Sustainable Marketing Supported by Green Technologies (3D Printing's Contributions to Reducing Carbon Footprint)

Tarek Guendouz [1]

[1]University of Tabuk (Kingdom of Saudi Arabia), tguendouz@ut.edu.sa

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Abstract:

These research papers address a significant contemporary issue in modern marketing literature: Sustainable Marketing, which aims to sell Eco-Friendly Brands. Professional marketers are ethically committed to Environmental Responsibility at a time of widespread Pollution and Environmental Degradation. The emergence of Green Technologies such as 3D Printing, also known as Additive Manufacturing, has helped marketing management achieve Environmental Sustainability. In addition to reducing the Carbon Footprint. The study concludes that harnessing these Clean Technologies based on the Circular Carbon Economy model contributes to achieving a Green Competitive Advantage, especially with the spread of Environmental Awareness of the threats of Carbon Dioxide Emissions and dangers of Global Warming and Climate Change.

Keywords: Sustainability; Green Marketing; Clean Technologies; 3D Printing.

***Corresponding author**: Tarek Guendouz, e-mail : tguendouz@ut.edu.sa*

1. Introduction

Environmental Pollution is a perplexing and thorny issue that represents a global challenge of our time. Pollution is the introduction of contaminants and harmful substances into the Natural Environment and wildlife, causing negative changes that pose a direct threat to the Earth and often impacting human health, Quality of Life (QoL), and well-being. Pollution can take the form of any substance (solid, liquid, or gaseous) or energy such as radioactivity, heat, sound, or light. There are various types of Pollution, including air, water, and land Pollution. Due to excessive human activities and the use of fossil fuels, the amount and magnitude of excess Carbon Dioxide Emissions into the atmosphere are steadily increasing, reaching record levels more than ever before, and unfortunately, they are on the rise. Experts have sounded the alarm, warning that this is leading to Global Warming, the rise in the planet's temperature, which in turn leads to Climate Change.

Environmental Responsibility is an integral part of the Social Responsibility of governments, companies, and individuals. With the persistence and permanence of global Environmental Degradation problems, and their repercussions on the Environmental Commitment and loyalty of productive and industrial companies, this suggests an increased importance for embracing Environmental Management and harnessing Cleaner Production methodologies. It has become imperative to adopt standards for measuring and evaluating Environmental Performance when making decisions and formulating policies and strategies. This is to limit the damage caused to nature, or what is known as the depletion of Natural Capital. It is essential to avoid harming Natural Environments, or at least to ensure minimal environmental damage. Undoubtedly, embodying and achieving Environmental Responsibility requires a real shift in organizational practices at all levels, which requires restructuring and reengineering entire business organizations towards a green approach.

The term Environmental Sustainability is derived from and stems from sustainable development, a framework from an Ecosystem perspective. It refers to the duty and commitment of governments, businesses, and individuals to seriously commit and work diligently in an environmentally

sustainable manner, ensuring a prosperous future for future generations on planet Earth. It is no surprise that Environmental Sustainability is everyone's responsibility: governments through environmental welfare efforts, businesses through the slogan of prioritizing green growth, and individuals through Environmental Culture and awareness, such as green purchasing and sustainable consumption. In this regard, the Circular Carbon Economy (CCE) has emerged as an evolution of what is known in literature as the green economy. It is an effective, innovative model and a comprehensive and integrated framework aimed at intelligent management and rational treatment of Carbon Emissions and Greenhouse Gases by reducing, mitigating, reusing, recycling, and removing them from the Natural Environment.

In a related context, with the increasing Environmental Awareness among consumer and purchasing groups, companies are under increasing pressure to offer socially responsible and Eco-Friendly products and services. As a result of the above, marketing experts have made significant and strenuous efforts to develop a proactive approach that can respond to the goals and objectives of social and Environmental Responsibility and contribute to achieving sustainable development. This has resulted in the birth of Sustainable Marketing as a natural and cumulative extension of Green Marketing, which is conscious of Environmental Protection. Environmental Vigilance and Ecosystem protection are effective tools for managing modern marketing and production activities. Sustainable Marketing, within a business strategy, seeks to formulate and implement Eco-Friendly programs and initiatives by designing an environmentally committed marketing mix that achieves sustainable results in the future. Naturally, Sustainable Marketing will only bear fruit with the presence of marketing skills and competencies that embrace environmental issues and sustainable practices, and that believe in the contribution of product, price, promotion, and distribution to the long-term well-being of the world's population.

