THE ELECTRONICS INDUSTRY AND ENVIRONMENTAL GOVERNANCE: CHINA AND APPLE INC. CASE STUDIES

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Abstract

Addressing environmental challenges has become a top priority for the international community. In the context of globalization, the electronics industry has developed significantly, especially with the expansion of digitalization. Nevertheless, from its manufacturing, including semiconductors, to its end-of-life product, electronic waste, this industry is a major contributor to resource depletion and environmental pollution. This article describes the challenges encountered by a state sector, China and a transnational corporation, Apple Inc., for the development of the electronics industry while limiting its environmental impact.

Keywords

Semiconductors, electronics industry, electronic waste, CO2 emission, depletion, pollution, environmental issues, China, Apple Inc., transnational corporations, environmental governance.

INTRODUCTION

With the expansion of digitalization, the electronics industry, including the semiconductor production, plays an important role in the global economy. Nevertheless, the electronics industry is a major contributor to environment degradation through pollution and resource depletion. The amount of electrical and electronic equipment waste, also called e-waste (electronic waste) or WEEE (Waste Electrical and Electronic Equipment), is tragically expanding: 57.4 million tons of e-waste, outweighing China's great wall, were produced in the world for the year 2021[1] and it is expected to reach 120 million tons in 2050.

At the global scene, state actors and transnational corporations have the necessity to conduct their development while keeping their technological sovereignty or leadership. Therefore, these actors face antagonist forces while both fostering digitalization and the electronics industry and considering the environmental impact of their strategies.

The objective of our study is to provide an understanding of these forces by presenting the electronics industry and its impacts on the efforts for fighting environmental issues in 2023.

We use a descriptive method by analyzing China and Apple Inc. transnational corporation strategies for the electronics and semiconductor industry development and its consequences on the environment.

The first part of the article presents the environmental impacts of the electronics industry.

The second part studies the stakeholders' cases by:

1. Describing their main challenges and strategies for the electronics industry and its corresponding environmental impact.
2. Calculating some projections of e-waste impact.
3. Applying a range of tests using the information provided above in the points 1 and 2.
4. The conclusion gives a synthesis of our study highlighting the main outcomes.

THE ELECTRONICS INDUSTRY AND THE ENVIRONMENT

CARBON FOOTPRINT

The Full Life Cycle Assessment (LCA) method provides the equivalent CO2 emission of an electronic product, from cradle to grave, by considering raw material extraction, supply chain, manufacturing, and recycling at the end of the product life. For smartphones LCA study, the manufacturing phase has been identified as the most consuming of energy and mineral resources. For example, a report on an Apple iPhone14 [2] shows that manufacturing generates 79% of the total smartphone CO2e emission. In the manufacturing phase, the semiconductor production – part of the electronics industry - has the higher contribution with 29%. This could be explained by the several hundreds of pieces (semiconductors, plastic, metal parts) from which a smartphone is made. Therefore, the manufacturing is the result of a fabrication requiring tens to hundreds of operations performed in several locations around the world. Consequently, beside the manufacturing, transportation has also a significant carbon impact.

In 2020, the quantity of emissions, equivalent CO2, reported for top semiconductor manufacturers were: 29.5 Mt for Samsung Electronics, 35.4 Mt for Intel Corp, and 17 Mt Taiwan Semiconductor Manufacturing Corporation (TSMC) [3]. Additionally, the trend of the semiconductor sector pollution is driven by

the technology. As demonstrated by an IMEC expert research for the EETimes in 2020 [4], advanced technologies consume more energy and generate more CO2e emissions.

ENVIRONMENTAL DISFIGURATION AND WATER DEPLETION

The construction and the functioning of semiconductor and electronic factories lead to deforestation, drought of water, and disfiguration of the environment, in order to convey large amounts of electricity and water. For instance, the plants of the top worldwide semiconductor company located in Taiwan (TSMC), require approximately 5% of the island's electricity. In 2021, due to the high demand, this top company's consumption has increased to 7.2%. In 2019, 63 million tons of water a year were consumed by TSMC factories [5].

HAZARDOUS POLLUTION

Resources needed for semiconductor manufacturing are the combination of mineral and chemical elements resulting from complex fabrication processes. Almost all the elements of the Mendeleev periodic table are used in the semiconductor and electronics industry. A study reports [6] that in South Korea, 12 semiconductor plants used 345 different chemical products and constituents among which several were carcinogen. The environmental performance web page of Ocotillo Intel Corp plant in Arizona [7] provides us some quantitative information. For instance, during Q1 2023, the factory generated 11 tons of waste among which 53% were hazardous.

