The New York Times* and *The Guardian*.

During the inspection of these articles, there were several cases where different scientific journals or newspapers covered the same subject. For instance, there were multiple articles referring to the scientists who developed lithium-ion batteries and won the 2019 Nobel Prize in Chemistry. Such overlaps were avoided in order to expand the thematic range of the sample. Various keywords were used (due to the way that the algorithms function in each site) such as “lithium-ion batteries”, “smartphones lithium-ion”, “smartphone lithium-ion batteries” and “lithium-ion batteries cobalt”. The articles included in the primary material were selected after reading the summaries of the articles that were generated by each search.

The articles that comprise the primary material were chosen after scrutinizing multiple sources and creating a coding scheme. The first step was to read and select approximately the 15 most relevant articles after searching for some of the key words in each journal or newspaper. The second step was to insert the 90 documents into a data set on a qualitative coding platform named “ATLAS.ti”, where the preliminary process of open coding generated 136 codes. Afterwards, the codes were sorted and categorized into the following 14 code families (groups of codes) which correspond to the themes that emerged from the secondary literature: “Accumulators–Batteries”, “Airplanes”, “Beyond lithium-ion”, “Bomb-Safety”, “Cars”, “Critical metals”, “Development”, “Environment”, “Lithium-ion battery”, “Mining conditions”, “Optimization”, “Smartness”, “Supply chain” and “Technopolitics”. Lastly, the articles that did not produce a sufficient number of codes were excluded, while the ten most predominant articles (those that generated the most codes from each source) were included in the sample.

The key phrase “lithium-ion batteries” produced 131 results for the *New Scientist* and 288 results for *Scientific American*. For the same keyword, the *Nature* journal returned 2035 results. Therefore, in order to narrow the search down, the keyword “smartphones lithium-ion” was used, which generated 35 results. In *The New York Times*, the keyword “lithium-ion batteries” generated 1390 results and more specific parameters were used by selecting the option “technology” and “world”, which returned 227 results. In *The Guardian*, the keyword “lithium-ion batteries” provided 732 results. Then, the more specific keyword “smartphone lithium-ion batteries” was used, which limited the results to 237 articles. In the case of the *Science* journal, the keyword “lithium-ion batteries” produced 417 articles. As the algorithm did not respond well to the keyword “smartphones lithium-ion”, “lithium-ion batteries cobalt” was used instead and it generated 83 results.

4. Presentation of Primary Literature

4.1. Lithium-Ion Batteries as a Vehicle of Development

In this section we are going to investigate how different representations of lithium-ion batteries become signifiers for dominant discourses. To be more precise, the first axis of the analysis refers to representations of lithium-ion batteries that emerge from the narrative of development. The second axis emphasizes how lithium-ion batteries become a nodal point for sustainability and other environmental issues.

Development as a dominant narrative departs from a point of lack—a need for cleaner, greener and fossil-free societies—which hinges other narratives such as sustainability and smart energy storage. The task of materializing development is assigned to different actors. Nations, firms and companies are competing with each other for the next breakthrough in the electrochemical cell industry. Lithium-ion batteries—just as their constituent parts—are the surface where competing practices unfold. At the same time, development obscures the contingent conditions of its emergence. Access to natural resources and other disruptions are dislocated from the master narrative.

An often-overlooked point has to do with how difficult it is to define what technology really is. Some argue that technology has a very solid meaning, whereas others claim that it is a very fluid concept. In any case, if one is to understand technology as detached from its surroundings, then it is more than likely that many of its important aspects will remain unnoticed. This is the reason why “although we cannot say exactly what that "it" really is, it nonetheless serves as a surrogate agent, as well as a mask, for the human actors actually responsible for the developments in question” (Marx, 1997, p. 984).

In the article “A ‘Technology Smart’ Battery Policy Strategy for Europe”, lithium-ion batteries are perceived as a core component in the Global North for three main reasons. Firstly, it is the backbone of the electric vehicle technology: “The cell makes up roughly 70% of the cost of an automotive battery, which currently amounts to more than 40% of the cost of a fully electric car” (Beuse, Schmidt & Wood 2018). Secondly, electrochemistry is a dynamic field with ongoing developments. Scientists are constantly optimizing batteries either by changing their material components or by improving their design. Thirdly, localizing the production of these cells provides a strategic advantage to a country's economy. Being capable of producing rather than sourcing lithium-ion batteries from abroad is perceived as an attribute of an economically independent and wealthy country.

Asian companies have a head start in developing batteries, whereas the European Union is trying to catch up, especially with electric vehicles cells. "East Asian manufacturers have achieved continual improvements in terms of performance (e.g., lifetime or energy density) and cost. Recently, several East Asian players announced the construction of Gigafactories in Europe (battery cell manufacturing factories with output capacity in excess of 1 GWh/year; e.g., CATL in Germany, LG Chem in Poland, Samsung and SK Innovation in Hungary" (Beuse, Schmidt & Wood 2018). For the first half of the twentieth century, South Korea was a Japanese colony and its economy was primarily focussed on the agrarian sector. Yet, it managed to become a leading nation in technological innovation. According to the primary material "large industrial groups called chaebols, which were owned and controlled by South Korean individuals or families" had very close ties to the government and managed to accelerate R&D. South Korea's primary goal was to apply the new knowledge to create innovations. Eventually, these dynamics led to the emergence of new industries. Successful development is perceived as a constellation of top-down innovation systems, government policies and academic community developments. The milestone of this development is a well-known *chaebol* called Samsung (Dayton 2020).

> By the 1990s and 2000s, Samsung was a world leader in tablets and mobiles, and in the design and manufacture of computer chips. The company is by far South Korea's leading corporate institution in the Nature Index, based on contributions to research articles published in the 82 high-quality natural science journals tracked by the Index. With a Share of 10.36 in 2019, it ranked 28th among the country's institutions overall, eclipsing its nearest rival in the corporate ranks, LG, which had a Share of 1.99. Samsung also features in each of South Korea's nine leading corporate-academic collaborative pairs in the Nature Index (Dayton 2020).

In a nutshell, South Korea managed to become the paradigm of development. Furthermore, lithium-ion batteries are presented as the vehicle that will take democracy to the next level. Batteries are portrayed as devices with inherently political properties. "Better batteries would enable the democratisation of electricity" (Hodson 2015). The problem here is that this technology is depicted in a predetermined way, thereby reducing innovations to a seamless essence. Put simply, lithium-ion batteries are presented as the innovation that is going to power up social change. Attributing an essence to lithium-ion batteries dictates a determinism between technology, politics and society (Winner, 1980, p. 122).

"Now lithium-ion batteries are a $15 billion business; big companies are taking notice" (Hodson 2015). On the one hand, markets encompass the studies in the field of electrochemical cells. "Consumers are unlikely to embrace a wristwatch computer like the one being worked on by Apple, or Google's smart glasses, if they work only a few hours between charges and must be removed to be plugged in" (Chen & Bilton 2014). On the other hand, stakeholders and other actors are competing for access to infrastructures, equipment and, most importantly (Beuse, Schmidt & Wood 2018).

For the scientific community involved in advancing electrochemical cells, the mandate of development is translated and expressed in two ways. The first task is to optimize the design of lithium-ion batteries by applying new knowledge in the manufacturing processes. The second task is to find materials that will substitute the lithium-ion's components. "Battery scientists and engineers have been making batteries 5–10% more efficient every year for the past 25 years, says George Crabtree, a materials scientist at Argonne National Laboratory in Illinois" (Evarts 2015).

