Journal of Economics, Finance and Management Studies

ISSN (print): 2644-0490, ISSN (online): 2644-0504

Volume 07 Issue 02 February 2024

Article DOI: 10.47191/jefms/v7-i2-32, Impact Factor: 8.044

Page No: 1133-1139

Greening Innovation: A Roadmap for Sustainable Product Development

Nino Tchanturia[1], Taso Getashvili[2]

[1,2] Georgian International University GIU, Georgia, Tbilisi

ABSTRACT: In the midst of unprecedented technological advancements and rapid industrialization, the imperative for sustainability has emerged as a paramount challenge. This article explores the realm of sustainable product development at the intersection of innovation and ecological responsibility. Recognizing the profound impact of products on the environment, businesses and industries are shifting away from the traditional linear production model to embrace circular and regenerative approaches. Sustainable product development has become a linchpin for reconciling economic prosperity with environmental preservation. The article delves into the intricate web of interactions constituting a product's life cycle, addressing aspects from eco-design principles to circular economy practices and cutting-edge technologies. It provides insights and strategies for harmonizing the process of product creation with the imperatives of ecological sustainability, offering a roadmap for industries, innovators, and consumers to navigate towards a more sustainable and resilient future.

KEYWORDS: Sustainable product development, Eco-design, Circular economy, Environmental stewardship, Technological innovation

I. INTRODUCTION

In an age marked by unprecedented technological advancements and rapid industrialization, the imperative for sustainability has emerged as a defining challenge. As the global community grapples with the environmental consequences of unchecked growth, the spotlight is now firmly on redefining the way we conceive, design, and manufacture products. At the intersection of innovation and ecological responsibility lies a pivotal realm—sustainable product development. This article embarks on a journey through the intricate landscape of creating products that not only meet the demands of a dynamic market but also bear the insignia of environmental stewardship.

In recent years, the discourse surrounding sustainability has transcended mere rhetoric to become a foundational pillar in the strategic objectives of businesses and industries. The realization that products, from their conception to disposal, wield a profound impact on the environment has sparked a paradigm shift. The traditional linear model of production, characterized by a take-make-dispose approach, is yielding ground to a circular and regenerative ethos. In this evolving landscape, sustainable product development emerges as a linchpin for reconciling the often conflicting realms of economic prosperity and environmental preservation.

As we delve into this exploration, the crux lies in comprehending the intricate web of interactions that constitute a product's life cycle. Beyond the apparent facets of design and manufacturing, the environmental footprint extends its tendrils to encompass raw material extraction, energy consumption, waste generation, and the product's ultimate fate. Our journey seeks to unravel this complexity, offering insights and strategies for harmonizing the process of product creation with the imperatives of ecological sustainability.

From the conceptualization of products imbued with eco-design principles to the embrace of circular economy practices and the adoption of cutting-edge technologies, the trajectory towards sustainable product development is both challenging and promising. This article endeavors to shed light on the multifaceted aspects of this transformative journey, providing a roadmap for industries, innovators, and consumers alike to navigate the path towards a more sustainable and resilient future.