MINING AND RESOURCE DEPLETION

Each raw material extraction has a contribution to environmental degradation and its consequences. For instance, Cobalt and Coltan are essential for a large number of electronic components: Cobalt for Batteries, Cobalt and Coltan for semiconductors. In 2023, DRC supplies about 63% of the Cobalt global needs which will grow by 60% in 2025. The consequences in the country are resource depletion, pollution of soils, destruction of gorillas' habitats, illegal exploitation of adults and children in unsafe conditions and financing the guerillas. Moreover, rare earth metals are particularly well known for their high polluting energy-intensive extraction and transformations.

E-WASTE

The demand of the developing countries for second-hand electronic equipment and recycling activities is growing. Therefore, developed countries export their electrical and electronic end of life products to the developing countries. Moreover, for many years, organized crime has been rising in the sector by permitting to circumvent legislation on hazardous material transportation legislation. In 2017, a study [8] from the Basel Action Network, used GPS technology to track 314 pieces of e-waste. It demonstrated that 6% was exported and 37% of these exportations, went from the EU to Africa. In the importing countries, "Waste mountains" disposal pollutes soils, water and air resulting in lands where agriculture is not possible. As a consequence, the country could face impoverishment due to economic development slowdown and food insecurity that can lead to instability. Moreover, the local population is exploited as a low-cost labor for disposal, repair and recycling. Man, women and children, manipulating component wastes that may lead to injuries, inhale toxic smokes when burning plastic to extract copper, gold or other metals. Women and children account for up to 30% of the workforce. As an example, Agbogbloshie's disposal site in Ghana receives 40,000 tons each year mainly

coming from outside Africa. In this site, every day, 5,000 people work as “burner boys” of plastic.

ELECTRONICS INDUSTRY VULNERABILITY

Beside its environmental impact, the electronics industry faces the associated risks towards its dependency on energy for electricity, water and material resources. For example, a 2017 report from ADEME, stated that there was only 12 years left of resources of Antimonies, a material absolutely needed for the industry [9]. As reported by McKinsey [10], the interdependencies and complexity make the semiconductor supply chains vulnerable to climate change issues. The disruption may last for months and the impact can lead to the loss of 200% of yearly profits or 35% loss of revenues. Other industries dependent on electronics are therefore also vulnerable as for the automotive industry.

INTERNATIONAL EFFORTS FOR ELECTRONICS IMPACT

Since 2018, several UN entities have signed a letter of intent to form the UN e-waste coalition, in order to tackle the electronic waste issue. In this context, statistics are provided by the Global E-waste Statistics Partnership (GESP) [11], also in collaboration with the StEP (Solving the E-waste Problem) initiative. Especially, the StEP initiative supports researches and projects for the redesign, reuse, recycling, capacity building and policy for e-waste. The Global E-waste Monitor 2020 [12] provides an overview of statistics of e-waste global, regional and national levels while the Global Transboundary E-waste Flow Monitor 2020 [13] focuses on exportations and importations. Moreover, the international institutions provide solutions and frameworks for policies and regulation, in order to support national developments. As reported by the UN E-waste coalition, 39% of all countries have put in place policies and legislation for the e-waste management. Additionally, the public-private Platform for Accelerating the Circular Economy (PACE), launched by the World Economic Forum in 2017, also addresses the e-waste issue in its report A New Circular Vision for Electronics [14] and where we can find e-waste data and guidelines for transforming the economy to attain the zero-waste objective.

The pollution generated by the electronics industry is addressed by different protocols, agreements and conventions: the Paris Agreement, the Kyoto protocol, the Stockholm conventionor the Basel convention. Besides, transnational corporations actors in the electronics industry must comply with legislation RoHS [15] and REACH [16] legislations, and participate in the efforts with their expertise.

DESCRIPTION OF THE TESTS FOR THE CASE STUDIES

In this article, the last step for China and Apple Inc. analyses permits to assess forces in favor or disfavor of the actors’ Green strategies. Therefore, it will help to confirm or infirm that the electronics industry challenges their efforts for addressing environmental issues by reducing their efficiency, polluting more, impacting environment in other countries by moving away e-waste.