One of the most important challenges scientists are facing regarding energy storage is how this can be accomplished in a smart and efficient way. Here, "efficient" means that the device will have the capacity to adjust the flow of electricity depending on the work it has to perform. "Demand for electricity varies through day and night and through different seasons. Currently, the energy needed to meet peaks in demand is stored in the form of natural gas and coal. These fossil stores sit around in back-up power plants that ramp up when demand is high" (Hodson 2015).

Another aspect of optimizing lithium-ion batteries is to upgrade their safety, therefore avoiding any potential hazards due to temperature issues. "First, it is important to develop in situ or in operando methods to detect and monitor the internal health conditions of LIBs" (Liu et al., 2018). This becomes imperative, as electric vehicles are going to rely on large batteries that will generate lots of heat. In every case, taming lithium is the key to producing better and safer batteries. "The more tightly scientists can control lithium ions in structures such as these, the more stable the battery becomes" (Evarts 2015).

Nonetheless, there are some cases where the optimization process can be ambiguous. In particular, Apple was accused of purposely slowing down old iPhones, as the devices became dysfunctional after a certain time period. Engineers designed the iPhone models 6, 6s, SE and 7 in terms of saving power. Put differently, the device's processing power decreases in favour of a more efficient battery management, avoiding any unexpected shutdowns. Additionally, updates and applications can gradually make the smartphone even more power hungry, overloading the device's battery. "Apple's website says the battery loses about 20 percent of its original capacity after 500 charge cycles" (Chokshi 2017).

Incidentally, Apple chose to not be transparent about this specific aspect of their product, which in turn dramatically affected the customers. In particular, consumers had to find out empirically, that their mobile phone's performance was optimized at the expense of the battery's capacity. Therefore, people started to suspect that the company was "deliberately crippling their devices to get them to buy new ones. This episode is a good reminder that even digital devices need maintenance" (Chokshi 2017). In effect, Apple un/intentionally forced costumers to buy new devices and consume more smartphones.

Ultimately, if it is true that—despite multiple optimization efforts—lithium-ion batteries are on the verge of their electrochemical capacity, why is it so difficult to move beyond the lithium-ion battery?

Many researchers are looking for possible alternative materials that would dethrone lithium-ion batteries. Yet, given that optimization is based on previous knowledge, moving beyond lithium-ion batteries is quite challenging. The quest for a material that is going to satisfy the markets is presented as an empirical process, which is based on trial and error. According to a certain article "good batteries are like needles in the haystack of all possible materials" (Hodson 2015).

Identifying the material with optimal electrical density, weight, size and safety is very complex and demands lots of calculating. This is why researchers "use supercomputers to virtually study hundreds or thousands of chemical compounds at a time, quickly and efficiently looking for the best building blocks for a new material, be it a battery electrode, a metal alloy or a new type of semiconductor" (Ceder & Persson

2013). The process of identifying the most efficient materials for batteries, can be very challenging and according to the article *Building The Battery Of The Future – Today*:

> Finding the right combination is only one part of the challenge… You also have to process it into an electrode and get the best out of it in that way. We have an understanding of that. You cannot design the best material unless you understand how it performs as an electrode and in a battery cell.

Designing such a battery relies on finding the right material with the appropriate properties. Over the years, numerous studies have claimed to have found the right material, but we have yet to see a breakthrough in the market. Regardless of the experiments with multiple materials, lithium-ion batteries remain prominent and are perceived as the foundation of portable technological devices. For instance, "Li-air still has a long 'slope of enlightenment' ahead of it before it can really compete with Li-ion, let alone fossil fuels" (Fares 2016).

Taking the above into consideration, lithium-ion batteries have the capacity of dis-articulating scientific practices. On the one hand, scientists are trying to optimize the current performance of lithium-ion batteries, while, at the same time, other scientists are looking to transcend the limitations posed by the materials comprising these batteries. In short, these batteries emerge simultaneously both as a boundary and a point of departure—they demarcate just as much as they expand the scientific practices. Consequently, the narrative of development is supported by the successful production and optimization of lithium-ion batteries. Moreover, what has been perceived as the 'battery r-evolution' establishes a prominent paradigm, according to which national innovation systems are either leading or just keeping up with development.

In conclusion, development is established in the Global North and it is represented as an autonomous "object" that drives the advancements in the field of rechargeable batteries. In the meantime, the Global South appears to be dislocated from this process. "Therefore, hegemony is in reality a hinge, given that on the one hand it sutures the relationship between two elements (the task and the agent); But on the other hand, … the hegemonic relationship can be thought only by assuming the category of lack as a point of departure" (Laclau, 1990, p. 96).

4.2. A Battery (R)Evolution Fuelled by Minerals

The purpose of this chapter is to present how the Global South becomes dislocated from the narrative of development and to illuminate the contingent conditions of lithium-ion battery production.

> For what is at stake is not the degree of effectiveness of a fully constituted object – the economy on the rest of social development, but to determine the extent to which the economy is constituted as an autonomous object, separated by a boundary of essence from its factual conditions of existence (Laclau, 1990, p. 24).

Nowadays, the issue at hand seems to be sustainability. Although there have been many suggestions as to how sustainability can be achieved, the common denominator seems to be an ambiguous combination of renewable energy and batteries. As stated in the article *The Journey Of An Electrifying (R)evolution*, scientists need to invest in developing "new energy storage systems capable of sustaining future human societies in the Anthropocene era".

Be that as it may, not everyone is convinced that this would be the best approach. Articles such as *The Battery Revolution That Will Let Us All Be Power Brokers* mention that, in the years to come, we will witness great developments in the field of energy storage. Likewise, "Tesla CEO, Elon Musk, described the potential of a world entirely powered by batteries charged with renewable energy. But energy storage experts remain unconvinced. Even Panasonic – supplier of the lithium-ion cells that form the foundation of Tesla's batteries, and partner on the company's forthcoming battery factory – calls Musk's claims hyperbole. "We are at the very beginning in energy storage in general… We wish we could but it's not really possible yet" (Westervelt 2015).

> Besides being presented as the epitome of the rechargeable revolution, lithium-ion batteries are also clearly linked to environmental optimization practices. One of the lithium-ion founding fathers, John Goodenough, has stated that: "Modern society is completely dependent on fossil fuels, so there's a huge incentive to find a replacement for the internal combustion engine… We have to find a way to liberate society from that dependence (Evarts 2015).

Despite the fact that renewable energy appears to be an environmentally friendly source of energy, it is quite untameable due to its nonlinear nature, as renewable energy sources (such as wind, sun and water) have a high level of unpredictability. "On 20

March this year, for example, a solar eclipse knocked out two-thirds of Germany's solar generation capacity for about an hour. Grid operators, aware of the impending shortfall, spun up alternative generation from coal, gas and hydroelectric systems to meet it. With sufficient battery storage, though, the eclipse would have been a non-event from the start" (Hodson 2015).