II. UNDERSTANDING THE ENVIRONMENTAL IMPACT OF PRODUCTS:

To achieve sustainable development, it is crucial to understand the complex network of effects embedded in the life cycle of products. This comprehension surpasses the visible characteristics of a completed object, exploring extensively the intricacies that encompass its origin to its final disposal (Nguyen, 2023). The Life Cycle Analysis (LCA) is a strong methodology that thoroughly examines the environmental consequences of each stage in a product's life cycle. Life Cycle Analysis is not simply a technique, but rather a philosophy that involves a methodical approach to thoroughly examining the whole life course of a product (Levy, 2017). LCA comprehensively encompasses the entire life cycle of a product, including the extraction of raw materials, the manufacturing processes, the consumption of the product, and the considerations for its end-of-life. This comprehensive analysis offers a detailed comprehension of the interrelated aspects that influence the environmental impact of a product. Life Cycle Assessment (LCA) plays a crucial role in evaluating the actual environmental consequences of products, providing a perspective that goes much beyond the end product alone (Levy, 2017). By quantifying the ecological burdens at each stage of the life cycle, it allows stakeholders to make well-informed decisions. This analysis, which combines both quantitative and qualitative methods, is essential for ensuring that economic interests are in line with environmental responsibility (Herrero et al., 2020). The voyage commences with the procurement of raw materials, illuminating the environmental impact of extraction procedures. The LCA (Life Cycle Assessment) examines the sustainability of the sources of materials, which is an important factor that is typically ignored in conventional studies. Methods of Production: LCA carefully examines the manufacturing phase, assessing energy usage, emissions, and waste production(Levy, 2017). This examination reveals valuable information about the environmental sustainability and effectiveness of production systems. In addition to creation, LCA also encompasses the product's operating phase. The analysis thoroughly evaluates factors such as energy efficiency, maintenance requirements, and overall impact during operation, incorporating real-world considerations. Disposal, the ultimate stage in the life cycle of a product, is a crucial aspect of Life Cycle Assessment (LCA) (Rödger et al., 2020). This analysis examines the environmental consequences of various means of disposing of the product, considering factors such as its potential to be recycled or biodegraded. It provides a thorough comprehension of the product's overall ecological impact. The use of Life Cycle Analysis into product development signifies a paradigm shift towards more mindful decision-making. It enables enterprises to pursue sustainable innovation by finding areas for enhancement and promoting a culture of responsible manufacturing. In this exploration, we will further examine the practical insights obtained from LCA (Purvis et al., 2023). These findings will be transformed into strategies for environmentally conscious design, sustainable material selection, and energy-efficient manufacturing methods. By adopting this comprehensive approach, we are creating a path towards a future in which items effortlessly integrate with their surrounding environment.

III. INCORPORATING ECO-DESIGN PRINCIPLES

In the field of sustainable product development, the concept of eco-design serves as a guiding principle for creating environmentally sensitive innovations. It goes beyond the traditional model, encouraging innovators to incorporate sustainability into the core of their creations from the beginning (Kobayashi, 2006).

Eco-design fundamentally represents a shift in thinking, moving away from the traditional linear approach to product development and embracing a circular and regenerative mindset. This viewpoint asserts that environmental factors should not be treated as an afterthought, but rather as an essential component of the design process (Hollander et al., 2017). By incorporating eco-design concepts throughout the first stages of product development, producers can integrate sustainability into the fundamental nature of their goods, resulting in a more significant and long-lasting influence on both the industry and the environment (Ahmad et al., 2018).

The initiation of a product determines the path it will follow during its entire life cycle. Therefore, it is imperative to include environmental factors from the outset, as it is not only an option but a requirement (Diaz et al., 2021). Through this approach, designers may proactively tackle issues concerning the use of resources, emissions, and the disposal of products at the end of their life cycle. This sets the groundwork for a product that effortlessly harmonizes with the environment (Barros et al., 2021).

Material selection is a fundamental aspect of eco-design. Choosing sustainably sourced, renewable, or recycled materials helps to decrease the environmental consequences linked to resource extraction and lessens the ecological footprint of the product. Energy efficiency is the deliberate consideration of energy-saving features when designing products (Martins & Marto, 2023). This approach not only helps to lower operational expenses but also minimizes the total impact on the environment. This entails the optimization of energy consumption throughout the processes of manufacture, transportation, and product utilization. Recyclability and considerations for the end-of-life stage: An essential aspect of eco-design is the ability to anticipate and plan for the fate of a product at the end of its life cycle (Barros et al., 2021). Creating products that are easily recyclable and can be taken apart helps in the retrieval of precious materials, promoting a closed-loop system that reduces waste and prolongs the lifespan of components.

Eco-design is not a limitation, but rather a call to envision the creative process in a new way. Designers are prompted to go beyond the surface appearance and practicality of objects, and instead, imbue them with a feeling of accountability and durability (Ahmad et al., 2018).