Green Technology refers to all clean, Eco-Friendly Technologies. Necessity is the mother of invention. The depletion of natural resources, industrial waste, toxic gases, and other harmful and detrimental impacts on the planet have driven a shift from conventional energy to renewable and

alternative energies that are less harmful to the environment and atmosphere. This has also led to the allocation and injection of huge sums of money into green innovation and creativity, as well as spending on sustainable supply chains and networks. It's worth noting that the Green Technology market is an emerging market that promises a prosperous future, especially with the influx of investors and their increased Environmental Awareness. It has managed to attract significant capitalists' attention. All the above comes amidst the harbingers of the emergence of the fifth wave of industrial revolutions and super-intelligent societies, which primarily focus on environmental QoL in their agendas and protocols.

Green AI and Eco-Friendly IoT sensors are manifestations of Clean Disruptive Technologies, optimal mechanisms and smart solutions designed to mitigate negative impacts on the planet through sustainable practices enhanced by computer science, machine learning algorithms, and automation. In recent years, these Eco Cyber-Physical Systems (CPSs) have made remarkable progress, demonstrating tangible advancement in gaining a competitive advantage based on Environmental Responsibility. Green computing, software, information technology, telecommunications, wireless networks, and Predictive Analytics for Big Data are receiving significant attention from relevant authorities, given their noticeable role in protecting the Earth and preserving nature by reducing the effects of Global Warming and Carbon Emissions. It is worth noting that many digital enablers have contributed to establishing and developing the foundations of a sustainable environment, such as cloud and quantum computing, augmented and virtual reality, blockchain, nanotechnology, etc.

Developing environmentally sustainable solutions for a better life for humanity has led inventors to discover 3D Printing (Additive Manufacturing). Unsurprisingly, this revolutionary and transformative technology, considered the spark of a new industrial revolution, is one of the innovative tools in the fields of manufacturing and marketing. It relies on computers and the digital files and models they contain, and is supported by advanced software, such as Computer-Aided Design (CAD), where developers create parts, components, blocks, models, and three-dimensional objects. The mechanism of action of these adaptive printers, which have the

superior ability to receive instructions from the computer equipped with operating systems, to print overlapping, solid parts and complex shapes, is such that they place and stack small, precise, successive layers of printable materials (such as plastics, metals, ceramics, sand, etc.), by printing one layer on top of the other, then combining and assembling them together, and so on. These steps and stages continue over time, until the final shape is formed with specific functional, mechanical, and physical specifications, i.e. in terms of thickness, size, length, width, height, color, weight, etc.

These research papers will address the key benefits and returns of Sustainable Marketing for Eco-Friendly products and brands, supported by 3D Printing (Additive Manufacturing) technologies, particularly in the areas of reducing Carbon Footprints, minimizing waste, and hyper-customizing the Customer Experience, known as the green consumer or environmentally conscious buyer. Despite the growing popularity of this technology, marketers have been slow to embrace and harness it. Fortunately, the success of several companies that have adapted 3D Printing has helped them discover that marketing (traditional and digital) and adaptive 3D Printing can go hand in hand. In this context, we present to the reader the most important gains resulting from the application of automated 3D Printing Technology to marketing in general, and product management and advertising campaigns in particular, which yield tremendous benefits for marketers and shoppers alike.

2. The Integration of Green Marketing with Environmental Sustainability amid the Growing Challenges of Global Climate Change

2.1 The Spread of Pollution and Degradation of Ecosystems as Direct Natural Result of Carbon Emissions and Global Warming

The phenomenon of Pollution of ecological and biological systems, and the depletion of Natural Resources due to the negative, harmful, and detrimental effects of Carbon Dioxide Emissions and waste, and the excessive and intensive industrial, agricultural, and logistical use of chemicals, plastics, and energy, pesticides, nitrogen fertilizers, and heavy metals, as well as forest fires, desert dust, and other Pollutants and toxic waste, has become an intractable problem, requiring long-term, radical solutions, there is a need for the solidarity, cooperation, and support of governments and countries, and the concerted efforts of societies and peoples

to confront this terrifying shock and impending catastrophe, given its close connection to the Sustainability of planet Earth and the safety of natural life.

