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Strategies to decarbonize the consumer electronics industry

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Abstract
The electronics industry, a key player in modern society, is critical for the operation of essential devices like smartphones, computers, and medical equipment. However, its environmental impact, driven by energy-intensive production methods, complex supply chains, and high energy consumption during operation, has resulted in significant carbon emissions. The sector contributes notably to global greenhouse gas emissions, with the information and communication technology sector alone accounting for 1.3% of global emissions in 2007. The industry's reliance on finite resources and lack of effective recycling systems exacerbates its environmental footprint. To meet global climate objectives, including the Paris Agreement's goal to limit global warming to well below 2°C, the electronics industry must work towards achieving net-zero emissions by 2050. This involves reducing emissions across production, enhancing supply chain transparency, and adopting energy-efficient technologies. Primary data is crucial in driving these changes, enabling accurate emissions measurement, and guiding targeted interventions. By embracing advanced manufacturing techniques and renewable energy sources, the electronics sector can significantly mitigate its environmental impact, ensuring sustainable growth and contributing to the global decarbonization effort.

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Keywords: Electronics industry, Carbon emissions, Net-zero emissions, Energy consumption

Introduction

The electronics sector plays a crucial role in todays society, underpinning the functionality of devices such as smartphones, computers, and medical equipment. According to the European Chips Report, the demand for chips is projected to double across various industries from 2022 to 2030 (Sekiguchi, 2022) [1]. However, the production methods, complex supply chains, and energy consumption during usage contribute to significant carbon emissions. Reducing carbon emissions in the consumer electronics industry is important because it significantly impacts global emissions and environmental harm.

The electronics industry is one of the most polluting sectors, contributing significantly to global greenhouse gas emissions. For instance, the information and communication technology sector alone accounted for 1.3% of global emissions in 2007, with media electronics contributing even more (Słoma, 2013) [2]. The manufacturing and disposal of electronic devices release harmful substances, including heavy metals and dioxins, into the environment, posing threats to ecosystems and human health (Ritter, 2014) [3]. The operational phase of electronic devices, such as computers and telecommunications networks, consumes a considerable amount of electricity, often derived from fossil fuels, leading to high carbon emissions (Słoma, 2013) [2]. Implementing energy-efficient technologies and processes can significantly reduce the carbon footprint of the electronics industry. For example, the use of photovoltaic power generation and solid-state lighting can decrease energy consumption and emissions (Charles & Sinnadurai, 2008) [4] (Sinnadurai & Charles, 2009) [5]. The electronics industry relies heavily on finite natural resources, and the current rate of consumption is unsustainable. If global consumption patterns mirrored those of the average American, it would require the resources of five Earths (MacKerron, 2011) [6]. The lack of effective recycling and waste management systems for electronic devices leads to the accumulation of e-waste, which is often improperly disposed of, causing environmental harm (Ritter, 2014) [3]. Since the industry's carbon output is driven by energy intensive manufacturing processes and the reliance on fossil fuels. Additionally, short lifespan and limited recyclability of electronic devices leads to higher environmental impacts a manufacturing processes and the reliance on fossil fuels nd depletion of resources. This necessitates the decarbonization of the industry. To address climate change, the electronics industry is tasked with reaching net-zero emissions by 2050. This objective necessitates a thorough strategy that involves minimizing emissions during production, enhancing supply chain transparency, and developing energy-efficient technologies. This paper focuses on how to achieve transparency regarding supply chain emissions and manage the reduction of these emissions effectively.

Net-Zero

Net zero refers to the balance between the amount of greenhouse gases (GHG) emitted into the atmosphere and the amount removed, aiming for a net effect of zero emissions. Net-zero targets are crucial in the global effort to combat climate change. Net zero is achieved when a company balances its GHG emissions with equivalent removals, either through direct reduction or offsetting measures. This is essential to limit global warming to well below 2°C,preferably to 1.5°C, above pre-industrial levels as outlined in the Paris Agreement (Allen *et al.*, 2022) [7]. Emissions are categorized into Scope 1 (direct emissions from owned sources), Scope 2 (indirect emissions from purchased electricity), and Scope 3 (all other indirect emissions in the value chain) (Piacentini & Garro, 2022) [8]. Net zero encompasses all Scopes of emissions. This concept is crucial for mitigating climate change and is a central goal of international agreements like the Paris Agreement. Companies can achieve net zero by implementing a combination of strategies that reduce emissions and enhance carbon removal.