TEST 1, 2 and 3 were defined in accordance with the environmental degradation whereas TEST 4, 5, 6 were defined in accordance with lowering the efficiency of the mechanisms of the governance.

TEST 1: Environmental impact of the electronics.

Can the actor increase the electronics industry’s impact on environment?

This question has to be considered from cradle to grave (including e-waste), from depletion to pollution.

TEST 2: Enabler of globalization of supply chains, communications.

Can the actor accelerate the phenomenon of globalization of supply chains and development of communication infrastructures? And therefore, can it expand globally the electronics industry's impact on the environment?

TEST:3: Society Shaping (driven by digitalization).

Can the actor, through digitalization, shape the society by further increasing the consumption of electronic products?

This can be done by influencing or expanding the use of electronic devices.

TEST 4: Lack of will or transparency (Green washing).

Can the actor use the lack of transparency, as for example Green Washing, or mislead the international community about its efforts in fighting the environmental threat and therefore with a risk of compromising common efforts?

TEST 5: Effect of alliances and partnerships.

Can the actor through its alliances and partnerships be restrained, slowed down in its efforts in fighting the environmental issues?

TEST 6: Technological competition in the electronics industry and digital sovereignty.

Can the actor, competing for power, can further the development of the electronics industry while reducing the efforts for the sustainable development?

CHINA

CHINA'S CHALLENGES

Over the last few decades, China has succeeded its industrial and economic growth. As reported by the World Economic Forum in 2018, China is a manufacturing hub producing 39% of the world electronics and 70% of mobile phones [17]. China has strengthened its essential role in global supply chains that has been shown with the global impacts of its lockdowns during the COVID-19 pandemic. The PRC government has exploited opportunities of EU and US delocalization policies have facilitated China's electronics sector rise. Particularly, liberalization steps through reforms, which permitted the financial system to support the export-oriented manufacturing, have boosted and maintained the industrial sector. It has become the first country for its semiconductor investments which represent 27% of global investments in 2020 [18]. The China's strategy also has global impact as it scales up the trade with other countries' economy. Therefore, these countries develop their electronics industry, like the case of India which has the objective to double the value of its electronics industry by 2026 [19].

In its Made in China 2025 plan, PRC wants to become the first global manufacturer and a country of innovation, especially in the electronics sector [20]. Nevertheless, the country faces challenges for keeping its industry competitive. First, as a drawback of its economic development, Chinese labor is becoming expensive at the global market comparing to other countries as Vietnam and India [21]. Secondly, technical competition is becoming more aggressive. Finally, the environmental issues are the new factors to be taken into account. As the first producer and consumer of coal, the country has generated 33% of the total global CO2e emission in 2021.

Among the main challenges to be addressed by China to reach its objectives, we can mention;

- The Taiwan reunification. This will permit to remove Taiwan as a competitor and significantly increase China's technological and economic power. In particular, Taiwan Semiconductor Manufacturing Company is one of the most valuable companies in the world (ranked in the top 10 in terms of capitalization).

- The One Belt One Road initiative is a way to secure China's access to additional raw material resources located in other countries.
- Its rivalry with the US: Although the US and China are big trade partners, the status of China as the second economic power after the US makes it the principal adversary and a threat for the US. Furthermore, with the expansion of digitalization, China fights for its technological leader position in the Cyberspace. Its companies ZTE and Huawei, own the 5G technology bringing the country a technological competitive advantage. Consequently, China's technology is considered as a National Security threat for the US [22] which has become more aggressive in the economic sphere by sanctioning Huawei and ZTE in 2018. In 2022, the US Department of Commerce's Bureau of Industry and Security has restricted 31 Chinese companies and institutions to obtain high-technology chips [23]. Moreover, the US has maintained closed relationships with Taiwan (economic, military) and can use this advantage in its rivalry with China.

At a national level, the central government has launched several policies which have been also fostered with the increasing rivalry with the US. In 2014, the central government launched the China's National Integrated Circuit Industry Investment (as known as the Big Fund) to support promising start-ups. China's components industry still rely on imports of equipment and circuits. In Jan 2021, in the context of the US sanctions on China, the Ministry of Industry and Information Technology launched its plan 2021-2023 to bolster the electronics industry [24]. The action plan promotes innovation and the development of domestic production of new technologies such as connected vehicles, smart devices and 5G technology products. The aim is to strengthen the position of companies in supply chains and reduce dependency towards foreign products. In this plan, the goal is to increase total sales revenues to Rmb 2.1 trillion by 2023.