Batteries offer the opportunity to tame the power that is generated by renewable sources. Rechargeable batteries that have the ability to accumulate energy and release it when needed are depicted as "smart energy storage". Furthermore, agents of sustainability, such as Elon Musk, are promoting rechargeable batteries on all scales, as "Tesla Motors is not simply an automaker. It is an "energy innovation company" a critical element in its broader quest for "zero emission power generation" (Eisler, 2016a, p. 36). From electric vehicle car batteries and household batteries "which are about the size of a gas boiler" to the world's largest lithium-ion battery in Australia (Vaughan & Gibbs 2019).

Even though South Australia is considered to be the country that has adopted renewable technologies in the most efficient way, unexpected blackouts made the region's power system unreliable. For this reason, Tesla offered a solution by installing the largest lithium-ion battery in the world. One of the contract's conditions was the commitment that, if the project does not meet the preassigned deadline within 100 days after signing, then it would be for free. The battery will in fact be made up of thousands of Tesla car lithium ion batteries packed into hundreds of refrigerator-sized units spread across a field. Combined, they will be able to power 30,000 homes. "You can essentially charge up the battery packs when you have excess power when the cost of production is very low… and then discharge it when the cost of power production is high, and this effectively lowers the average cost to the end customer". Musk told reporters in Adelaide, South Australia today. "It's a fundamental efficiency improvement for the grid (Klein 2017).

All things considered, one could legitimately claim that lithium-ion batteries are becoming a symbol and a currency of sustainability. But the question is: What is going to fuel this transition? According to Balch:

> Clean energy transition will be significantly mineral intensive*" Sustainable Minerals And Metals For A Low-Carbon Future*. This means that access to natural resources becomes imperative for a greener future. According to the primary material, lithium has become an equivalent of petrol oil. "The sudden excitement

> surrounding *petróleo branco* ("white oil") derives from an invention rarely seen in these parts: the electric car. Lithium is a key active material in the rechargeable batteries that run electric cars (2020).

In order to power the innovations that will lead us to sustainability, access to white oil and other minerals must be ensured. The intensive demand for transition unfolds as a competition to access territories rich in mineral deposits. The mandate of development localizes zones that are sources of raw materials and zones that compete for superiority of lithium-ion production. All things considered, the Global South is disarticulated from the master narrative of development yet signifies a point of departure for the Global North—which lacks natural resources. This is why the development of lithium-ion batteries appears to be independent from the Global South. Thus, pinpointing the contingent conditions of sustainability and development brings to light the entanglements between the Global North and the Global South.

For instance, Bolivia "contains as much as half the world's lithium reserves. In the early to mid-2010s, when talk of lithium-ion batteries began circulating in every mining town, a raft of new licences was requested, investments made, and extraction facilities expanded" (Balch 2020). As Oji Baba, an executive in Mitsubishi's Base Metals Unit, stated: "If we want to be a force in the next wave of automobiles and the batteries that power them, then we must be here" (Romero 2009). Extracting lithium has become a foundational practice, deeply rooted in the necessity for sustainability. This is often projected as a solution to the environmental crisis. "Advocates of Portugal's hoped-for lithium boom argue that local disruption is a small price to pay for tackling the climate crisis" (Balch 2020).

As one would expect, countries with rich mineral deposits are very cautious about the imminent mining activities. "The previous imperialist model of exploitation of our natural resources will never be repeated in Bolivia," said Saúl Villegas, head of a division in Comibol that oversees lithium extraction. "Maybe there could be the possibility of foreigners accepted as minority partners, or better yet, as our clients" (Väyrynen et al., 2010). "Yet mining is linked to all sorts of environmental headaches. In the so-called Lithium Triangle of South America – made up of Chile, Argentina and Bolivia – vast quantities of water are pumped from underground sources to help extract lithium from ores, and this has been linked to the lowering of ground water levels and the spread of deserts" (McKie 2021).

Interestingly, it has recently become common knowledge that Afghanistan has rich resources of rare earth minerals and, especially, lithium. To be more specific, in a 2010 U.S. Department of Defence memo, Afghanistan was described as the "Saudi Arabia of lithium" (Reuters, 2021), which grants to this country a strategic value for the various competitors (such as China and the U.S.) during the ongoing social and political crisis of 2021.

Another critical metal that is necessary for the production of lithium-ion batteries is cobalt, which has also been referred as the "hottest commodity of 2017" Nkulu et al., 2018). In the article *Cobalt in lithium-ion batteries*, we see that cobalt is perceived as a scarce source material that is a substratum of lithium-ion batteries. At the same time, many companies are trying to detach from this resource due to the ethical and reputational concerns surrounding cobalt mining. For this reason, scientists are urged to find a new transition metal that would be capable of substituting cobalt.

> Followers of Elon Musk are used to big claims on Twitter. The social media habits of the Tesla and SpaceX billionaire have landed him in legal hot water on several occasions. But for the battery industry one boast stands out: a tweeted pledge to remove an obscure mineral mined in the Democratic Republic of Congo from the next generation of Tesla's electric cars. Batteries are the key component in the electric car revolution that Tesla kickstarted, and each one contains cobalt. Yet, concerns about human rights abuses and child labour have prompted a dual effort to cut the amount of cobalt used in batteries and to clean up complex global supply chains" (Jolly 2020, January 5).

Despite these statements concerning the reduction of reliance on cobalt, the demand for this critical metal has significantly increased and will continue to do so in the future. "These lithium-ion batteries are increasingly in demand for electric cars, laptops and mobile phones, which means cobalt – once deemed a worthless chemical – is now the object of a geo-strategic rivalry between the world's biggest economies. It is also potentially exposing humans and other species to greater doses" (Watts 2019). "If people should be worried about the supplies of any material, it should be cobalt, a material many times more valuable than lithium but likely to be phased out of vehicle batteries over the coming years" (Taylor 2009).

Furthermore, the reputation of companies such as Apple, Dell, Google, Microsoft and Tesla took a big hit when they were accused of using cobalt that was excavated under unethical conditions. A lawsuit initiated by Siddharth Kara, an anti-slavery activist and Harvard professor, represented 14 Congolese parents and children. As Siddharth Kara has stated in an article: *Is Your Phone Tainted By The Misery Of The 35,000 Children In Congo's Mines?* "While market prices of cobalt have spiked 300% in the past two years, none of that increase makes its way down to *creuseurs*".

Apple, Glencore, Dell, Umicore have publicly stated they are not going to support this kind of mining activity. "Glencore's operations in the DRC do not purchase or process any artisan-mined ore". "Apple is deeply committed to the responsible sourcing of materials that go into our products". Dell has claimed that: "We have never knowingly sourced operations using any form of involuntary labor, fraudulent recruiting practices or child labor. We work with suppliers to manage their sourcing programs responsibly. Any supplier with reports of misconduct is investigated and, if misconduct is found, removed from our supply chain". "Umicore has been addressing ethical supply for 15 years, ensuring no issues related to human rights, child labor, safety conditions and environmental impact related to cobalt extraction" (Kelly 2019).

As a result, alternative solutions are promoted in order to achieve sustainability in an ethical way. For instance, mining from the ocean floor "potato-sized globs of mineral are rich in copper, cobalt, manganese and other metals. According to the International Seabed Authority, some deposits contain millions of tonnes of cobalt, copper and manganese" (McKie 2021). Conversely, many scientists highlight that more research is needed because, at the moment, it is premature to determine how and if these activities could destabilize the ecosystem. There is a big contradiction behind the mining for a sustainable future. "Everyone having an electric vehicle means an enormous amount of mining, refining and all the polluting activities that come with it" (Balch 2020).