Primary Data

Primary data plays a crucial role in achieving net zero emissions by providing the foundational information necessary for accurate measurement, analysis, and decision-making. It serves as the raw, unprocessed data that is essential for understanding current emissions levels, evaluating the effectiveness of interventions, and guiding policy and technological innovations. Primary data is essential for the accurate measurement of emissions and energy consumption, which is critical for tracking progress towards net zero goals. For example, in the agriculture industry, primary data on energy consumption and carbon emissions from irrigation systems provides insights into the environmental impact of different irrigation practices, enabling the development of more sustainable solutions (Qin *et al*., 2022) [9]. Primary data is fundamental for research and development efforts aimed at achieving net zero. It provides the baseline information needed to explore new technologies and methods for reducing emissions across various sectors (Fraser & Milne, 1990) [10]. The importance of primary data is underscored by its ability to inform various sectors in their efforts to reduce carbon footprints and transition towards sustainable practices. In contrast, secondary data is usually aggregated and can be pulled from industry reports, life cycle assessment databases such as Ecoinvent and Gabi, published literature, etc. Secondary data offers a look at average industry performance, common trends in industry, and is good for benchmarking GHG emissions. Secondary data is often utilized while calculating emissions, however, it does not reflect the specific emissions associated with specific suppliers, manufacturers, specific manufacturing processes, etc. As a result, secondary data can help understand general trends and establish baselines but it cannot provide the detailed information necessary to achieve net zero goals. Accurate primary data is crucial for pinpointing areas with high emissions and for developing focused strategies for reduction.

Tackling emissions from manufacturing

The primary challenge in reducing carbon emissions within the electronics sector is for companies to effectively assess and lower the emissions generated by their manufacturing operations. These emissions arise from multiple sources, such as the direct use of fossil fuels, the consumption of electricity, etc. The manufacturing of electronics is notably energy-intensive, with various processes and components contributing to high energy consumption. This energy demand is driven by the need for precise environmental conditions, complex manufacturing processes, and the rapid turnover of electronic products. Semiconductor manufacturing is particularly energy-intensive, accounting for 1.3%-2% of the total US electricity consumption in the manufacturing sector. Processes such as layering and diffusion are significant contributors to this energy use (Gopalakrishnan *et al*., 2010) [11]. In a case study of a MEMS fabrication facility, it was found that 270 kWh of electricity were required per six-inch wafer, highlighting the substantial energy demand of semiconductor production (Branham & Gutowski, 2010) [12]. The manufacturing of ICs, essential for ICT devices, involves high cumulative energy demand (CED), ranging from 9 to 38 MJ/cm². (Nagapurkar & Das, 2022) [13]. The global energy demand for IoT semiconductor manufacturing is projected to increase significantly, from 2 EJ in 2016 to 35 EJ by 2025, driven by the production of energy-intensive components like sensors and processors (Das & Mao, 2020) [14].

Strategies to address these emissions

Reducing emissions from high energy consumption in electronics manufacturing is a multifaceted challenge that requires a combination of innovative manufacturing techniques, energy management systems, and the adoption of renewable energy sources. The integration of these strategies can significantly mitigate the environmental impact of electronics manufacturing, which is crucial for achieving sustainability goals.