The Carbon Footprint is the total amount of Greenhouse Gases, including Carbon Dioxide and methane, generated by human behavior as a primary and significant driver. Human activity is the direct factor responsible for the worsening problem of Carbon Emissions and Greenhouse Gases. These gases cause Global Warming, rising temperatures, and increasing the warmth of the weather, also known as Climate Change. These embarrassing and explosive Emissions around the world are typically caused primarily by the burning of fossil fuels for electricity generation, heating, and transportation (coal, oil, and natural gas).

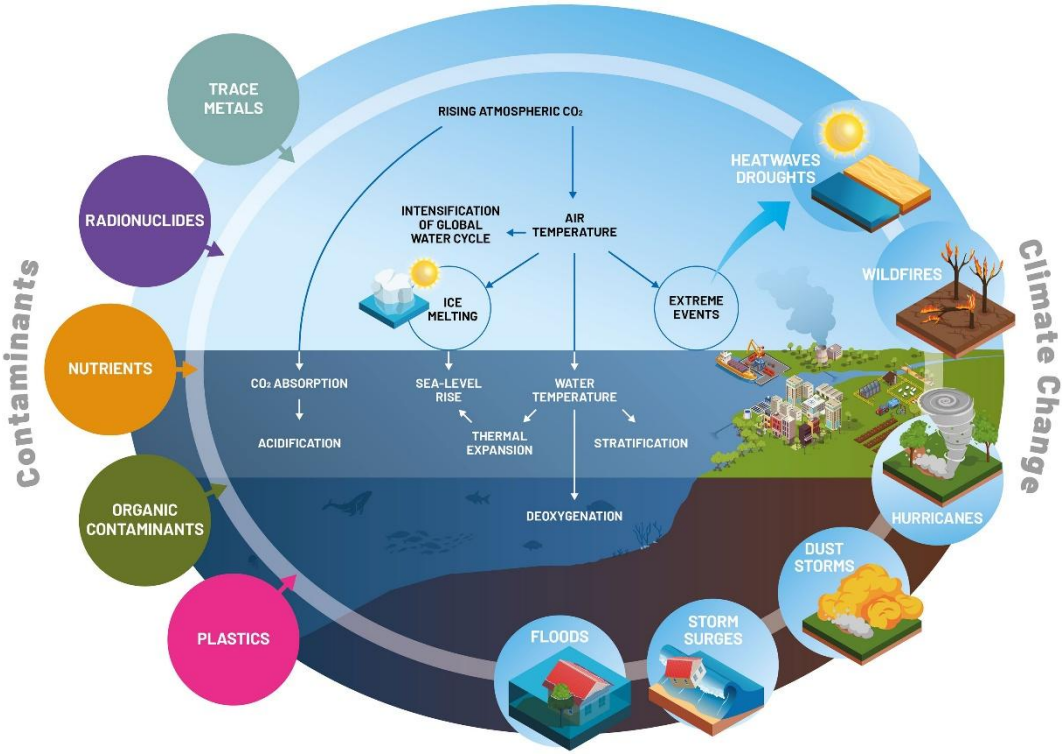
The average per capita Carbon Footprint in the United States is 16 tons, one of the highest in the world. Globally, the average Carbon Footprint is closer to 4 tons. Meanwhile, the three largest greenhouse gas emitters—the People's Republic of China, the United States, and India—contribute approximately 42.6% of Global Emissions. Faced with these threats and dangers, countries have begun implementing plans to transition to renewable and clean energy, such as hydropower generation, solar photovoltaic, wind energy, nuclear energy, and electric vehicles.