In September 2022, the General Office of the State Council approved an institutional reform with the aim of facilitating innovation, enhance market vitality, improve standards and high-quality development of electrical and electronics industry. Above all, improvements will address certification and license mechanisms for reducing the delay in the processes for approval. Moreover, R&D import and export tax system will be improved to facilitate the cross border of e-commerce.

Finally, in 2023, cash incentives and policy support are doubling and increasing the domestic semiconductor industry in order to be self-sufficient and ensure China's sovereignty. For example, in Lishui city (eastern Zhejiang), if the annual revenue of a chip design company exceeds from Rmb20 million to Rmb500 million, the government will give respectively from Rmb300,000 to Rmb5 million yuan in subsidies. Another example is the Shenzhen attracting policy which gives Rmb30 million cash reward to top chip companies.

CHINA'S ELECTRONICS ENVIRONMENTAL IMPACTS

PRC has an important responsibility in resource depletion for global electronics. In 2023, among the 50 critical raw materials identified by the EU, 10 are only provided by China [25]. In particular, the country provides 90% of Rare Earth metals used in all electronics and 60% of Lithium used mainly for batteries. Moreover, mining and extraction for these materials are large contributors of China's responsibility in the greenhouse gas emissions. With "Reducing poverty" and "Improving financial stability", "Fighting pollution" is one of the "three tough battles" of the President Xi Jinping [26].

China is the second producer of e-waste after the US. Its population, industries and infrastructure make it one of the largest consumers of electronic products. The e-waste ends up in open landfills or is further sent to other

countries in Southeast Asia. In 2019, 10.12 Mt of e-waste were generated in the country (7.2 kg/capita) with only 1.54 Mt collected. In 2020, the e-waste was generated by 800 million units of electronic products [27]. Moreover, China is both an exporter and importer of e-waste. The area of Guiyu in China [28] is one of the largest e-waste recycling hub, competing with Agbogbloshie in Ghana. In addition to domestic e-waste transferred to this location, it receives millions of tons of imported e-waste from developed countries (US, Europe). In 2020, more than 100,000 people processed 150 to 300 million of e-waste annually.

CHINA'S E-WASTE GOVERNANCE

Since 2009, policies have restricted imported e-waste and today most of the e-waste is generated domestically. Nevertheless, informal e-waste transnational trade results from the contradictions of legislations and heterogeneity of the waste collected.

In 2012, Guiyu was identified as a priority with the "Comprehensive Remediation Scheme of Guiyu e-waste Pollution" 2013 and Circular Electronics in China project was launched in 2017. This project involves the Platform for Shaping the Future of Global Public Goods of the WEF, the Platform for Accelerating the Circular Economy (PACE), and the Danish International Development Agency (Danida). In this project private and public entities collaborate in order to support companies to attain the objective of reducing and recycling 50% of e-waste by 2025 [29].

The public-private collaborations between the China Association of Circular Economy (CACE) and China National Resource Recycling Association involve transnational corporations such as Dell, Oppo, Xiaomi, Siemens, Huawei with the aim of providing policy recommendations for a circular economy.

The current e-waste management system in China is focused on management, treatment and subsidies, treatment standards, auditing and implementation, and the institutional reform launched in September 2022 is taking into account the e-waste issue, and will give support to the development of e-waste and recycling. Improvement in the systems is expected using Artificial Intelligence, big data and online real-time monitoring.

As the first producer and ownership of Electrical Vehicles (EV), China faces the challenges of EV batterie recycling. The Measures for Echelon Utilization of Power Batteries of New Energy Vehicles and Interim Measures for the Administration of Recycling and Utilization of Power Batteries for New Energy Vehicles 2018 deals with this issue.

E-WASTE PROJECTION

We perform calculations to assess the China's electronic waste projection for 2025 and 2050. We are interested about the remaining electronic waste which will continue to pollute the environment. In other words, the part of the end-of-life electronic products which is not collected and recycled, and, additionally the part from which any material to be reused is recovered. As a starting point for the trends, we exploit the 2019 quantity of e-waste provided by the Global e-waste Statistics Partnership (GESP). The calculation we propose is the following:

- e-waste not recycled = e-waste generated x (1-recycling rate);
- e-waste not recovered = e-waste recycled x (1-recovering rate);
- Remaining e-waste = e-waste not recycled + e-waste not recovered

with recycling rate = quantity of recycled e-waste / generated e-waste and recovering rate = quantity of material recovered / quantity of e-waste recycled.