Advanced Manufacturing Techniques

Advanced manufacturing techniques offer promising solutions to reduce emissions from high energy consumption in electronics manufacturing. Additive manufacturing, including 3D printing, inkjet printing, and other advanced printing technologies, allows for precise material deposition, reducing waste and energy consumption compared to traditional subtractive methods. These techniques enable the production of electronic components with minimal material usage and fewer processing steps, leading to lower energy requirements and emissions (Altay *et al*., 2020) [15]. Process performance simulators and parametric optimization techniques can further enhance energy efficiency by optimizing machining parameters, reducing energy consumption, and minimizing carbon emissions. These methods focus on achieving a balance between product quality, energy use, and cost, promoting sustainable manufacturing practices (Khan *et al*., 2021) [16]. Implementing methods that enhance the energy efficiency of manufacturing processes, such as the use of vacuum chambers to reduce surface pressure during PCB coating, can lead to significant energy savings and emission reductions (Yuanxiong, 2017) [17].

Renewable Energy Integration

Integrating renewable energy into electronics manufacturing can significantly reduce emissions associated with high energy consumption. This transition not only addresses the environmental impact but also enhances the sustainability of manufacturing processes. Solar photovoltaic (PV) systems are a viable solution for reducing emissions in electronics manufacturing. They can be integrated into manufacturing facilities to provide a substantial portion of the energy required, thereby decreasing reliance on fossil fuels. For instance, a solar-based co-generation system can meet the electricity needs of semiconductor wafer fabs, making it economically competitive in regions with fewer overcast days (Taboada *et al*., 2012) [18]. Aligning manufacturing energy demand with renewable energy availability can optimize the use of renewable sources. This approach involves adjusting production parameters, such as cutting speed, to match the power supplied by renewable sources like PV systems, thus reducing energy costs and CO2 emissions (Materi *et al*., 2021) [19] (Materi *et al*., 2020) [20]. The integration of battery-super capacitor energy storage systems enhances the sustainability of clean energy load demand. These systems can store excess energy generated from renewable sources, ensuring a stable energy supply and reducing emissions by approximately 0.098 metric tons of CO2 per metric ton of electricity produced (Duan, 2022) [9].

Emission Reduction Technologies

The electronics industry has made progress in reducing emissions of fluorinated compounds (FCs), which are potent greenhouse gases. Implementing cost-effective FC abatement technologies, such as catalytic decomposition and reduction processes, can help achieve significant emission reductions. Electronics manufacturing industries can reduce N2O emissions, a potent greenhouse gas, through catalytic decomposition or hybrid reduction processes. These methods are essential for minimizing the environmental impact of replacing fluorinated gases with N2O (Lee *et al*., 2012) [22].

Product Design

Reducing emissions from the consumer electronics industry through product design involves integrating sustainable practices throughout the product life cycle. This approach not only addresses the environmental impact of manufacturing and disposal but also enhances the overall sustainability of electronic products. Selecting materials that are recyclable and have a lower environmental impact is crucial. The trend towards using recyclable and remanufacturable materials is gaining momentum, as it reduces the need for virgin material extraction and minimizes waste (You *et al*., 2016) [23]. Designing products with modular components facilitates easier disassembly and recycling. This approach not only extends the product's life but also simplifies the recycling process, thereby reducing emissions associated with waste management (Green *et al*., 2019) [18]. Designing products that encourage sustainable consumer behavior can further reduce emissions. The Sustainable Behavior Design (SBD) framework integrates features that promote environmentally friendly usage and disposal practices, potentially reducing life cycle impacts by up to 30% (Komeijani *et al*., 2016) [25]. Providing clear and accessible information on product packaging and labels can guide consumers towards more sustainable choices, such as proper recycling and energy-saving practices (You *et al*., 2016) [23]. The development and use of eco-design tools can aid designers in creating products with reduced environmental impacts. These tools help in assessing and selecting design options that align with sustainability goals, bridging the gap between engineering and ecological considerations. Implementing sustainable design practices at the early stages of product development ensures that environmental considerations are integrated from the outset, leading to more sustainable outcomes (Abdalla & Ebeid, 2011) [26].