Advancements in materials for the purpose of promoting sustainability: Within the progression towards sustainable product creation, the selection of materials plays a pivotal role as a crucial factor in determining both the environmental impact and lifespan of a product. The selection of materials for product creation has significant consequences for the environment, impacting resource usage, emissions, and considerations for disposal (Pollini & Rognoli, 2021). Sustainable materials are defined as those that minimize negative environmental effects, taking into account variables such as their ability to be renewed, recycled, and their reduced ecological footprint (Ulucak & Khan, 2020). Incorporating these materials into product design demonstrates a dedication to ethical practices that go beyond the boundaries of manufacturing. Advancements in Technology and Novel Ideas: Materials that can be broken down and decomposed by natural processes, such as bacteria or other living organisms, are known as biodegradable materials (Moshood et al., 2022). Advancements in biodegradable materials present a remedy for the enduring problem of plastic pollution. Obtained from natural sources, these materials decompose gradually, lessening the impact of non-biodegradable trash on ecosystems. Materials that have been processed and reused (Pilapitiya & Ratnayake, 2024). The incorporation of recycled resources in product creation exemplifies a closed-loop methodology. Utilizing materials derived from trash generated by consumers or industries decreases the need for new resources and mitigates the environmental consequences of extraction procedures. Polymers derived from biological sources: Biopolymers, sourced from renewable materials like plant starch or sugarcane, are increasingly recognized as substitutes for conventional plastics (Sonia et al., 2023). These materials possess comparable characteristics to traditional plastics and also aid in decreasing carbon emissions. Intelligent materials: The emergence of smart materials adds a dynamic element to the concept of sustainability (Shukla & Garg, 2023). Materials with the ability to adjust to varying conditions, such as coatings that are sensitive to temperature or polymers that can repair themselves, improve longevity and contribute to an extended lifespan of the product (Ratwani et al., 2023). Nanotechnology expands the boundaries of materials science, providing possibilities to improve the characteristics and effectiveness of materials. Nanocomposites, a type of innovation, allow for the production of materials that are both lightweight and robust, while also being environmentally benign. These materials have a wide range of applications. The combination of sustainable materials and technical innovation is a powerful force that brings about significant changes in the field of product creation. By utilizing these developing technologies, companies can steer towards a future where materials not only fulfill functional requirements but also adhere to ecological imperatives. The following sections will delve deeper into the seamless integration of these materials into design processes, promoting a comprehensive approach to sustainable product creation. As we begin this study, the journey reveals a path towards a stronger and more accountable connection between products and their surroundings (Onyeaka et al., 2022).

IV. ENERGY-EFFICIENT MANUFACTURING PROCESSES

Efficient energy usage in industrial processes is crucial in the quest for sustainable product development. Lean manufacturing prioritizes the eradication of inefficiencies, such as excessive energy usage, surplus materials, or wasted time (Haleem et al., 2023). Optimizing processes to decrease inefficiencies inherently reduces the energy consumption needed for production. Regularly conducting energy audits enables manufacturers to identify specific locations where energy consumption is excessive. Implementing real-time energy usage monitoring allows for proactive adjustments, promoting a culture of ongoing enhancement(Energy, 2023). Adopting energy-efficient machinery and technology can result in significant decreases in energy usage. Contemporary equipment, ranging from sophisticated robotics to energy-conserving lighting and heating systems, is purposefully engineered to prioritize sustainability (Del Rio et al., 2021). Implementing process optimization and automation enhances both efficiency and reduces the energy intensity of manufacturing. Intelligent systems have the ability to adapt production parameters in response to real-time data, hence maximizing energy efficiency(Edgar & Pistikopoulos, 2018). Utilizing solar power for manufacturing operations is a crucial tactic in diminishing dependence on traditional energy sources. Facility design can incorporate solar panels, which offer a sustainable and environmentally friendly means of generating electricity(Maka & Alabid, 2022). Wind turbines, whether located on-site or integrated into a larger renewable energy grid, provide a sustainable solution for powering manufacturing activities. Due to their scalability, they may be easily adjusted to suit different industrial environments. Integrating hydropower systems can effectively harness water resources, offering a dependable and steady supply of sustainable electricity (Systèmes, 2023). This is especially beneficial for industries situated in close proximity to bodies of water. The use of Internet of Things (IoT) sensors and devices enables the implementation of data-driven decision-making processes in the industrial industry. Manufacturers can achieve greater efficiency, process optimization, and energy consumption reduction by collecting and analyzing real-time data (What Is IoT (Internet of Things) & How It Helps Businesses, 2024). Artificial intelligence (AI) applications, such as predictive maintenance and energy management systems, improve production efficiency. Predictive algorithms have the ability to anticipate equipment malfunctions, thereby avoiding periods of inactivity and minimizing the need for energy-consuming urgent repairs(Energy, 2023). EMS platforms enable the consolidation and supervision of energy consumption. These technologies empower manufacturers to establish energy consumption objectives, monitor performance, and execute plans to achieve sustainability objectives(Energy, 2023). Envisioning a Future of Sustainable Manufacturing: Manufacturing businesses can achieve environmental sustainability by implementing a comprehensive strategy that incorporates energy-efficient practices, the incorporation of renewable energy sources, and the utilization of smart technologies (5 Ways to Achieve More Sustainable Manufacturing Practices | POWERSTM Manufacturing Productivity Experts, 2023).