The last stronghold of sustainability is recycling the necessary materials from spent lithium-ion batteries. Yet again, there is no consensus regarding this subject. The arguments are not questioning recycling in general but, rather, the terms under which recycling will take place. From one point of view, the business of recycling the materials of lithium-ion batteries could be a profitable financial venture. On the other hand, critics argue that the process of recycling these materials is highly toxic and very difficult to accomplish. “Removing the battery’s heavy plastic casing is easy enough; the challenge is how to access the lithium inside the battery cell itself. Currently, two main options exist: either heat the components to about 300C to evaporate the lithium, or apply acids and other reducing agents to leach it. Both approaches are complicated by lithium’s extreme volatility (it is prone to exploding) and its amalgamation with other metals (which are added in for better conductivity)” (Balch 2020).

Furthermore, consumer behaviour seems to be an inhibitory factor towards recycling. According to the article: *The EU May Make Reycling E-Waste A Legal Requirement – Will It Work?* “It is estimated that there are more technology critical metals in household drawers than in Europe’s largest mines”. People in the UK throw away 22,000 tonnes of batteries a year, according to Esa, but only 45% are recycled properly (Carrington 2020). In effect, the European Union has introduced legislative regulations in order to reinforce recycling across the continent.

> The European Union, for example, requires companies to collect batteries at the end of their life and either repurpose them or dismantle them for recycling… Meanwhile, the EU is considering a 70% target for batteries to be collected by 2030. In addition, it wants 4% of the lithium in new batteries made in the EU to be from recycled material by 2030, increasing to 10% by 2035 (Larcher & Tarascon 2014).

These efforts are going to reduce the amount of illegal e-waste exports and will “create financial incentives for companies to recover critical raw materials, for instance by reducing the tax on products made with recycled content” (Liverpool 2021).

For the most part, sustainability is a narrative enchained by the broader narrative of development. Technological innovations emerge as a necessity in the face of environmental degradation. Thus, lithium-ion batteries are transformed from a floating signifier into a reference point of sustainability and fossil-free societies. Be that as it may, the battery r-evolution obscures other important aspects of lithium-ion batteries, such as our dependence upon critical minerals and the contingencies of mining them. To quote Laclau (1990), “contingency is eliminated and radically absorbed by necessity” (p. 20). Meanwhile, the narrative of sustainability remains unquestioned.

Actors that belong in the Global North are competing with each other for access to natural resources, whereas in the Global South “certain territories and natural environments have always been “sacrificeable” in the name of progress” (Balch 2020).

Therefore, critical metals are translated into a currency of the post-petroleum era. Countries rich in mineral deposits are the ones that will fuel the electrical r-evolution in the Global North. Sustainability and development are placed in a concentric arrangement, which “in other words, causes all of its focal points to coincide in a single center that is in constant movement but remains invariant through its movements” (Deleuze & Guattari, 2014, p. 212). Hence, inasmuch as battery industries distance themselves from minerals such as cobalt, they are going to continue to be attracted by it for as long as minerals are the centre—and the reference point—of sustainability.

4.3 Lithium-Ion Batteries as a “Time Bomb”?

Ever since its very beginning, the lithium-ion battery has been perceived as an attractor for many technological applications due to its rechargeability and resilience. The capacity for re-charging electronic devices multiple times is the product of engineering in terms of electrochemical density, appropriate size and weight. When lithium-ion batteries are in a stable state, they are represented as an efficient and safe rechargeable cell. Be that as it may, there are several occasions when lithium-ion batteries deviate from their intended mode of operation and are, therefore, perceived as unstable rechargeable cells or potential bombs. By contrast, other opinions point out that an exploding lithium-ion battery is a rare occurrence. Hence, this case is presented as an exception. Why are lithium-ion batteries and their early prototypes considered “ticking time bombs”? (Evarts 2015). Let us start from the beginning:

> “If we think about batteries or energy in general, there are two components. One is work, which in the context of a battery is delivering electricity. The second is heat. The more electricity a battery can deliver while generating less heat, the more effective the battery is at doing its job” (Greenemeier 2014).

Batteries are delicate electrochemical cells that need careful treatment in order to remain in their stabilized state. Then again, the market’s demand for lighter, thinner and faster portable electronic devices has influenced how engineers optimize lithium-ion batteries. “Companies are working hard to increase the amount of energy that can be packed into a battery, and to bring down the cost of making them” (Vaughan & Gibbs 2019). In fact, the mandate for the scientists who develop lithium-ion batteries is to minimize their size while maintaining an optimal electrical density. Unfortunately, squeezing a certain amount of energy in a very tiny space may cause structural failure which can lead to a thermal runaway. In short, changing a battery’s size whilst demanding the same amount of work leads to heat problems during the process of dis/charging (Eisler, 2017, p. 372).

Usually, once a stable lithium-ion battery is fully charged, the charging process will automatically stop—but this might not be the case with faulty ones. “If left plugged in for too long, the lithium ions can collect in one spot and be deposited as metallic lithium within the battery... Also, heat from the overcharging can cause oxygen bubbles within the gel, which are highly reactive with metallic lithium” (Geggel 2016). This combination of a rising temperature and accumulated oxygen, in addition to the lithium (the electrolytes that function as a fuel to this reaction), set off the battery in a phase of uncontrolled positive feedback or, else, to an explosion. This capacity of lithium-ion batteries to potentially turn into a bomb (of sorts) is a prime example of their exceptionalism.

Although dysfunctional lithium-ion batteries are usually perceived as a product of engineering problems (Eisler, 2017, p. 369), there also are other factors that can transform rechargeable cells into small bombs. Environmental factors (such as temperature and pressure) have the capacity to destabilize lithium-ion batteries. For example, new batteries are developed in terms of performing “well in temperatures as low as −60 degrees Celsius, unlike standard lithium-ion batteries, so they could power instruments in high-altitude drones and long-range spacecraft” (Seddaca 2017). Another example is when *The New York Times* reporter John M. Broder test-drove a Tesla Model S electric car from Delaware to Connecticut, when “He became stranded after he exhausted the battery in cold weather” (Eisler, 2016a).

For the above reasons, lithium-ion batteries also present a potential risk. Several cases in the primary literature support this interpretation. A prime such example was when Samsung had to “recall 2.5 million of the devices because of an issue with the lithium-ion batteries in the phones, which can catch fire and explode” (Kang 2016). Furthermore, in the article *The Science Behind Samsung Phone Battery Fires* it was mentioned that “the Samsung Galaxy Note 7 is suffering the same fate as countless hoverboards—there are reports that some phones have been bursting into flames, prompting Samsung is [to] issue a recall and the U.S. Federal Aviation Administration to strongly discourage passengers from carrying the device on planes, news sources report”.

Explosions, even if they are small, become more terrifying whenever they are linked to aeroplanes. Airlines across the world together with “the Federal Aviation Administration ‘strongly’ advised passengers onboard planes not to use the Galaxy Note 7” (Kang 2016). Likewise, other companies avoided having lithium-ion batteries as a part of their power system. “Boeing rival Airbus has decided to abandon the battery in question, Bloomberg reported. It will not use lithium-ion batteries for its A350, the direct rival to the 787, after Boeing encountered problems” (Tatlow 2013).