One of the major challenges facing the survival of life on Earth is increasingly severe Climate Change. Scientists use observations from the ground, air, and space, along with computer and cloud models, to monitor and study past, present, and future Climate Change. Climate data records provide evidence of key indicators of Climate Change, such as:

- Rising global land and ocean temperatures.
- Rising sea levels.
- Ice loss at the Earth's poles and in mountain glaciers.
- Changes in the frequency and intensity of extreme weather events such as hurricanes, heat waves, wildfires, droughts, floods, and rainfall.
- Changes in cloud and vegetation cover.

See: Yoro, K. O., & Daramola, M. O. 2020; Kabir, M., et al. 2023; Maximillian, J., et al. 2019; Edo, G. I., et al. 2024; Sadatshojaie, A., & Rahimpour, M. R. 2020; Singh, P., & Yadav, D. 2021; Lin, J., et al. 2023; Haque, A. 2024

Fig.1. Climate Change and Pollutants in Ecosystems
(Degradation, Carbon Emissions, Global Warming)



Source: Hatje, V., et al. (2022)

2.2 Environmental Responsibility Towards Natural Capital as a Strategic Approach and a Vital Driver within Corporate Social Responsibility

Corporate Social Responsibility (CSR) is traditionally divided into four categories:

- Environmental Responsibility
- Philanthropic Responsibility
- Moral Responsibility
- Economic Responsibility.

Corporate Environmental Responsibility (CER) refers to a company's ability to fulfill its obligations toward the environment. This means that management's decision-makers pledge to minimize harm to the Natural Environment as much as possible. Over time, Environmental Discipline has become critical to achieving competitive advantage in an environmentally sustainable manner. Undoubtedly, the success of this organizational

philosophy requires employees support and advocate for Environmental Quality as an effective mechanism for reducing and mitigating Environmental Degradation and Pollution. The positive behavior and intrinsic motivation of environmentally conscious employees is the key to achieving CER. Therefore, the widespread belief in Environmental Orientation within an organization goes beyond mere compliance with environmental laws and regulations stemming from external environmental contexts.

Considering that the business world is part of the environmental problem, the executive management of companies striving to protect the environment bears a grave responsibility to demonstrate their adoption of a synergistic friendship and strategic partnership with the Natural Environment, and to reduce harmful practices and negative impacts represented by the Carbon Footprint. This requires activating and promoting green initiatives that encourage sustainable activities such as supporting biodiversity, planting trees, increasing vegetation cover, funding environmental research, and donating to environmentally related causes such as preserving the oceans from pollutants. This also includes adopting Cleaner Production methods and techniques, waste management, Environmental Safety, and resource conservation. Furthermore, rationalizing and regulating energy consumption efficiently and rationally, and increasing reliance on renewable energy sources, sustainable resources, and recycled materials as much as possible.

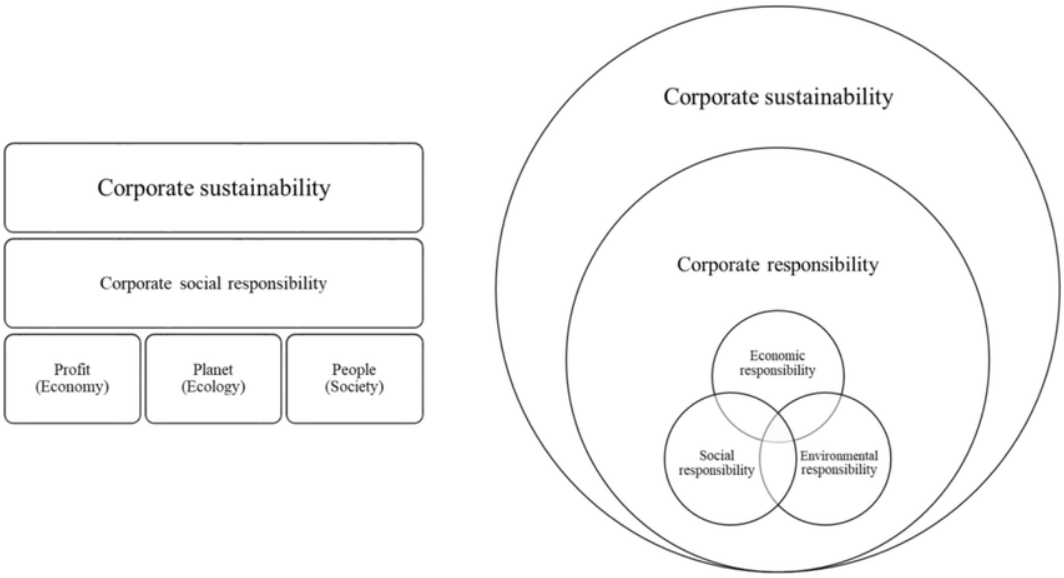
The business world's engagement and integration in implementing national environmental plans and addressing serious environmental problems, in line with Environmental Governance, requires a roadmap that begins and ends with establishing consistent links and bonds with stakeholders who embrace green development and advocate for environmental and biodiversity protection, both internal and external audiences. The more the behavior of influential stakeholders is inclined toward assuming environmental responsibilities and supporting Sustainability, the result is an enriched and sustainable Environmental Responsibility. Evidence demonstrates this. Partners in success are the safety valve for achieving the goals of Environmental Citizenship and