V. WASTE REDUCTION AND CIRCULAR ECONOMY PRACTICES

Efforts to achieve sustainable product creation focus on implementing waste reduction techniques and embracing circular economy ideas, which are crucial for creating a more responsible and regenerative future (Velenturf & Purnell, 2021). Industries contribute to the preservation of finite resources and reduce the environmental effect of resource extraction by limiting the materials discarded during production and consumption (Bianchi & Cordella, 2023). The amount of energy dedicated to the production of goods is significant. When resources are unintentionally discarded, the energy used in their manufacture is wasted. Reducing waste is a direct means to achieve energy savings and establish a more sustainable manufacturing process (Yang et al., 2022). Waste, especially non-biodegradable substances, presents a substantial threat to ecosystems. Industries actively reduce their environmental impact by giving priority to waste reduction, hence reducing the strain on landfills and ecosystems (Bianchi & Cordella, 2023). In a circular economy, products are designed with the intention of having several lifecycles. Designing for reuse entails the creation of products that possess the ability to be readily disassembled, refurbished, and reintegrated into the market, hence prolonging their operational lifespan (Yang et al., 2022). The circular economy promotes the use of remanufacturing, a process in which items are dismantled, mended, and restored to their initial specifications. This not only eliminates waste but also fosters the effective utilization of resources (Velenturf & Purnell, 2021). Incorporating recyclability into product design guarantees that materials can be reused or repurposed when they reach the end of their lifespan. This entails utilizing reusable materials and establishing mechanisms that streamline the recycling procedure (Yang et al., 2022). The core principle of the circular economy is around the idea of achieving a closed-loop system, wherein materials are consistently reused or recycled. This stands in stark contrast to the conventional linear economy, in which products are disposed of after a solitary utilization (Bianchi & Cordella, 2023). Extended Producer Responsibility (EPR) initiatives incentivize manufacturers to assume accountability for the complete life cycle of their products. This include the execution of take-back initiatives, the facilitation of recycling, and the active engagement in the management of items at the end of their life cycle (Velenturf & Purnell, 2021). Collaboration is essential for the success of the circular economy. Collaborations between different industries facilitate the sharing of expertise, assets, and optimal methods, resulting in a stronger and more linked system (Bianchi & Cordella, 2023). By implementing waste reduction strategies and embracing the concepts of the circular economy, industries not only demonstrate their commitment to environmental sustainability but also contribute to the development of a more resilient and resource-efficient future.

VI. CHALLENGES AND OPPORTUNITIES IN SUSTAINABLE PRODUCT DEVELOPMENT

Sustainable product development is a commendable goal that involves intricate processes, filled with difficulties and many possibilities (Diaz et al., 2021).

A major obstacle is the belief that implementing sustainable practices can result in increased expenses. The adoption of environmentally sustainable materials, processes, and technologies may necessitate upfront capital expenditures, which can discourage certain businesses from transitioning (Agrawal et al., 2023). Supply chain complexity can provide challenges in maintaining sustainability, particularly for international corporations with sophisticated and elaborate networks. Obtaining sustainable resources, ensuring ethical labor methods, and preserving uniformity across suppliers present substantial challenges (Patil et al., 2022).

Consumer Awareness and Demand: Although there is an increasing level of awareness, not all customers give priority to sustainability when making their purchase choices. The problem of bridging the divide between consumer awareness and the need for sustainable products persists, especially in areas where price frequently takes priority. Global variations in regulatory frameworks for sustainable practices present difficulties for organizations that operate in different locations. To successfully navigate various and ever-changing legislation, one must possess adaptability and a sophisticated comprehension of local compliance standards(Barbarossa & Pastore, 2015).

Lack of Standardization: The absence of uniform definitions and indicators for sustainability poses a difficulty for firms to properly convey their sustainability initiatives. Standardization is essential to provide uniformity in reporting and comparing progress(Maione, 2023).

