Decarbonizing the Electronics Industry to Achieve Net Zero (2024)

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Abstract—**The electronics industry, a vital pillar of modern society, faces substantial challenges in its path to achieving net-zero emissions by 2050. Central to this effort is the need to decarbonize the entire supply chain. This article explores the complexities associated with collecting primary emissions data from both manufacturing processes and supply chain partners. It emphasizes the importance of primary data over secondary data, which only provides industry averages that are insufficient to achieve a net-zero target. The discussion looks at technological advancements, collaborative strategies, and policy measures required to transform the electronics industry into a net-zero industry.**

Index Terms—**Carbon emissions, carbon footprint, carbon neutral, environmental, supply chain, sustainable development.**

I. INTRODUCTION

THE electronics industry has become an integral part of modern life. It is the basis for the operation of smartphones, computers, medical devices, and numerous other technologies. And its dissemination is expected to further increase, according to the European Chips Report, the future chip demand across industrial ecosystems is expected to double between 2022 and 2030 [1]. However, the manufacturing processes, the extensive supply chain, and the electricity demand during the use phase generate high levels of carbon emissions. As part of the global community's efforts to combat climate change, the electronics industry faces the daunting task of achieving net-zero emissions by 2050. This goal requires a comprehensive approach that includes reducing emissions in manufacturing, improving transparency in the supply chain, and innovating energy-efficient technologies. The focus of this article is how transparency about supply chain emissions can be achieved and how supply chain emissions reduction can be managed.

A. Understanding Net-Zero Targets and Their Meaning

Net-zero targets refer to the balance between the amount of greenhouse gases (GHG) emitted into the atmosphere and the amount that is removed or offset, resulting in a net-zero carbon footprint. These targets are critical to mitigating climate change and preventing global temperatures from rising to dangerous

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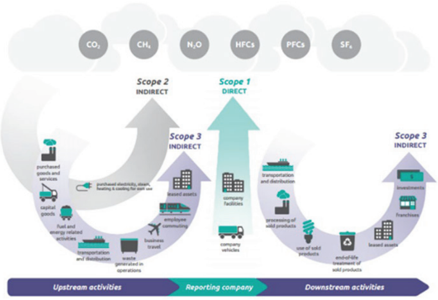

Fig. 1. Overview of scopes and emissions across a value chain [3].

levels. Achieving net zero requires reducing emissions as much as possible and offsetting the remaining emissions through compensation strategies such as reforestation or carbon capture and storage. Net-zero targets are important because they provide governments, businesses, and organizations with a clear and measurable goal to work toward to ensure that efforts to combat climate change are coordinated and effective. By committing to net-zero emissions, companies demonstrate their commitment to sustainability, reducing the impact of global warming and protecting the environment for future generations [2].

"The Greenhouse Gas Protocol" supplies the most widely used GHG accounting standards and guidance. It defines which GHGs are to be considered and structures GHG emissions in direct emissions (Scope 1), indirect energy related emissions (Scope 2), and indirect supply chain emissions (Scope 3 upstream and Scope 3 downstream) [3]. See Figure 1 for the overview of scopes and emissions across a value chain.

The terms "carbon neutral" and "net-zero" are often used interchangeably, but they have distinct meanings and implications.

Carbon neutrality typically covers only a defined part of business operations, e.g., Scope 1 and Scope 2, and means that any carbon dioxide released into the

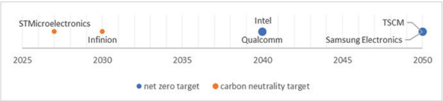

Fig. 2. Net-zero/carbon neutrality target dates of selected chip manufacturers [5][6][7][8][9][10].

atmosphere from a company's activities is balanced by an equivalent amount being removed or offset. This can be achieved by purchasing carbon credits that support renewable energy projects, reforestation, or other carbon offset initiatives.

Net-zero emissions means that a company includes all its GHG emissions across its whole supply chain (Scope 1, Scope 2, and Scope 3) to as close to zero as possible, and any remaining emissions are balanced out by removing an equivalent amount of GHGs from the atmosphere. [4]

Figure 2 illustrates the climate targets of some leading semiconductor manufacturers as of May 2024. Several companies are aiming for a net-zero target for 2050. Others have committed to carbon neutral goals.