Material Science Innovations

Innovations in materials science are crucial in reducing manufacturing emissions in the consumer electronics industry. This sector is a significant contributor to global greenhouse gas emissions due to its reliance on energy-intensive processes and materials. Replacing traditional materials with more sustainable alternatives can significantly reduce emissions. For instance, using materials that require less energy to produce or that are derived from renewable sources can lower the carbon footprint of electronic products. Creating products that are easy to disassemble facilitates recycling and reuse, reducing the need for new materials and the associated emissions. This approach supports a circular economy by enabling the recovery of valuable components and materials (O'Connor *et al*., 2016) [27]. Implementing energy-saving techniques in the manufacturing process, such as improved surface mounting and coating methods, can reduce energy consumption and emissions. These methods enhance the efficiency of production lines and minimize waste (Yuanxiong, 2017) [17]. Developing flexible and reusable electronic components can decrease the environmental impact by reducing the need for new materials and allowing for the adaptation of existing components to new applications (Lehmann & Hamilton, 2010) [28]. Employing strategies such as light-weighting and downsizing of products can lead to substantial emission reductions as well. These strategies focus on using fewer materials without compromising product performance, thereby reducing the overall carbon footprint (Hertwich *et al*., 2019) [29].

Supply Chain Emissions

In order to successfully tackle the total environmental impact of consumer electronics, it is important to calculate a product carbon footprint (PCF). Calculation of a PCF involves a detailed analysis of the suppliers present in the entire supply chain. As mentioned before, collection of primary data is key in order to accurately calculate the PCF. However, collecting primary data is a complex challenge as the supply chain for consumer electronics is spread out worldwide and involves multiple tiers of suppliers. Another challenge is the lack of standardization in calculations and reporting of environmental data which further increases the difficulty of this endeavor. PCF calculations need to be comparable amongst suppliers in order to accurately determine the emissions (Vasan *et al*., 2014) [30]. A strategy to accurately measure and reduce supply chain emissions hinges on transparency and standardization. In order to provide a way for companies to do this, the CARE (Calculate, Analyze, Report/Request, Engage) decarbonization cycle developed by CircularTree can be applied. In this approach, a PCF is performed using primary bill of material data and secondary emission factors in order to develop a hotspot analysis. Component suppliers identified in this hotspot analysis can then be engaged in order for them to set carbon reduction targets and encourage them to provide primary data. The PCF then gets refined with this primary data and the cycle continues. This approach enables the PCF to be continuously refined and eventually the product is decarbonized.

Policy Measures

Governmental regulation and policy play a crucial role in helping the consumer electronics industry decarbonize by setting standards, incentivizing innovation, and promoting sustainable practices. Implementing Minimum Energy Performance Standards can compel manufacturers to produce more energy-efficient products, thereby reducing energy consumption and emissions. This approach has been effective in various jurisdictions, including the United States and the European Union, where it has led to substantial energy savings across multiple product categories, including consumer electronics (Sachs, 2012) [31]. Policies that encourage Design for Environment can lead to cleaner manufacturing processes and more sustainable product designs. This approach not only reduces emissions but also enhances the competitiveness of the electronics industry by fostering innovation (Chakrabarti, 1994) [32]. Providing financial incentives for the development and purchase of energy-efficient electronics can stimulate market demand and encourage manufacturers to innovate. This approach can be particularly effective when combined with consumer education to raise awareness about the benefits of energy-efficient products (Arguedas & Rousseau, 2021) [33]. Offering tax credits for research and development in energy-efficient technologies can lower the cost barriers for companies investing in sustainable innovations. This can accelerate the adoption of low-carbon technologies in the consumer electronics industry (Sachs, 2012) [31]. Government policies that fund research and development can drive technological advancements necessary for decarbonization. This includes supporting innovations in electrosynthesis and other low-carbon technologies that can be integrated into the production processes of consumer electronics (Schmidt & Schmidt, 2021) [34]. Raising consumer awareness about the environmental impact of electronics and the benefits of energy-efficient products can influence purchasing decisions and drive demand for sustainable options. This can be achieved through labeling schemes and public education initiatives (Arguedas & Rousseau, 2021) [33]. Engaging consumers, manufacturers, and retailers in discussions about sustainability can foster a culture of environmental responsibility and encourage the adoption of best practices across the industry (Chase *et al.*, 2008) [35]. These measures can drive significant reductions in energy consumption and greenhouse gas emissions, aligning the industry with broader climate goals.