Potential prospects and financial advantages:

Innovation and Market Leadership: Adopting sustainable practices cultivates an environment conducive to innovation, driving businesses to create state-of-the-art technology and solutions. This innovation not only establishes organizations as frontrunners in the industry but also creates opportunities for additional sources of income (Srisathan et al., 2023).

Cost Savings Through Efficiency: Despite the common belief that sustainability leads to increased expenses, numerous sustainable measures actually enhance operational efficiency and generate cost savings. The economic bottom line is positively impacted by energy-efficient procedures, waste minimization, and resource optimization (Javaid et al., 2022).

Improved Brand Reputation: Companies that embrace sustainability generally have an enhanced brand reputation. Consumers are placing more importance on firms that demonstrate a strong dedication to environmental and social responsibility. This is leading to increased brand loyalty and positive word-of-mouth (Dapi & Phiri, 2015).

Access to New Markets: Implementing sustainable practices can provide entry to markets that favor environmentally-friendly products. Businesses that conform to global sustainability trends position themselves to join markets where there is a strong demand for sustainable products (Seven Clean Seas - October 2023, n.d.).

Risk mitigation and resilience: Sustainability measures help reduce risks related to fluctuating resource prices, regulatory modifications, and harm to reputation. Businesses can strengthen their resilience in the face of unpredictability by diversifying their supply networks and implementing circular economy principles (Energy, 2023).

Despite the ongoing hurdles, firms are driven to pursue sustainable product development due to the compelling economic benefits and prospects associated with environmental stewardship.

CONCLUSIONS

In today's ever-changing business climate, there is a strong need for sustainable product creation. This demand reflects a deep commitment to creating a future where innovation and environmental responsibility go hand in hand. By examining environmental factors in design and manufacturing, enterprises can discover a path to address difficulties, capitalize on opportunities, and actively contribute to the development of a more sustainable planet and prosperous economy.

The main lessons learned from this investigation emphasize the significant impact of incorporating sustainability into the fundamental aspects of product creation. By adopting a life cycle perspective and incorporating eco-design principles, utilizing innovative materials, implementing energy-efficient manufacturing processes, reducing waste, practicing circular economy principles, complying with regulations, fostering collaboration, and raising consumer awareness, each aspect contributes significantly to creating a more responsible and resilient industrial ecosystem.

Sustainable product development goes beyond being just a commercial plan; it encompasses a vision where economic growth and ecological responsibility are interwoven. It involves a dedication to promoting new ideas, developing the ability to bounce back from challenges, increasing the worth of the brand, and creating an environment where accountability is deeply ingrained in all aspects of the organization's operations. As industries undergo this transformative process, they evolve from mere producers of things to guardians of a heritage—a heritage that places sustainability as the fundamental element of achievement. As firms strive to balance economic interests with environmental concerns, sustainable product development emerges as a crucial link—a remarkable structure that connects profitability with the well-being of the world. It represents a cultural transformation that goes beyond financial gains, aiming to foster a feeling of accountability and a commitment to building a society where future generations can flourish.

In the pursuit of sustainability, each product serves as evidence of careful deliberation regarding its environmental footprint, as well as a demonstration of innovation and the dedication of industries to create a future where progress and the protection of our planet are harmoniously intertwined. Industries utilize sustainable product development to not only create goods, but also to construct a narrative that depicts a future where economic prosperity and ecological harmony may coexist.

REFERENCES

1) Energy, E. C. (2023, December 1). *Circular Economy and Sustainable Approaches to Supply Chain Management*. Utilities One. https://utilitiesone.com/circular-economy-and-sustainable-approaches-to-supply-chain-management