In fact, almost all the big companies that sell products containing lithium-ion batteries have made recalls of their devices. To be more precise, Dell and Sony have had at least 21 recalls from 2000 to 2005, of which nine went totally unnoticed by the media. The most well-known recall is, perhaps, a 2006 one, when "on only six reports of overheating, Dell recalled 4.2 million Sony lithium-ion battery packs manufactured in Japan and China for Latitude, Inspiron, Dell Precision, and XPS notebooks. Representing 15 to 18 percent of Dell's laptop production for the period, it was the largest recall of consumer electronics to that time" (Eisler, 2017, p. 380). Apple had to recall 1.1 million Sony power packs, while Lenovo/IBM had to recall 520,000 packs.

Another instance when lithium-ion batteries can be presented as a catalyst of potential catastrophes is if they take the form of e-waste. To be more precise, e-waste is perceived as a huge environmental risk in the Global North. "Old batteries are hard to reprocess and could become a ticking time bomb for the environment, says Adam Vaughan" *Here's How We Can Stop A Mountain Of Electric Car Batteries Piling Up*". Moreover, lithium-ion batteries have caused at least 250 fires in the UK in 2020 (Geggel, L. (2016, September 12).

Henceforth, the Global North has attempted to reduce the risk of destabilizing lithium-ion batteries. Legislations ensuring "better enforcement of existing laws banning the export of e-waste from the EU would also be key to guarantee there is enough e-waste to be recycled, says Gavin Harper at the University of Birmingham, UK. "Ensuring waste stays within the bloc both ensures that wastes are handled responsibly and also ensures feedstock of secondary materials for recycling," he says" (Liverpool 2021).

In the Global North, once a rechargeable battery loses its capacity to sustain a linear development, it is detached and discarded in the Global South, where unstable lithium-ion batteries are perceived as e-waste rather than a risk. Therefore, mountains of non-functional batteries find a home in the Global South. "Batteries [are] being exported to a country like India for a legitimate second use, such as powering a microgrid, but where no recycling facilities exist when they [the batteries] are spent. That could be a growing time bomb, especially if things take off quickly" *Here's How We Can Stop A Mountain Of Electric Car Batteries Piling Up.* Choosing the e-waste sites for lithium-ion batteries reveals a technopolitical aspect of waste planning. It is a prime example of how the materials and technologies of modernity become instruments of slow violence (Hecht, 2018, p. 130).

In conclusion, despite scientists' efforts to create safer lithium-ion batteries, rechargeable batteries continue to be perceived as a potential "ticking bomb" whenever they deviate from their stable status. Unequal distribution of risk is the product of overemphasising on the exceptional conditions under which lithium-ion batteries transform into bombs in the Global North while undermining the accumulated waste in the Global South. Altogether, the un-stable state of lithium-ion batteries has the potential to become "the conceptual and material border … dividing those who value and those who are disposable" (Armiero, 2021, p. 12).

Different states of lithium-ion batteries appear in different territories. The lithium-ion batteries are presented in the Global North as Nobel Prize-winning rechargeable cells that are the vehicles of sustainable development. In this context, any sort of deviation from their stable sate is represented as an exception and, therefore, as an unintended consequence. Conversely, in the Global South lithium-ion batteries are presented as an event that takes place before and after (*ex ante* as a resource and *ex post* as waste of) their emergence.

Ultimately, lithium-ion batteries have multiple representations which perpetuate certain practices of development and sustainability. However, at this point, it is important to look beyond the representations. For "representation has only a single centre, a unique and receding perspective, and in consequence a false depth. It mediates everything, but mobilises and moves nothing" (Deleuze, 1994, pp. 55–56). What are the technopolitics of lithium-ion batteries beyond their representations?

5. Discussion

5.1. The Emergence of Smartness

Given how rarely one thinks about the smartness of everyday devices, it is even rarer that someone thinks about how smartness rearranges technological, political and ecological conditions in different environments. Smartness has become a representation that obscures all the messy and un/intended consequences of technological development. This occurs because smartness is detached from its social and economic relations. Therefore, certain parts of its material production become invisible. But the tricky question is this: What is the origin of smartness? Is smartness an 'essence' locked within technological devices?

Although smartness has several meanings attached to it, we are going to focus on smartness as approached by Halpern, Robert & Geoghegan (2017). According to them, the concept of "smartness" can be traced back to IBM chairperson Sam Palmisano, who, in a 2008 talk about overcoming the economic and environmental crisis stated that smartness is: "the interweaving of dynamic, emergent computational networks with the goal of producing a more resilient human species – that is, a species able to absorb and survive environmental, economic, and security crises by means of perpetually optimizing and adapting technologies" (Halpern, Robert & Geoghegan, 2017, p. 107).

Treating smartness as an emergent property of technological assemblages means that it cannot be reduced to its constituent parts. For this reason, smartness can be better understood as a stratum that functions as an expressive part of a material substratum. According to Deleuze & Guattari, an assemblage:

> divides into parastrata according to its irreducible forms and associated milieus, and into epistrata according to its layers of formed substances and intermediary milieus. Epistrata and parastrata must themselves be thought of as strata. A machinic assemblage is an interstratum insofar as it regulates the relations between strata, as well as the relations between contents and expressions on each stratum, in conformity with the preceding divisions (2014, p. 73).

Common mobile phones—the predecessors of smartphones—were introduced to us as a yellow-tinted screen with a physical keypad and limited functionality. But how can a common phone be transformed into a smartphone? A phone becomes smart only when it is related to a network of data that is generated by a population of other smart devices. "The phone becomes a mechanism for creating data populations that operate without the cognition or even direct command of the subject" (Halpern, Robert & Geoghegan, 2017, p. 117). Hence, smartphones compared to common mobile phones have contributed greatly to the acceleration of the ideology of intelligence technology. The main reason for this is that they are used in order to exchange populations of data. In other words, the critical threshold between a normal mobile phone and a smartphone is *data friction*. But what is data friction and why is it so important?

The technological developments that occurred over the last decades have made algorithms and data an integral part of our everyday life. "Where data (and in-form-ation) are conceptualized primarily as abstract forms (texts, numbers, sequences, etc.), historians should ask after their material basis, what we have called "data-as-object". (Strasser & Edwards, 2017, p. 229). Grounding data to their material conditions is important because it allows us to approach data as objects. Different material forms encapsulate and code data in a corresponding manner that can only be expressed within a specific infrastructure. To put it differently, the flow of data through an analogue form (such as a book) presents much more friction compared to a computer's digital data; especially if we consider that one megabyte approximately contains a five-hundred-page book (Strasser & Edwards 2017, p. 334). In a way, analogue data has been the substratum for the emergence of digital data.

Technological devices such as computers and smartphones can be used not only to maximize the digital convergence but also to drastically accelerate the quantity of data production. Hence, smartness did not emerge out of thin air. Rather, it is an internet of things that can "generate the data necessary for organizing production and labor, enhancing marketing, facilitating democracy and prosperity, and – perhaps most important– for enabling a mode of automated, and seemingly apolitical, decision-making" (Strasser & Edwards, 2017, p. 107). Such networks are based on material infrastructures and resources.

Furthermore, the diffusion of smart devices depends on the friction presented in a broad environment. Institutions, knowledge networks and infrastructures can play a catalytic role in reducing the friction, thereby enabling greater diffusion of a new technology (Prasad, 2019, p. 1061). The Global North appears to be populated by a plethora of smart devices that have a “way to add value to a range of products and services, whereby scaling up the advancement of smartness will “force economic growth” and “force societal progress” (Sadowski & Bendor, 2019, p. 3). At the same time, the Global South is perceived as the “dark hole of the information age”. In effect, the emergence of smartness creates different territories.