Conclusion

In conclusion, the consumer electronics industry faces significant challenges in its quest for decarbonization, given its substantial contribution to global greenhouse gas emissions. The urgency of reducing carbon footprints is heightened by the projected doubling of chip demand and the industry's reliance on energy-intensive manufacturing processes. This paper has explored various strategies to mitigate emissions, emphasizing the importance of primary data for accurate emissions assessment and management. By adopting innovative manufacturing techniques, integrating renewable energy sources, and implementing effective product design and material science innovations, the industry can significantly reduce its environmental impact. Additionally, addressing supply chain emissions through transparency and standardization, alongside supportive governmental policies, can further enhance sustainability efforts. Ultimately, achieving net-zero emissions by 2050 will require a comprehensive and collaborative approach, integrating technological advancements, regulatory frameworks, and consumer engagement to foster a more sustainable future for the consumer electronics sector.

References

1. Sekiguchi A. The requirement for a bright future in semiconductor device manufacturing is… innovation, collaboration and care for the environment. IEEE Electron Devices Technol Manuf Conf. 2022 Mar 6. https://doi.org/10.1109/EDTM53872.2022.9798235
2. Słoma M. Carbon footprint of electronic devices. [Conference/Journal Name Missing]. 2013 Jul 25. https://doi.org/10.1117/12.2030271
3. Ritter SK. Toward sustainable electronics. Chem Eng News. 2014. https://doi.org/10.1021/CEN-09113-SCITECH1
4. Charles HK, Sinnadurai N. Electronics, energy, and the environment. Electron Syst Integr Technol Conf. 2008. https://doi.org/10.1109/ESTC.2008.4684315
5. Sinnadurai N, Charles HK. Electronics and its impact on energy and the environment. Int Spring Semin Electron Technol. 2009. https://doi.org/10.1109/ISSE.2009.5206941
6. MacKerron CB. Moving toward sustainable consumption in electronics design, production, and recycling. Utah Environ Law Rev. 2011.
7. Allen MR, Friedlingstein P, Girardin CAJ, Jenkins S, Malhi Y, Mitchell-Larson E, *et al*. Net zero: science, origins, and implications. Annu Rev Environ Resour. 2022. https://doi.org/10.1146/annurev-environ-112320-105050
8. Piacentini RD, Garro S. Carbon neutral industries and compensation for greenhouse gas emissions. Drying Technol. 2022. https://doi.org/10.1080/07373937.2022.2149181
9. Qin J, Duan W, Zou S, Chen Y, Huang W, Rosa L. Solutions to achieve net-zero emissions in irrigated agriculture. [Journal Name Missing]. 2022. https://doi.org/10.5281/zenodo.7395799
10. Fraser CJ, Milne JS. Measurement of primary data. [Book/Journal Name Missing]. 1990. https://doi.org/10.1007/978-1-349-20800-5_2
11. Gopalakrishnan B, Mardikar Y, Korakakis D. Energy analysis in semiconductor manufacturing. Energy Eng. 2010. https://doi.org/10.1080/01998591009709867
12. Branham MS, Gutowski TG. Deconstructing energy use in microelectronics manufacturing: an experimental case study of a MEMS fabrication facility. Environ Sci Technol. 2010. https://doi.org/10.1021/ES902388B
13. Nagapurkar P, Das SK. Economic and embodied energy analysis of integrated circuit manufacturing processes. Sustain Comput Inform Syst. 2022. https://doi.org/10.1016/j.suscom.2022.100771
14. Das S, Mao E. The global energy footprint of information and communication technology electronics in connected Internet-of-Things devices. Sustain Energy Grids Netw. 2020. https://doi.org/10.1016/J.SEGAN.2020.100408
15. Altay BN, Bolduc M, Cloutier SG. Sustainable advanced manufacturing of printed electronics: an environmental consideration. [Book/Conference Name Missing]. 2020. https://doi.org/10.5772/INTECHOPEN.91979
16. Khan AM, Khan AM, Liang L, Mia M, Gupta M, Wei Z, *et al*. Development of process performance simulator