B. Importance of Primary Data

Secondary data related to GHG emissions refers to information previously collected and published by other sources. This data is usually aggregated and available through various platforms, including industry reports, government publications, and foremost life cycle assessment databases such as Ecoinvent and GaBi. Secondary data provides industry averages, general trends, and benchmark values in terms of GHG emissions from different sectors, processes, and activities. Although widely used, it does not capture the specific emissions of individual suppliers, processes, or products. Therefore, while secondary data can be valuable to understand general patterns and establish a baseline, it is insufficient to achieve precise and targeted emission reductions required for net-zero targets.

Primary data is company-specific data collected from individual suppliers. Accurate primary data is essential for identifying emission hotspots and implementing targeted reduction strategies [11].

C. Corporate Carbon Footprint vs. Product Carbon Footprint

When accounting for GHG emissions, a distinction is generally made between two basic approaches: The corporate carbon footprint describes the GHG emissions of a company as a whole. The product carbon footprint (PCF), on the other hand, comprises product-specific emissions, i.e., emissions that can be directly attributed to a product [11]. To calculate carbon emissions along the supply chain, it is required to exchange PCF at every step of the supply chain.

II. EMISSIONS FROM OWN MANUFACTURING

The first major challenge in decarbonizing the electronics industry is for companies to accurately measure and reduce emissions from their own manufacturing processes. These emissions come from various sources, including the direct consumption of fossil fuels and electricity consumption.

A. Energy Consumption in Manufacturing

Production facilities in the electronics industry are generally highly automated and rely heavily on electricity. Especially cleanrooms consume large amounts of energy compared with non-classified rooms; scientific literature and experience in the field show that cleanrooms use up to 25.3 times more energy (1.25 kW/sqm vs. 0.06 kW/sqm). The energy requirement of HVAC systems usually amounts to 50%–75% of electricity consumption in a clean production space due to the high airflow rates needed for particular ISO classes [12]. But also processes such as soldering, etching, and assembly are energy-intensive. The production of printed circuit boards (PCBs), for example, involves several steps that consume energy, such as laminating, drilling, and coating.

B. Strategies for Reducing Emissions

Technological Advancements in Manufacturing

To mitigate these emissions, the industry is exploring various technological advancements. These include the development of more energy-efficient fabrication techniques, e.g., STMicroelectronics has reduced its energy consumption per unit of production by 56% since 1994 [13].

Renewable Energy Sources

The use of renewable energy sources is a widely used method to reduce carbon emissions. Apple, for example, has committed to powering all of its facilities with 100% renewable energy and has already achieved this milestone for its corporate offices, data centers, and retail stores worldwide [14]. However, it is important to understand that due to the fact that Apple’s manufacturing is outsourced to third-party suppliers, the manufacturing facilities are not included in that renewable energy claim.

Product Design

In many products, the rigid PCB also primarily fulfills a mechanical function, which simplifies the product design but worsens the GHG balance. Sometimes up to half of the PCB area is used merely to bridge a gap between two pole connections, for example. Alternative approaches to secure fixing and contacting could significantly improve the GHG balance.

Advanced Cooling Technologies

Innovation in advanced cooling technologies is another key area. Traditional cooling methods for semiconductor manufacturing facilities are energy-intensive. Newer methods, such as immersion cooling and more efficient HVAC systems, can significantly reduce energy consumption.

Materials Science Innovations

Advancements in materials science are also contributing to lower emissions. Researchers are developing new materials that require less energy to produce and have better electrical properties, which can reduce the overall energy consumption of electronic devices. For instance, gallium nitride semiconductors are more efficient than traditional silicon semiconductors and are increasingly used in power electronics.

III. SUPPLY CHAIN EMISSIONS

In order to accurately calculate the environmental impact of electronic products, it is essential to determine the PCF. This calculation requires a comprehensive analysis of the upstream supply chain for all suppliers and sub-suppliers. The different stages of the upstream supply chain are referred to as Tier 1, Tier 2, Tier 3, etc., starting from the original equipment manufacturer. Figure 3 shows an example of an upstream supply chain.

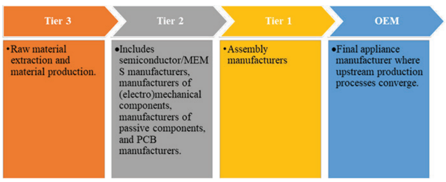

Fig. 3. Exemplary upstream supply chain.