Arguably, one of the most important parameters that has reduced data friction (and, at the same time, redefined our relationship with telecommunications), is the fact that phones became mobile and rechargeable. After all, how smart would a smartphone be if it was not wireless?

In a way, lithium-ion batteries have functioned as a substratum for the emergence of smartness. These energy storage units seem to be the foundational layer for smartphones, electric cars, laptops, aeroplanes and, even, smart homes. Therefore, they contribute to the acceleration of energy consumption and data production.

> The materials furnished by a substratum are no doubt simpler than the compounds of a stratum, but their level of organization in the substratum is no lower than that of the stratum itself. The difference between materials and substantial elements is one of organization; there is a change in organization, not an augmentation (Deleuze & Guattari, 2014, p. 49).

Given that lithium-ion batteries function as an attractor of smart devices, what are the technopolitics that surround the production of these technological devices? Is it possible that lithium-ion batteries have divided the world into two main territories: “into an industrialized “center” and a raw-materials-producing “periphery”? (Hecht, 2014, p. 80).

5.3. Anthropocene vs Cobalt as an Interscalar Vehicle

An often-overlooked point is that one of today's most pressing issues is humanity's response to the ongoing environmental crisis. According to Paul Crutzen (2006), a 1995 Nobel Prize laureate in chemistry, "Humankind is bound to remain a noticeable geological force, as long as it is not removed by diseases, wars, or continued serious destruction of Earth's life support system, which is so generously provided by nature cost-free" (p. 17). For this reason, various technologies (such as lithium-ion batteries) have been presented as a means to a fossil-fuel-free and rechargeable society (Scrosati, 2011, p. 1629). In some cases, lithium-ion batteries are even considered to be a key innovation towards a green economy. Thus, access to natural resources becomes essential for a sustainable and green development.

Yet, how does the environmental crisis and the notion of sustainability affect different populations? Is access to natural resources achieved through an equal exchange? In the following chapter we are going to navigate through the secondary literature and present how lithium-ion batteries created different territorial zones of smartness and waste.

The growth of human population, greenhouse gasses, deforestation, ocean acidification and other destabilizations of the environment transform the earth's surface into an uninhabitable territory for humans. Humans and their industrial activities have dominated the current geological epoch at the cost of leaving a massive environmental footprint. Due to that, many scientists argue we have entered the Anthropocene era. The Anthropocene is a concept that signifies the end of the Holocene, while also attributing to humanity the lion's share of the earth's strategraphic transformation. Humanity's mode of energy production (along with its model of energy consumption) has led us to a point where "mankind will remain a major geological force for many millennia, maybe millions of years, to come" (Paul Crutzen, 2006, p. 17).

The Anthropocene has generated lots of arguments in diverse academic fields. According to Armiero (2021), in a Google search on "January 23, 2020 the word Anthropocene gives more than five million results in 0.7 minutes" (p. 4). The problem with this master narrative is that it generates approaches that make universalistic claims by reducing humanity to a seamless totality. It obscures the heterogeneity amongst the human population (such as social classes, inequalities and accessibility), while, at the same time, naturalizing neoliberal practices. “It depicts human/natural history as a succession of technological innovations, thus ignoring the social relations that drive this history” (Kaika, 2018, p. 1718).

Although the Anthropocene has the ability to raise environmental awareness, it often lead to solutions without questioning the conditions that are steering humanity at this point. More specifically, the Anthropocene depoliticizes the status quo terms of production-consumerism, while, at the same time, projecting them as a fundamental aspect of the solution to the environmental crisis.

Hence, if we were to implement the Anthropocene analysis in our attempt to understand the relations between the Global South and the Global North, we would remain ignorant of the dynamic relations between those territories. As Armiero has stated (2021), the Anthropocene’s weak point is: “its invisibilization, or at least undervaluation, of social, historical, racial, and gender inequalities in the paths toward the contemporary ecological crisis” (Armiero, 2021, p. 9).

This brings us to the following question: How could we emphasize the environmental cost of producing lithium-ion batteries without ignoring the inequalities that are being generated? How can we tie together within the same analysis the accumulation of value in one environment and the concomitant degradation of another environment?

The answer to the aforementioned questions would be to place all the moving parts on the appropriate scale. This means that we need to engage in the task of tracing the material components that assemble the lithium-ion batteries. Following the material flows enables us to map out the entanglements between the Global North and the Global South. Such an approach will require us to navigate the seemingly irreconcilable realms of nature and civilization.

At this point, it is important to mention that scales “are emergent rather than eternal… we must treat scales as outcomes of social, cultural, and technopolitical processes” (Hecht, 2018, p. 114). Ontological and epistemological commitments like these usually raise arguments such as the following: “symmetrical relational ontologies have not only served as common foundation for a fundamental rethinking of socioenvironmental issues, but that they also stand guarantee for a post-capitalist politics" (Swyngedouw & Ernstson, 2018, p. 12).

In order to manoeuvre between the different territories, we will need to use an interscalar vehicle (Hecht 2018, pp. 113–115). In this case, we are going to focus on cobalt, which is a crucial element in the production of lithium-ion batteries. A vast number of today's technological devices rely on lithium-ion batteries, which, in turn, creates a huge demand for raw materials. This demand can be understood as a flow of materials from one territory to another, thereby establishing a very complex circuit where one environment is the terminal that accumulates value, while another is the terminal that is steadily devalued and impoverished. According to Hecht: "Europeans built political philosophies premised on the radical Otherness of Africans. Armed with Maxim guns and industrial goods, they saw artisanally produced African technologies as proof of a primitive existence. "Africa" became seen as a place without 'technology'" (2014, p. 16).

A natural resource cuts through local, national and transnational boundaries, thus binding them together. "Besides, the extracted resources themselves may become used as technopolitical objects, making them vehicles of technopolitical action. Unpacking such processes helps us to interpret how engineers and politicians use already defined resources and their flows for political gains, also to create new resource infrastructures with inherent political goals" (Veraart et al., 2020, p. 4).

The second key point is the waste that is produced as a technological device's by-product. For the last two centuries, societies have witnessed an acceleration of both production and consumption, which, consequently, creates an enormous quantity of waste. According to some researchers, it is estimated that approximately 11 million tons of lithium-ion batteries will be produced by 2030 (Chandran et al., 2021, p. 2). In effect, tracing the different forms of waste and discards (from the excavation of natural resources to electronic waste pits) illuminates the different inequalities and types of violence that are entangled with different environments (Hecht, 2018, p. 111).

Additionally, waste as a relation has the capacity of "producing wasted human and nonhuman beings, then wasted places, and wasted stories, the proximity, or overlapping, of a given community and a contaminating facility is more than a matter of miles and ZIP codes" (Armiero, 2021, p. 2).

Equally important is how waste is distributed between different zones. One territory gains value, whereas the other territory gradually becomes value-less. One population of humans becomes visible, while the other becomes invisible. The Global North accumulates smartness (with an increasing number of lithium-ion batteries powering smartphones), in contrast to the Global South, which is "subjugated to the mining industry under the usual extractivist regime which produces the ultimate other, disposable places and people to be exploited up to their exhaustion" (Armiero, 2021, p. 29).