To calculate the projected electronic waste generated by a population, first we calculate the e-waste generated per capita. Then, we use the formula

proposed in 2017 by Kush and Hills [30], who have demonstrated that the quantity of e-waste is correlated with GDP PPP growth:

- e-waste generated per capita - GDP PPP * 0.5 kg per 1000.

Then, we calculate the volume of e-waste generated by the population with the following calculation:

- e-waste generated by the population = e-waste generated per capita * population.

Finally, we can calculate the range for the accumulated remaining e-waste, from 2025 to 2050:

- best_case = min (remaining e-waste for 2025; remaining e-waste for 2050) x 25 years;
- worst_case = max (remaining e-waste for 2025; remaining e-waste for 2050) x 25 years;
- range of accumulated remaining e-waste from 2025 to 2050 = [best_case; worst_case].

Table 1

China: E-waste Projections

	2019	2025	2050
Population	1 400 170 000 (1)	1 409 170 000 (2)	1 313 000 000 (2)
GDP PPP (k$)		26,54 (2)	26,54 (3)
E-Waste generated (kg) per capita	7,20 (1)	13,27	13,27
E-Waste generated (Ktons)		18 700	17 424
E-waste generated (number of Eiffel tower)	1 003	1 851	1 725
Recycling rate (4)	16% (1)	50%	90%
E-Waste Recycled (Ktons)	1 621	9 350	15 681
Remaining E-Waste (Ktons) after recycling	8 508	9 350	1 742
Recovery rate (5)	90%	90%	90%
E-Waste Recovered (Ktons)	1 459	8 415	14 113
Remaining E-Waste (Ktons) after recovering		935	1 568

Total Remaining E-waste (Ktons)	8 670	10 285	3 310
Total Remaining (number of Eiffel tower)		1 018	328

Sources: GESP, available at: https://globalewaste.org/ (Accessed 05 July 2023) (1); IMF, available at: https://www.imf.org/ (Accessed 05 July 2023) (2).

From our calculations, the result of the accumulated remaining e-waste during 25 years is: from 2025 to 2050 is [10,285 Ktons * 25; 3,310 Ktons * 25] = [82 Mt; 257 Mt]. To have an order of magnitude, we compare the results with the weight of the Eiffel tower (10.1 Ktons) like the World Economic Forum in its 2019 report.

It will be equivalent to 8,194 Eiffel towers in the best case, and to 25,457 Eiffel towers in the worst case. Therefore, even if the e-waste quantity will diminish after successful policies, the remaining e-waste is expected to remain significant in the mid and long term.

Table 2

China: Forces in favor and disfavor of the environment

In favor of the environment	In disfavor of the environment
TEST 1: Environmental impact of the electronics.	
- Importations of e-waste from developed countries have been reduced. - Strong willingness of the Chinese government to strictly apply policies (punishment and incentive). - Rise of legislation concerning EV batteries and use of recycled material.	- The 2025 plan will boost the electronics industry. - The GDP growth and consequently the consumption of the population as calculated for the e-waste. - The raise of electronic Vehicles increases the issue of EV batteries challenge.
TEST: 2 Enabler of globalization of supply chains, communications.	
- The need of a renewable energy for manufacturing as a choice criterion for manufacturers can accelerate China's energy transition.	- The development of 5G and Five years plan will challenge the objectives. - After the COVID-19, China has to relaunch its economy with surpassing its emissions attaining 33% of the global emissions in 2021. China's industrial development scales up the industrial development of other countries.

TEST 3: Society shaping (driven by digitalization).	
- Digitalization will permit to build broader awareness to the environmental issue and accelerate implementation of policies. - This can be fostered by the efficiency of the government through its authority.	- Policies are increasing for domestic production and exportations of 5G, connected products will increase electronics' environmental impacts.
TEST 4: Lack of will or transparency (Green washing).	
- Governance is based on audit of system and results of recycling. - E-waste legislation encourages formal channels for recycling (finance). - There is a growth of formal companies' registration.	- The efforts in the development of renewable energies and e-waste recycling can hide the real impacts of the electronics industry.
TEST 5: Effect of alliances and partnerships.	
- The collaboration between leaders for the e-waste issue to set standards (WEF/PACE working group).	- Partnerships with other countries can bolster their development of electronics' manufacturing.
TEST 6: Technological competition in the electronics industry and digital sovereignty	
- Competition can lead to new constraints and legislation in favor of the Green Economy.	- The competition between the US and China will foster Electronic Production. - With the future Taiwan reunification, the impact of the semiconductor and electronics industry will grow. - The rivalry with the US increases policies to stimulate growth of the domestic electronics and semiconductor industry.