Understanding these stages and the associated emissions is crucial for calculating the PCF and achieving net-zero targets.

A. Complexity and Lack of Standardization

Collecting primary emissions data from the supply chain is a complex challenge. The electronics supply chain is global and involves multiple tiers of suppliers spread across different regions with different environmental regulations and levels of transparency. The lack of standardized calculation and reporting practices increases the difficulty of obtaining accurate emission data. If PCF calculations are not comparable between different manufacturers and if there is not a standardized reporting template, the efforts for companies along the supply chain are tremendous; that is why as of today, only very few companies actually provide PCF data.

B. Initiatives to Improve Transparency

Partnership for Carbon Transparency

The Partnership for Carbon Transparency (PACT), initiated by the World Business Council for Sustainable Development aims to enhance transparency and decarbonization in the supply chain by enabling the secure and standardized exchange of product-level emissions data across organizations. The Pathfinder Framework [15] developed by PACT provides guidelines for calculating and exchanging primary-data-based PCFs, improving data reliability and consistency across value chains. This initiative also involves collaboration with technology providers like Siemens, SAP, and CircularTree to create interoperable solutions for data exchange, thus fostering transparency and accountability in corporate climate action.

Industry Initiatives

Addressing the emission challenges in the electronics industry requires a collaborative approach. Companies must work closely with their supply chain partners to ensure transparency and consistency in emission reporting. Industry-wide initiatives, such as those led by the Japan Electronics and Information Technology Industries Association (JEITA), are crucial for fostering cooperation and setting standardized practices across the sector. JEITA focuses on promoting sustainable development and environmental management in the electronics industry, advocating for standardized reporting practices and collaborative efforts to reduce emissions throughout the supply chain.

C. Workflow for PCF Transparency and Reduction

CARE Decarbonization Cycle

The key to practical transparency and decarbonization is efficiency. Only if companies, especially small- and medium-sized companies, get the opportunity to achieve transparency and decarbonization with a reasonable effort, the targets can be achieved. To empower companies to do this, CircularTree has developed the CARE decarbonization cycle. This approach enhances supply chain transparency and facilitates a gradual path to decarbonization. The process begins with uploading a bill of material and a hotspot analysis using secondary data to identify key suppliers and components with significant emissions. These identified suppliers are then prioritized for requesting primary data. By obtaining and utilizing this primary data, reduction targets can be established collaboratively. This method continuously refines the PCF by

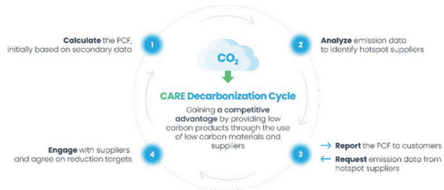

Fig. 4. CARE decarbonization cycle.

progressively replacing secondary data with primary data and implementing agreed-upon reduction targets. As the primary data share increases, the accuracy and value of the PCF improves. The steps of the *CARE* decarbonization cycle as illustrated in Figure 4 include:

1. *Calculate* the PCF, initially based on secondary data
2. *Analyze* emission data to identify hotspot suppliers
3. *Report* the PCF to customers *Request* emission data from hotspot suppliers
4. *Engage* with suppliers and agree on reduction targets

IV. POLICY MEASURES

A. Regulatory Frameworks

Government policies play a crucial role in driving the decarbonization of the electronics industry. Regulations that mandate emission reporting and set stringent emission reduction targets can compel companies to adopt greener practices. For instance, the European Union's Green Deal aims to make Europe climate neutral by 2050 and includes measures to reduce emissions from the electronics sector.

Incentives and Penalties

Incentives for using renewable energy and penalties for high carbon footprints can further accelerate the transition to net zero. Governments can provide tax breaks, grants, and subsidies for companies that invest in renewable energy projects and energy-efficient technologies. Conversely, imposing carbon taxes on high-emission activities can encourage companies to reduce their carbon footprint.

B. International Agreements

International agreements, such as the Paris Agreement, also influence the electronics industry's approach to decarbonization. These agreements set global targets for emission reductions and encourage countries to implement policies that support sustainable practices. Companies operating internationally must comply with these regulations and align their strategies with global sustainability goals.

V. CONCLUSION

Achieving net-zero emissions in the electronics industry by 2050 is crucial due to its significant environmental impact. A multitude of strategies by all companies in the industry needs to be put in place to achieve this target. It requires technological innovation, both in product design and manufacturing technology, as well as improved supply chain transparency with the widespread use of primary data.