It is important to mention that rather than reducing the differences between the territories to an "essence", we are going to treat them as different strata that lead us to the emergence of smartness. It "is not so much an essential property of things as it is distributed in things" (Hecht, 2007, p. 101). In the same manner, an innovation such as lithium-ion batteries is not something that was exclusively developed in a lab. On the contrary, it is a product of contingent relations between a territory that can provide the necessary materials and a territory that has the knowledge, infrastructure and access to produce these technological devices.

Finally, our point of departure is going to be the Democratic Republic of Congo (DRC) and, more specifically, the Katanga province, which produces almost "55.5 million tons of copper and 3.6 million tons of cobalt. The DRC thus possesses roughly 34% of the world's cobalt resources and 10% of the world's copper resources" (Sovacool, 2019, p. 916). These facts are translated in the Global North as source materials for companies such as Apple, Dell, Hewlett-Packard, Huawei, Lenovo, LG, Microsoft, Samsung, Sony, and Vodafone.

The prevalence of lithium-ion batteries in the Global North over the last thirty years is unquestionable. A long process of optimizing lithium-ion batteries has resulted in cobalt being a substratum for lithium-ion batteries and, by extent, for many other technologies. Lithium-ion batteries, regardless if it is un/intentional, establish technopolitical relations between the Global North and the Global South (Hecht, 2003,

p. 3). Let us now follow the material entanglements on a journey “*from stones to phones*”[3].

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[3] This phrase is mentioned in Siddharth Kara’s article “Is your phone tainted by the misery of the 35,000 children in Congo's mines?”, which was published in *The Guardian*.

5.4. The Technopolitics "From Stones to Phones"

Cobalt can be found in 21 different locations across the world, which overall produce 123-128kt (of which 69kt come from the DRC). China imports the largest quantities of cobalt and is also the main exporter of refined cobalt. But one can only wonder: What factors make the DRC the leading nation in cobalt production?

The DRC became an independent country on the 30th of June 1960. Previously, the country had been a Belgian colony with a long history in the mining sector. The DRC is the second largest country in Africa and, although it has a rich underbelly of mineral deposits, it is an extremely poor country. Be that as it may, cobalt is going to play a pivotal role for the years to come, as the demand for this mineral is expected to increase exponentially by the year 2050 (Van den Brink et al., 2020, p. 1).

The etymology of the word cobalt has its origins in the German word "Kobold", which means the subterranean gnome. "In ancient times, beginning as early as 2000 B.C. in Egypt, cobalt minerals were used as blue coloring agents for pottery, ceramics, jewellery, and glass" (Jensen & Tuchsen, 1990, p. 427). Until the fifteenth century, cobalt was considered to be a worthless metal and "the miners disliked it because of the labor of removing it and also because the arsenic in it injured their health" (Weeks, 1956, p. 152). During the following years, cobalt was used as a colouring agent due to its ability to give blue solutions whenever mixed with acids.

Be that as it may, the etymology of "cobalt" incidentally originates from an ancient German superstition, according to which "the Kobolds… [were], delighted in destroying the work of the miners, causing them endless trouble; and in mining towns the people used to pray in the churches for deliverance from the power of these malicious spirits" (Weeks, 1956, p. 157). In 1735, Georg Brandt managed to isolate cobalt. His discovery contributed greatly to what was later called the "Age of Freedom" in Swedish history.

Cobalt has a very unique status depending on the environment in which it is observed. In the DRC, it appears to be treated as a banal and cheap raw material, whereas in the Global North it is perceived as an ore with exceptional value (Hecht, 2014, pp. 36–38). While cobalt amounts to only 15% of a lithium-ion battery, it still remains a very expensive ore of crucial importance for the electrical industry. As mentioned earlier, cobalt is a critical ingredient for any kind of technological application that is powered by libs. Indeed, a typical electric car needs approximately 10–15 kg of cobalt (Calvão et al., 2021, p. 2).

Notably, cobalt has now been recognised as a critical and strategic metal. This characterization does not refer to the specific chemical synthesis of the metal, but, rather, it indicates the value of a given metal within a supply chain (Bookhagen et al., 2020, p. 1). Technopolitics has the ability to transform cobalt from a natural resource to a commodity. "Natural resources are materialities which human actors transform from matter into a commodity, a resource with economic value" (Veraart et al., 2020, p. 3). So, what gives cobalt this exceptional character?Cobalt becomes utilizable for the market only when it flows at a rate that allows calculations and predictions to be made on a market level. It is estimated that "cobalt demand will jump from 144,000 tons in 2023 to 218,400 tons by 2028" (Sovacool, 2019, p. 915). One may wonder how is it possible to ensure a steady and linear flow of cobalt in the Global North, when, at the same time, the very conditions of producing cobalt seem to be precarious in the Global South?

If we approach the demand for cobalt in a linear manner, then it is more than likely that we are going to overlook the potential risks that could disrupt its supply chain. African cobalt is usually excavated as a by-product of copper (70%) and nickel (20%) and only a 2% of global production comes from mines where cobalt is the primary commodity (Sovacool, 2019, p. 918). This means that this critical metal is dependent on the contingent circumstances created by its hosts. This kind of dependence reduces a resource's elasticity, and it is for this reason that primary cobalt mines are currently being developed (Van den Brink et al., 2020, p. 7).

Moreover, if we solely examine the production of cobalt on a national level, we might underestimate the fact that even a single mine could drastically destabilize the price and market value of cobalt. "For example, the closure of the Mutanda mine in 2019 removed around 20 % of the global cobalt supply" (Van den Brink et al., 2020, p. 2). Likewise, companies and shareholders that are either directly involved with cobalt's extraction and refinement, or indirectly via copper and nickel markets, can also cause a great disruption in cobalt's supply chain.

Mining in the DRC is considered to be an attractor of other economic activities. The narrative of economic development has been the axis for fighting poverty.

Institutions such as the World Bank Group (WBG), the state of the DRC state and private mining companies can either increase or decrease the flow of raw materials from the Global South to the Global North. For instance, the WBG provided the DRC with 1,4 billion U.S. dollars for the 2008-2010 time period in order to support the development of the country. During the same period, the WBG formed a "County's Assistant framework" which would eventually become the backbone of future developmental programs. The main goals of this project were the effective governance of the mines, the economic development in response to the question of poverty, the provision of basic services, providing a safety net and HIV/AIDS treatment (Campbell, 2009, p. 195).

The reforms that took place from the 1980s until 2010 had two main purposes: to circumvent corruption and to lure private investors to the mining sector. Unexpectedly, private companies ended up having more power than the state of the DRC. Buyers, due to their ability to secure investments, subjugated the DRC to a state of economic dependency, even though it was the actual producer of cobalt. As Campbell (2009) mentions: "The country is transformed into an immense reservoir of raw materials in which the central challenge is to manage to the best the flow of revenue resulting from resource exploitation, marketing and exporting" (p. 107). This is why "investments should not be measured by the power of their installations but against the developmental potential that they bring" (Hecht, 1994, p. 674).