Source: compiled by the author.

APPLE

APPLE'S CHALLENGES

Competition at the global stage: through its equipment, operator services and software applications, Apple Inc. plays a major role in the digital economy. Moreover, from the manufacturing point of view, as an Original

Equipment Manufacturer, Apple is at the center of a global supply chain network of suppliers and sub-contractors. The current expansion of Apple is both a factor and a consequence of the development of the digital economy and globalization. In August 2022, it had accounted for 7.3% of in the S&P 500, the highest weighting for any company since 1980 [31]. Apple competes, not only with other GAFAM companies (Google, Facebook, Amazon, Microsoft) for operating systems and web-browsers, but also with other companies for other markets addressed by its products. For instance, Apple is a major key player in the smartphone market: in 2022, the iPhone generated 52% of its revenue, fighting with Samsung for the TOP1 position [32].

Legislation: reaching standard level in the market satisfying the countries' legislations is a necessity to keep technical leadership and market position. Non-compliancy and change in legislation can have negative consequences. As for an example, Apple will struggle to change its iPhone ports in USB-C in order to be compliant with new legislations issued by the UE and India [33]. In order to meet the requirements, the company needs to redesign parts of the product and transform its supply chain. This will result in additional costs and delays.

Reputation: as a powerful corporation, Apple's behavior and corporate social responsibility are particularly in the center of the attention. For this reason, keeping a good reputation is a major challenge for Apple which has to ensure its image and identity. Apple is responsible for the well-being of its suppliers' workers. Sometimes, Apples faces subcontractors' issues that can threaten its business. As for example, in China, its supplier Foxconn, in October 2022, due to COVID-19, forced thousands of employees in Zhengzhou to be in lockdown in the plant and continue working for seven days [34]. Moreover, as other transnational corporations, Apple faces criticism for its Green Washing [35] as it misleads information on its environmental impact and policy.

Vulnerability and Opportunities in Geopolitical Tensions: as a technology leader and global manufacturer, Apple is impacted by geopolitical tensions. Tensions between states can impact sales market and supply chains. In March 2022, Apple decided to stop its activities in Russia complying with the response of the West to the Russian Operation in Ukraine. As a result, the loss of revenue is estimated at $2.5 million/year [36]. Despite the geopolitical tensions between US and China, Apple struggles to keep good relationships with China: in October 2022, one smartphone out of four sold in China was an iPhone [37]. The country market represents 19% of Apple's revenue in 2022. Furthermore, a large part of Apple's supply chain is located in China: in March 2023, the CEO of Apple, Tim Cook, visited China's Development Forum in Beijing with the aim of maintaining good relationships [38].

Beside negative effects of geopolitical tensions, positives effects can appear. As for instance, Apple's global market share has grown as a consequence of US sanctions against the Chinese company Huawei: in January 2022, Huawei, weakened by the sanctions, was positioned at the 9th place [39] although in 2018, the Chinese brand was the 1st provider before Apple [40].

APPLE'S GOVERNANCE FOR PROFITABILITY IN THE ELECTRONICS INDUSTRY

From the market point of view, Apple uses a wide range of mechanisms to keep its global position and get market opportunities. Here under we highlight some mechanisms used.

Marketing: Apple is well known for its successful marketing strategy and technical innovation. Numerous internet websites, such as Forbes [41], provides the basic lessons learned from its strategy and how Apple's product marketing is efficient. Especially, Apple accomplishes building and maintaining brand attachment with customers. By influencing the customer with its identity,

and the creation of a community, Apple ensures a sustainable competitive advantage.

Technology: Apple uses technology innovation as a driver to provide new experiences to the customer. In 2021, the BBC media reported that Apple had acquired 100 companies over six years [42]. By choosing a strategy of acquisition, Apple ensures early access to new technologies and therefore owning them. As a technological leader and its marketing, Apple has shaped the society by succeeding to create communities and new behaviors through Apple stores and Apple applications.