2) *Seven Clean Seas - October 2023*. (n.d.). https://www.sevencleanseas.com/post/consumer-trends-sustainability
3) Dapi, B., & Phiri, M. A. (2015, January 1). *The impact of corporate social responsibility on brand loyalty.* Journal of Governance and Regulation. https://doi.org/10.22495/jgr_v4_i1_p1
4) Javaid, M., Haleem, A., Singh, R. P., Khan, S., & Suman, R. (2022, January 1). *Sustainability 4.0 and its applications in the field of manufacturing*. Internet of Things and Cyber-Physical Systems. https://doi.org/10.1016/j.iotcps.2022.06.001
5) Srisathan, W. A., Ketkaew, C., Phonthanukitithaworn, C., & Naruetharadhol, P. (2023, September 1). *Driving policy support for open eco-innovation enterprises in Thailand: A probit regression model*. Journal of Open Innovation: Technology, Market, and Complexity. https://doi.org/10.1016/j.joitmc.2023.100084
6) Maione, G. (2023, July 7). *An energy company's journey toward standardized sustainability reporting: addressing governance challenges*. Transforming Government: People, Process and Policy. https://doi.org/10.1108/tg-05-2023-0062
7) Barbarossa, C., & Pastore, A. (2015, April 13). *Why environmentally conscious consumers do not purchase green products*. Qualitative Market Research: An International Journal. https://doi.org/10.1108/qmr-06-2012-0030
8) Patil, V., Tan, T., Rispens, S., Dabadghao, S., & Demerouti, E. (2022, April 1). *Supplier sustainability: A comprehensive review and future research directions*. Sustainable Manufacturing and Service Economics. https://doi.org/10.1016/j.smse.2022.100003
9) Agrawal, R., Agrawal, S., Samadhiya, A., Kumar, A., Luthra, S., & Jain, V. (2023, July 1). *Adoption of green finance and green innovation for achieving circularity: An exploratory review and future directions*. Geoscience Frontiers. https://doi.org/10.1016/j.gsf.2023.101669
10) Yang, M., Chen, L., Wang, J., Msigwa, G., Osman, A. I., Fawzy, S., Rooney, D., & Yap, P. (2022, September 6). *Circular economy strategies for combating climate change and other environmental issues*. Environmental Chemistry Letters. https://doi.org/10.1007/s10311-022-01499-6
11) Bianchi, M., & Cordella, M. (2023, January 1). *Does circular economy mitigate the extraction of natural resources? Empirical evidence based on analysis of 28 European economies over the past decade*. Ecological Economics. https://doi.org/10.1016/j.ecolecon.2022.107607
12) Velenturf, A. P., & Purnell, P. (2021, July 1). *Principles for a sustainable circular economy*. Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2021.02.018
13) *5 Ways to Achieve More Sustainable Manufacturing Practices | POWERS™ Manufacturing Productivity Experts*. (2023, August 18). POWERS™ Management Consulting. https://www.thepowerscompany.com/resources/sustainable-manufacturing/
14) Energy, E. C. (2023, December 1). *The Role of Artificial Intelligence in Predictive Maintenance for Electric Utilities*. Utilities One. https://utilitiesone.com/the-role-of-artificial-intelligence-in-predictive-maintenance-for-electric-utilities
15) *What Is IoT (Internet Of Things) & How It Helps Businesses*. (2024, January 12). Intuji. https://intuji.com/what-is-iot-how-iot-helps-businesses/
16) Systèmes, D. (2023, November 3). *Wind Farms Fit for the Future: Ensuring Offshore Wind Is Seaworthy*. Dassault Systèmes. https://www.3ds.com/sustainability/energy-use/wind-farms
17) Maka, A. O., & Alabid, J. (2022, June 1). *Solar energy technology and its roles in sustainable development*. Clean Energy. https://doi.org/10.1093/ce/zkac023
18) Edgar, T. F., & Pistikopoulos, E. N. (2018, June 1). *Smart manufacturing and energy systems*. Computers & Chemical Engineering. https://doi.org/10.1016/j.compchemeng.2017.10.027
19) Del Rio, D. D. F., Sovacool, B. K., & Griffiths, S. (2021, December 1). *Culture, energy and climate sustainability, and smart home technologies: A mixed methods comparison of four countries*. Energy and Climate Change. https://doi.org/10.1016/j.egycc.2021.100035
20) Energy, E. C. (2023, December 1). *The Role of Energy Audits in Infrastructure Energy Efficiency Assessments*. Utilities One. https://utilitiesone.com/the-role-of-energy-audits-in-infrastructure-energy-efficiency-assessments
21) Haleem, A., Javaid, M., Singh, R. P., Suman, R., & Qadri, M. A. (2023, May 1). *A pervasive study on Green Manufacturing towards attaining sustainability*. Green Technologies and Sustainability. https://doi.org/10.1016/j.grets.2023.100018
22) Onyeaka, H., Passaretti, P., Miri, T., & Al-Sharify, Z. T. (2022, January 1). *The safety of nanomaterials in food production and packaging*. Current Research in Food Science. https://doi.org/10.1016/j.crfs.2022.04.005
23) Ratwani, C. R., Kamali, A. R., & Abdelkader, A. M. (2023, January 1). *Self-healing by Diels-Alder cycloaddition in advanced functional polymers: A review*. Progress in Materials Science. https://doi.org/10.1016/j.pmatsci.2022.101001