However, making nature cheap can be very taxing if we consider the environmental cost. The extraction of cobalt seriously affects the environment, as its toxicity becomes imprinted in the areas from which it is extracted. Specifically, the excavation of cobalt contaminates water resources and creates industrial deserts or lunarscapes. Moreover, the dust from the mining activities spreads well beyond the mining sites. As clearly mentioned in Sovacool's (2019) research: "You have multiple pollution streams: pollution of the vegetables and farms. Pollution through dust. Pollution through the air. High levels of cobalt are in the urine and blood of mining workers and in entire mining communities" (p. 929).

At this point it is crucial to mention that accessibility is yet another technopolitical aspect that makes the DRC the main provider of cobalt. "The uniqueness of cobalt in Katanga is it is fairly shallow, it is amenable to artisanal mining, people don’t have to dig as deep for other minerals. The extraction technology can be low-level, low-tech, just a shovel, pick axes, and buckets” (Sovacool, 2019, p. 922).

There is uneven distribution of accessibility amongst the populations involved in the mining of cobalt. Mines are categorized according to the legal status. Therefore, there is industrial mining (or large-scale mines—LSM), small-scale mining (or artisanal mines—ASM) and, lastly, mixed mines. Each category represents a unique legal entity, which, in turn, creates different working conditions. The LSM mines are authorized. Therefore, they are granted legal recognition, whereas ASMs are unauthorized. The third type of mining basically refers to the process of formalizing ASMs.

According to recent studies there are approximately 100,000 to 150,000 ASMs in Katanga. Regardless of their unofficial state, they contribute greatly to the DCR’s economy, that approximately reflects 2.4% GDP. ASMs can be further distinguished depending on how the cobalt deposit is being accessed. In the first case, cobalt is accessed by digging underground tunnels, which are typically 30–40 meters deep. The miners are predominantly men who have not received any sort of training and do not possess the necessary safety or technological equipment. A typical ASM worker earns from 1 to 3$ per day and produces up to 30–50 kilos of cobalt per day, using shovels, chisels and mallets. “Note that many miners are so poor, they cannot even afford a ladder, merely digging extra steps into a pit; they almost never wear a helmet or protective equipment” (Sovacool, 2019, pp. 922–923).

Alternatively, ASM workers can obtain cobalt from the mining waste—also known as tailings. In this subcategory of ASMs, women and children are usually involved. Here, the workers are literally hand-picking the cobalt from the waste pits. The fact that ASMs have an unofficial status makes it impossible to enforce a minimum of regulations and safety measures. Yet, these mines produce almost 12.9% of the global cobalt supply (Sovacool, 2019, p. 923).

The LSMs usually refer to companies that have been granted the permission to excavate cobalt. This means they follow certain guidelines that ensure both the safety of the workers as well as of the mining site. LSMs are usually equipped with machinery and resort to automations that improve the working conditions. Bulldozers, diggers, dump trucks, dynamites, respirators, ventilation systems and other infrastructure guarantee better working conditions than in an ASM, but, still, they remain risky and far from ideal. To quote one worker: “We drill and blast with dynamite. We all have protective equipment such as dust masks or respirators, and the drilling and blasting teams are extremely safe. Perhaps the only unusual thing is the intensity of the shifts – we work 12 h shifts, and we do 24-7 mining, so it never stops” (Sovacool, 2019, p. 923).

The absence of a transparent legislative framework, combined with a lack of accurate knowledge, exposes the governance of the mines to corruption, various forms of violence and political instability. In the past, there have been efforts to legalize ASMs. The first attempt dates back to 1982 and Zaire’s President Mobutu Sese Seko. Some years later, in 2002, there was another attempt to protect the DRC’s natural resources. President Kabila, in collaboration with the WBG and the IMF, tried to formalize ASMs by creating the so-called *Zones d’Exploitation Artisanale*, which are also known as ZEAs.

Interestingly, ZEAs distributed accessibility to cobalt in an uneven manner. Given that formal mining sites bring back more profit through financial control and taxing, the sites with the big ore deposits went to the LSMs, whereas the ASMs zones were provided with less favourable territories, which contained fewer cobalt resources. In 2018, the mining code was revised “to the opposition of many major mining companies operating in the country” (Calvão et al., 2021, p. 6). As Campbell (2009) has mentioned: “Mining resources determine not only economic borders (zones of exploitation), but also social boundaries (mining increases inequalities) and political boundaries (the power base of political parties). On the other hand, they flout administrative borders, giving conflicts a regional dimension” (p. 213). What are the forms of exploitation produced by the extraction of cobalt? How is this critical metal related to exceptionally low-cost labour (Hecht, 2014, p. 62)?

ASM workers are basically trapped in a cycle of poverty, constantly trying to meet the breadline, without having any support from the government. Dispossession is a very common phenomenon and is expressed in different volumes. In several cases, an ASM mining site rich in cobalt can be taken over and privatized by LSM companies. In other cases, dispossession can be used as leverage in order to forcibly reduce cobalt prices, thereupon exposing ASM workers to an economic dependency, with no bargain power over the value of their work (Sovacool, 2020, p. 287).

Furthermore, the mining industry is linked to a more general notion of the DRC's economic development. Thus, the extraction of cobalt re-arranges gender roles and power amongst the populations involved in mining activities (Calvão et al., 2021, p. 4). This means that certain social groups, mostly men who are diggers or work in LSM, are perceived as the leaders of their nation's economic growth (Sovacool, 2019, p. 925). On the contrary, other people that are involved in less prestigious activities have a lower salary. Women rarely enter the mines and the work they perform usually involves collecting, cleaning and trading cobalt. In addition, prostitution poses a raised health risk within the mining camps, not only due to the lack of sanitation and hygiene, but also due to potential outbreaks of sexual diseases, such as HIV/AIDS. The extreme form of cobalt's division of labour is that "human lives have different values in different places" (Hech, 2014, p. 44–45).

Children are more vulnerable to the precarious conditions of mining cobalt. Child labour in the mines of Katanga is a very common phenomenon, according to an International Amnesty report. It has been estimated that 40,000 children were working in cobalt mining sites located in the southern DRC in 2014. They usually work 10–12 hours either as carriers, washers, hand-pickers or in the tunnels. Additionally, there is no certain way of ascertaining that their salary reflects their workload. The weight and the quality of the cobalt is measured and determined by the traders, which makes children even more susceptible to exploitation (Amnesty International, 2016, p. 6). Cobalt's exceptionalism becomes even more apparent if we consider that "the average laptop computer has about 3 min of child labor and the average electric vehicle 104 min of child labor" (Sovacool, 2020, p. 285).

In conclusion, using cobalt as an interscalar vehicle ellucidates the entanglements and the contingencies of different environments that are bound together. The flow of natural resources from the Global South to the Global North deconstructs our perception of "Africa" as being the "dark hole of the information age" and forces us to treat it as the substratum of technological development.

The diffusion of smart technological devices depends on catalysts that can either reduce or increase the friction of cobalt's flow from one terminal to another. It could be argued that the technopolitics between the Global North and the Global South comprise an assemblage that functions as an accumulator of energy and capital. Natural resources flow from a territory that is “energy source” to an environment that accumulates energy and translates it into “smartness”. All things considered, grounding narratives of sustainable fossil-free futures (or rechargeable and wireless societies) to the material conditions gives us a glimpse as to how “smartness”—rather than emerging out of thin air—is, actually, excavated.

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Appendix 2

Figure 1: Parts of a Lithium-ion battery: Created by the author

Figure 2: Representation of the lithium-ion battery’s supply chain between the Global South and the Global North: Created by the Author