environmental impact management, such as owners, employees, investors, creditors, shareholders, the public, government entities, suppliers, distributors, consumers, the media, etc.

Theoretically, CER has noble goals and honorable endeavors. However, the year- after-year increase in Carbon Emissions and toxic Pollutants from highly polluting factories places industries in the dock, as they are the perpetrators of these crimes against nature. Due to the motives of maximizing commercial profits and investment returns, generating additional sales, expanding market share in the competitive race, and other short-term financial gains and economic incentives, companies are sacrificing their social and environmental commitments, despite CEOs' constant claims and declarations that the environment is a top priority and a top concern. Indeed, a significant and growing number of business organizations claim to be part of the solution, not the problem. Therefore, it is actions and implementation that count, not words and theories.

See: Shaukat, A., et al. 2016; El Ghoul, S., et al. 2018; Li, Z., et al. 2020; Cai, L., et al. 2016; Jo, H., et al. 2015; Li, D., et al. 2017; Chen, S., et al. 2021; Hao, X., et al. 2023; Karassin, O., & Bar-Haim, A. 2016; Wang, M., et al. 2021

Fig.2. Protecting The Environment from Degradation as Part of Corporate Social Responsibility



Source: Fatima, T., & Elbanna, S. (2023)

2.3 Green Environmental Sustainability within the Dynamics of Sustainable Development and the Contexts of the Circular Carbon Economy (CCE)

Environmental Sustainability is the first thing that comes to mind for most of us when the term is mentioned, but it also relates to social well-being and economic development. There are international treaties, agreements, and commitments to live in a green environment, safely and reassuringly, and to avoid further Pollution and Degradation of our planet. These pressures and constraints come from the United Nations Environment Programme (UNEP) and the International Organization for Standardization (ISO), in addition to the widespread presence of environmental protection and consumer awareness groups. It is interesting to note that in some countries, these Environmental Sustainability and biodiversity groups even have the authority to prosecute crimes against the environment. All environmental entities and organizations have expressed grave concern about the global climate crisis, with rising temperatures, melting ice caps, and floods becoming more widespread. They have recommended the imperative of implementing long-term strategies to reduce Carbon Emissions to acceptable levels for a sustainable environment.