24) Shukla, U., & Garg, K. K. (2023, January 1). *Journey of smart material from composite to shape memory alloy (SMA), characterization and their applications-A review*. Smart Materials in Medicine.
25) https://doi.org/10.1016/j.smaim.2022.10.002
26) Sonia, P., Kumar, A., Khan, I., Pahwa, S., Salman, Z. N., & Singh, N. (2023, January 1). *Sustainable Manufacturing of High-Performance Composites from Recycled Materials*. E3S Web of Conferences. https://doi.org/10.1051/e3sconf/202343001105
27) Pilapitiya, P. N. T., & Ratnayake, A. S. (2024, January 1). *The world of plastic waste: a review*. https://doi.org/10.1016/j.clema.2024.100220
28) Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & AbdulGhani, A. (2022, January 1). *Sustainability of biodegradable plastics: New problem or solution to solve the global plastic pollution?* Current Research in Green and Sustainable Chemistry. https://doi.org/10.1016/j.crgsc.2022.100273
29) Ulucak, R., & Khan, S. U. (2020, March 1). *Determinants of the ecological footprint: Role of renewable energy, natural resources, and urbanization*. Sustainable Cities and Society. https://doi.org/10.1016/j.scs.2019.101996
30) Pollini, B., & Rognoli, V. (2021, October 1). *Early-stage material selection based on life cycle approach: tools, obstacles and opportunities for design*. Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2021.07.014
31) Martins, S. A. M., & Marto, J. (2023, October 1). *A sustainable life cycle for cosmetics: From design and development to post-use phase*. Sustainable Chemistry and Pharmacy. https://doi.org/10.1016/j.scp.2023.101178
32) Barros, M. V., Salvador, R., Prado, G., De Francisco, A. C., & Piekarski, C. M. (2021, June 1). *Circular economy as a driver to sustainable businesses*. Cleaner Environmental Systems. https://doi.org/10.1016/j.cesys.2020.100006
33) Diaz, A., Schöggl, J., Reyes, T., & Baumgartner, R. J. (2021, April 1). *Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management*. Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2020.12.044
34) Ahmad, S., Wong, K. Y., Tseng, M., & Wong, W. P. (2018, May 1). *Sustainable product design and development: A review of tools, applications and research prospects*. Resources, Conservation and Recycling. https://doi.org/10.1016/j.resconrec.2018.01.020
35) Hollander, M. D., Bakker, C., & Hultink, E. J. (2017, May 15). *Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms*. Journal of Industrial Ecology. https://doi.org/10.1111/jiec.12610
36) Kobayashi, H. (2006, April 1). *A systematic approach to eco-innovative product design based on life cycle planning*. Advanced Engineering Informatics. https://doi.org/10.1016/j.aei.2005.11.002
37) Purvis, B., Çelebi, D., & Pansera, M. (2023, May 1). *A framework for a responsible circular economy*. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2023.136679
38) Rödger, J. M., Beier, J., Schönemann, M., Schulze, C., Thiede, S., Bey, N., Herrmann, C., & Hauschild, M. Z. (2020, July 3). *Combining Life Cycle Assessment and Manufacturing System Simulation: Evaluating Dynamic Impacts from Renewable Energy Supply on Product-Specific Environmental Footprints*. International Journal of Precision Engineering and Manufacturing-Green Technology. https://doi.org/10.1007/s40684-020-00229-z
39) Herrero, M., Laca, A., Laca, A., & Díaz, M. (2020, January 1). *Application of life cycle assessment to food industry wastes*. Elsevier eBooks. https://doi.org/10.1016/b978-0-12-817121-9.00015-2
40) Levy, M. (2017, January 1). *Life Cycle Analysis—Strengths and Limitations of LCA*. Elsevier eBooks. https://doi.org/10.1016/b978-0-12-409548-9.10062-4
41) Nguyen, N. (2023, July 1). *Fast Fashion & Greenwashing: The Worst Combination for Sustainability*. ResearchGate. https://www.researchgate.net/publication/373632703_Fast_Fashion_Greenwashing_The_Worst_Combination_for_Sustainability