Lobbying: Anticipating new standards is a competitive advantage and the strategy towards legislation is critical for Apple. Lobbying permits Apple to influence legislation. As an example, in March 2023, Foxconn and Apple succeeded to change in their favor Karnataka state of India labor legislation [43]. From 2021 to 2022, the Apple lobbying budget increased by 44% to reach $9.4 million for the year 2022 [44].

Alliances, Partnerships and Collaboration: Apple uses alliances, partnerships with other companies or collaborations with laboratories or universities to benefit from best practices, common learning, or simply to gain power or accelerate its progress. For example, in 2019, Apple announced its Alliance with Amazon, Google and Zigbee to define smart home devices standards [45].

Environmental Governance: On the one hand, Apple has to comply with Green legislation to ensure its business continuity (like RoHS, and REACH, or other local legislations for e-waste as we have seen for China). On the other hand, it needs to reassure its customers which feel more concerned about environmental issues. Therefore, Apple governance and strategy towards environmental issues can be found in its 2022 environmental progress report [46]. In this report, Apple presents its willingness to take care about the environment stating its commitment and transparency. Here are some examples of Apple's actions:

- Apple has joined the RE100 initiative with the objective to use 100% renewable electricity worldwide (in 2021, Apple's total emissions were 23.3 million tons).
- Apple listens to stakeholders (suppliers, customers, employees, industry partners and investors) and is keen to share best practices. In particular, it shares knowledge, collaborates and partners with other actors (academia, intergovernmental organization, scientific communities, other business entities) from diverse countries (including US, Europe and China).
- Apple is a part of coalitions and partners in order to create standards, tools and opportunities in the Green Economy. In that way the company can influence the change in the industry engaging itself in initiatives. For example, Apple has developed a new standard the "IPC1402" (Green cleaners) in collaboration with 20 other companies. Apple is also part of First Movers Coalition, a private partnership launched by the US and the World Economic Forum with the aim of creating market demand in low-carbon technology.

Moreover, Apple informs its customers making them aware of the environmental impact of its products as for example the 2022 iPhone 14 Product Environmental Report which demonstrates their progress showing that the iPhone14 generates less CO2e emissions (61 kg) through its life cycle than the iPhone13 (64 kg).

CALCULATIONS

Here we propose to make some basic calculations and reasoning for evaluating Apple's Green Washing and its remaining environmental impact after implementation of its governance and measures.

IPHONE 14 CARBON FOOTPRINT

Here we propose to calculate the iPhone 14 Carbon Footprint by using the information provided by iPhone 14 Product Environmental report. The report states that one iPhone 14 smartphone generates 61 kg of carbon emissions in its lifecycle. Moreover, in November 2022, Bloomberg reported that Apple had lowered its production by 3 million and, therefore, the final number of iPhone 14 to be produced was 87 million units (instead of 90 million) [47]. Then, we are able to calculate the CO2 emissions for the total number of devices produced:

- iPhone 14 total carbon emission = single iPhone 14 lifecycle carbon emission * total units produced;
- iPhone 14 total carbon emission = 87 million of units * 61 kg/unit;
- iPhone 14 total carbon emission = 5.3 million tons.

As a result, the iPhone 14 will generate globally a total of 5.3 Mt of CO2e emissions.

However, Apple has the ambition to move all its iPhone 14 manufacturing supply chain using 100% renewable energy. From the Apple's report, the manufacturing represents 79% of its emissions. Therefore, 21% of its emissions will remain. Consequently, here is the quantity of carbon emissions of the iPhone that we can expect after the success of this strategy:

iPhone 14 manufacturing supply chain using 100% renewable energy.

- 21% * 5.3 Mt = 1.1 Mt of CO2

Nevertheless, as raised previously, Apple has more than hundred suppliers in 43 countries. The countries' location that could be, at least involved in the process steps, components and subcomponents of the iPhone 14 are: US, China, Malaysia, Philippines, Japan, Vietnam, India.

- All these countries do not have appropriate legislation or infrastructures for renewable energy.
- Moreover, before changing their fabrication processes, the suppliers should have access to renewable energy and technically define, implement and validate the change. First, expertise is needed, secondly this implies significant costs and delays (several months) that can impact its other customers and/or simply impact its business.
- However, Apple has just announced that it has moved part of its iPhone production to India and expected that it would reach 25% of its total production in 2025 [48]. Although we can imagine that the production in India use renewable energy, the production phase to be performed in the country is the assembly of the final product which is the process step generating less CO2 emission).