Primary data is essential for pinpointing emission hotspots and implementing effective reduction strategies. Advanced technologies and energy-efficient processes are key to reducing manufacturing emissions.

The global and complex nature of the electronics supply chain necessitates initiatives like the PACT, which enhances data transparency and consistency by setting the appropriate standards. Industry-specific collaborations and standardized reporting practices are vital for achieving reliable emissions data.

Policy measures, including regulatory frameworks, incentives, and international agreements like the Paris Agreement, support these efforts by creating an environment that encourages sustainable practices.

In summary, the electronics industry can achieve net-zero emissions through coordinated efforts that leverage technological advancements, supply chain transparency with primary data and supportive policies, contributing to a sustainable future.

References

[1] European Comission, (2022). European Chips Report. [Online]. Available: https://single-market-economy.ec.europa.eu/industry/strategy/digital-transformation/european-chips-report_en#.

[2] United Nations. (2023). Climate Action – Net Zero Coalition. [Online]. Available: https://www.un.org/en/climatechange/net-zero-coalition#.

[3] World Resources Institute and World Business Council for Sustainable Development. (2004, March). The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard. [Online]. Available: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

[4] World Economic Forum. (2022, August 23). Carbon neutral and net zero – what do they mean?. [Online]. Available: https://www.weforum.org/agenda/2022/08/carbon-neutral-net-zero-sustainability-climate-change/.

[5] STMicroelectronics. (2020, Dec. 09). STMicroelectronics to be Carbon Neutral by 2027. [Online]. Available: https://newsroom.st.com/media-center/press-item.html/c2974.html.

[6] Infineon Technologies AG. (2020, Feb. 20). Infineon to become a carbon-neutral company. [Online]. Available: https://www.infineon.com/

cms/en/about-infineon/press/press-releases/2020/INFXX202002-030.html?redirId=122056.

[7] Intel Corporation. (2023, November 14). Intel Commits to Net-Zero Greenhouse Gas Emissions in its Global Operations by 2040. [Online]. Available: https://www.intel.com/content/www/us/en/newsroom/news/net-zero-greenhouse-gas-emissions-operations.html

[8] Qualcomm Technologies, Inc.. (2021, Oct 31). Qualcomm Announces Goal to Achieve Net-Zero Emissions by 2040. [Online]. Available: https://www.qualcomm.com/news/releases/2021/11/qualcomm-announces-goal-achieve-net-zero-emissions-2040.

[9] Taiwan Semiconductor Manufacturing Company Limited: (2023, September 15). TSMC Accelerates Renewable Energy Adoption and Moves RE100 Target Forward to 2040. [Online]. Available: https://pr.tsmc.com/english/news/3067.

[10] SAMSUNG. (2022, September 15). Samsung Electronics Announces New Environmental Strategy. [Online]. Available: https://news.samsung.com/global/samsung-electronics-announces-new-environmental-strategy.

[11] World Business Council for Sustainable Development. (2023, January). Partnership for Carbon Transparency - Guidance for the Accounting and Exchange of Product Life Cycle Emissions. [Online]. Available: https://wbcsd.github.io/tr/2023/framework-20232601/framework.pdf.

[12] HPCi Media Limited. (2019, Jan. 31). Five forces driving energy efficiency in next-gen cleanroom design. [Online]. Available: https://cleanroomtechnology.com/five-forces-driving-energy-efficiency-in-next-gen-cleanroom-design-151385#.

[13] STMicroelectronics. (2024). We create Sustainable technology in a sustainable way. [Online]. Available: https://www.st.com/content/st_com/en/about/sustainability/sustainable-technology.html.

[14] Apple Inc.. (2018, April 9). Apple now globally powered by 100 percent renewable energy. [Online]. Available: https://www.apple.com/newsroom/2018/04/apple-now-globally-powered-by-100-percent-renewable-energy/

[15] World Business Council for Sustainable Development. (2023, January). PACT: Pathfinder Framework - Guidance for the Accounting and Exchange of Product Life Cycle Emissions. [Online]. Available: https://wbcsd.github.io/tr/2023/framework-20232601/framework.pdf.

[16] CircularTree. (2024). Decarbonization with CircularTree - Reach your net zero goals and optimize your product carbon footprint. [Online]. Available: https://circulartree.com/

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