(PPS) and parametric optimization for sustainable machining considering carbon emission, cost and energy aspects. Renew Sustain Energy Rev. 2021. https://doi.org/10.1016/J.RSER.2021.110738
17. Yuanxiong L. Electronic product manufacture method capable of realizing energy saving and emission reduction. [Journal/Conference Name Missing]. 2017.
18. Taboada HA, Xiong Z, Jin T, Jimenez JA. Exploring a solar photovoltaic-based energy solution for green manufacturing industry. Conf Autom Sci Eng. 2012. https://doi.org/10.1109/COASE.2012.6386321.
19. Materi S, D'Angola A, Enescu D, Renna P. Reducing energy costs and CO2 emissions by production system energy flexibility through the integration of renewable energy. Prod Eng. 2021. https://doi.org/10.1007/S11740-021-01051-5
20. Materi S, D'Angola A, Renna P. A dynamic decision model for energy-efficient scheduling of manufacturing system with renewable energy supply. J Clean Prod. 2020. https://doi.org/10.1016/J.JCLEPRO.2020.122028
21. Duan Y. Energy efficiency for manufacturing using PV, FSC, and battery-super capacitor design to enhance sustainable clean energy load demand. [Journal/Book Name Missing]. 2022. https://doi.org/10.1007/978-3-031-18326-3_26
22. Lee SJ, Ryu IS, Moon SH. N2O emission and reduction in the electronics manufacturing industries. Greenh Gases Sci Technol. 2012. https://doi.org/10.1002/GHG.1301
23. You Z, Hou W, Wang X, Ma J, Liu J. Design strategies for developing sustainable consumer electronics. J Residuals Sci Technol. 2016. https://doi.org/10.12783/ISSN.1544-8053/13/4/S29
24. Green JJ, Günay EE, Kremer GEO. A simulation model of consumer take-back decisions regarding product design. Procedia Manuf. 2019. https://doi.org/10.1016/J.PROMFG.2019.04.084
25. Komeijani M, Ryen EG, Babbitt CW. Bridging the gap between eco-design and the human thinking system. Challenges. 2016. https://doi.org/10.3390/CHALLE7010005
26. Abdalla H, Ebeid MA. A holistic approach for sustainable product design. [Book/Conference Name Missing]. 2011. https://doi.org/10.1007/978-3-642-15973-2_32.
27. O'Connor MP, Zimmerman JB, Anastas PT, Plata DL. A strategy for material supply chain sustainability: Enabling a circular economy in the electronics industry through green engineering. ACS Sustain Chem Eng. 2016. https://doi.org/10.1021/ACSSUSCHEMENG.6B01954
28. Lehmann T, Hamilton TJ. Integrated circuits towards reducing e-waste: Future design directions. Int Conf Green Circuits Syst. 2010. https://doi.org/10.1109/ICGCS.2010.5543018.
29. Hertwich EG, Ali SH, Ciacci L, Fishman T, Heeren N, Masanet E, *et al*. Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review. Environ Res Lett. 2019. https://doi.org/10.1088/1748-9326/AB0FE3.
30. Vasan ASS, Sood B, Pecht M. Carbon footprinting of electronic products. Appl Energy. 2014. https://doi.org/10.1016/J.APENERGY.2014.09.074
31. Sachs NM. Can we regulate our way to energy efficiency? Product standards as climate policy. Vanderbilt Law Rev. 2012.
32. Chakrabarti P. Designing revolution: Policy for a clean and healthy electronics industry. Int Symp Electron Environ. 1994. https://doi.org/10.1109/ISEE.1994.337275.
33. Arguedas C, Rousseau S. Energy-efficient design, consumer awareness, and public policy. SERIEs. 2021. https://doi.org/10.1007/S13209-020-00225-1.
34. Schmidt TS. Spurring low-carbon electrosynthesis through energy and innovation policy. iScience. 2021. https://doi.org/10.1016/J.ISCI.2021.102045.
35. Chase A, Pope T, Canny D. Consumer electronics efficiency programs: The next big challenge. [Journal/Conference Name Missing]. 2008.