From our point of view, the "move all its iPhone 14 manufacturing supply chain using 100% renewable energy" is a non-realistic target.

IPHONE 14 E-WASTE

To calculate the electronic waste generated by the iPhone 14 series, we use data from the Apple's website to have an average weight of one iPhone 14. The website provides a weight from 172 g (iPhone 14) and 240 g (iPhone 14 Pro Max). Therefore, we use the mean which is approximately 207 g. Then, we obtain the electronics waste generated by the iPhone 14 series by multiplying the weight by the total number of units produced.

Total E-Waste generated by iPhone 14 = iPhone weight * total units produced

Total E-Waste generated by iPhone 14 = 0.207 kg * 87 million units = 18 million kg.

This gives us 18 Ktons of E-Waste equivalent to more or less 1.8 Eiffel towers.

Table 3

Apple: Forces in favor and disfavor of the environment

In favor of the environment	In disfavor of the environment
TEST 1: Environmental impact of the electronics.	
- Apple has defined strategy and governance to reduce its CO2 emissions also through its suppliers. - Apple uses recycled materials in its products. - Apple has smarted chemistry strategy.	- The Objective of CO2 emissions reduction is non-reachable. - Furthermore, the electrification using renewable energy has an environmental impact. - The rate of use of recycled material is still too low. - Apple is more focused on the cleaning than the manufacturing of the components.
TEST: 2 Enabler of globalization of supply chains, communications.	
- The implementation of technical Green solutions developed by Apple can be rapidly spread into communication infrastructures or devices used for communications.	- As a technological leader, Apple permits the globalization of communications and infrastructure to expand.
TEST 3: Society shaping (driven by digitalization).	
- Apple can influence large populations and promote the Green Economy through its community	- Apple can drive a large number of people for its profitability interests prior to environmental issues.
TEST 4: Lack of will or transparency (Green washing).	
- With Green Washing, Apple simplifies things by informing the customer at a level of understanding addressing a wide range of people making them feel more concerned about the environmental issue.	- Apple is performing Green Washing that misleads the customer and the real impact of its products. - Apple use the environmental issue to make its reputation positive with the aim of making its products more attractive, and gaining market shares that results in increasing its production.
TEST 5: Effect of alliances and partnerships.	
- Coalition with other stakeholders can further the definition and implementation of technical solutions and standards for the Green Economy. - Apple participates in initiatives that increase expertise and education.	- By owning expertise and means of influencing, Apple favorizes its interests that can be a threat for governments. - Business competition leads to Green standards that can be biased and too constraining for other companies.

TEST 6: Technological competition in the electronics industry and digital sovereignty	
- Under the pressure for Digital Sovereignty, Apple is encouraged to produce locally. - Facing the issue of resource depletion that can threaten its product deliveries, Apple accelerates the race to recycling solutions.	- Apple is vulnerable to geopolitical tensions and is part of the technical competition between states and faces other issues (loss of market shares, shortages in supply chain) that can be more important than the environmental challenge. - Apple cannot transform rapidly its supply chain as it is complex. - Market competition for recycling may lead to not disclose green innovation to other stakeholders and delays the common fight against environmental issues.

Source: compiled by the author.

OUTCOMES AND CONCLUSION

In this article we presented how the electronics industry impacts the environment.

The case studies of China and Apple Inc. enabled us to understand the different factors and the complexity that they have to address in their strategies of developing the electronics industry while coping with the environmental issues.

Here the main outcomes:

Until now, policies of the Chinese government have been effective in developing its electronics industry, reinforced by the competition with the US. Its development drives the electronics industry and the digitalization development of the other countries. However, conscious of the environmental impact, the Chinese government rapidly implements policies in favor of the environment in particular for the e-waste issue.

Apple Inc. has to anticipate and comply with the environmental legislation while it has to influence it in order to expand its business globally, and therefore increase the environmental impact of its products.

In their governance, the two stakeholders show their willingness of using renewable energy and recycled materials. However, the magnitude of the trends of e-waste and greenhouse gas emissions obtained from the calculations, after successful policies, demonstrate that the electronics industry will continue to have a significant impact on the environment.

This study showed how the sovereignty and the fight for technical leadership can challenge the efforts for fighting against environmental issues and balance for more industrial development.

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