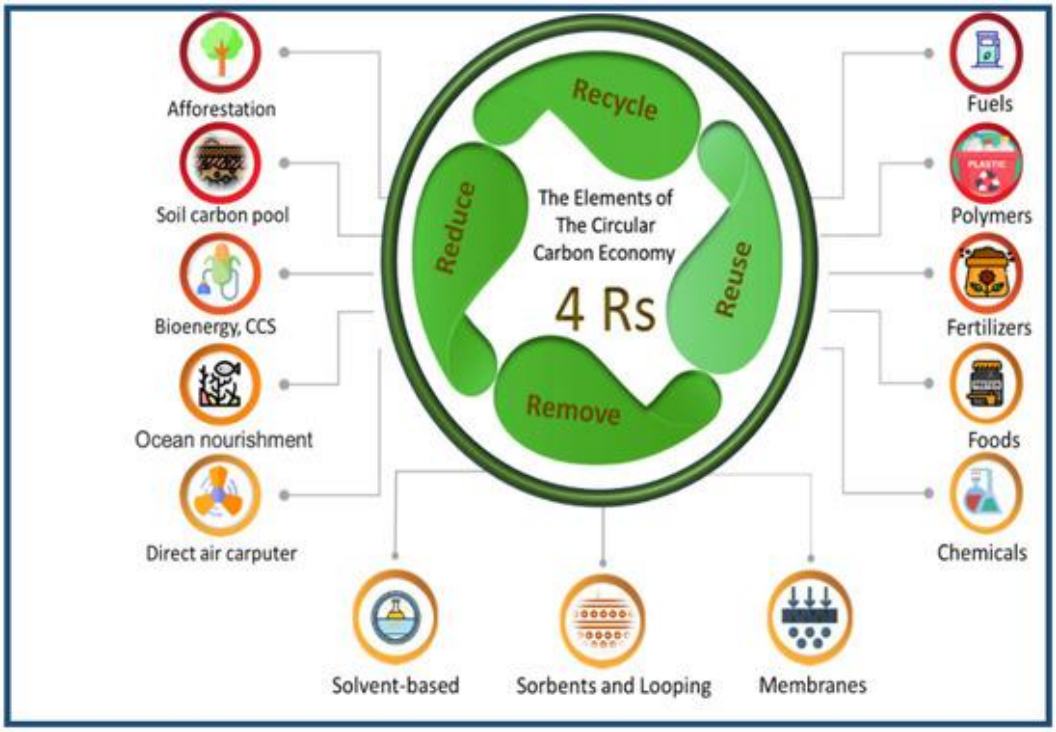
Achieving long-term environmental development goals in various sectors, such as industry, energy, buildings, and transportation, falls primarily

on national governments. These governments play a sovereign role in enforcing laws, legislation, and regulations related to the conservation of Natural Resources and wealth, forests, and water resources from depletion, and reducing Carbon Emissions, radioactive pollutants, and increasing toxic substances. These governments adopted the principle of carbon recycling to maintain balance, reduce chemical and plastic waste, and replace depleting traditional energy with clean energy, such as biofuels as an alternative to fossil fuels, and switch to electric vehicles. This considers meeting current needs for a decent living without compromising the rights of future generations, to help build prosperous and safe societies, ensure a healthy planet and a good climate for all living beings, and secure future growth potential driven by the quality of Ecosystems in the air, water, and soil.

At the same time, with the dramatic and rapid increase in Carbon Emissions and environmental disruptions due to the exponential growth of industrial production and the excessive consumption of non-renewable energy, strategic thinking among policymakers and decision-makers began to find optimal solutions to overcome this impasse. Undoubtedly, the CCE is a roadmap and an advanced model for embodying a green economy and protecting the Ecosystem through commitment to environmentally sustainable practices. It aims to encourage sustainable investment, financing, and green innovation in storage, utilization, removal, and capture of Carbon Dioxide and Gas Emissions from the economy and supply chains, preventing further damage caused by Global Warming. Therefore, there is an urgent need to accelerate and push countries toward a CCE, or what is known as achieving carbon neutrality to achieve net-zero Carbon Emissions. Unfortunately, carbon removal technologies are extremely expensive.

See: Ruggerio, C. A. 2021; Pascual, U., et al. 2023; Panchal, R., et al. 2021; Vidal, F., et al. 2024; Guo, Z., et al. 2021; Gautam, P., et al. 2025; Xiao, D. 2025; Shobande, O. A., et al. 2025

Fig.3. The Circular Carbon Economy (CCE) from the Perspective of Sustainable Development and Environmental Quality



Source: Alsarhan, L. M., et al. 2021

2.4 Emergence of Sustainable Marketing from The Green Orientation of Environmentally Responsible Marketing Activity

From a marketing perspective, Sustainability is a panoramic system and a robust business strategy comprising commercial activities and efforts related to marketing and sales, which considers the three dimensions of sustainable development. This performance measurement encompasses the three Ps: People, Profit, and Planet. In other words, Sustainable Marketing is a strategic approach consistent and aligned with achieving the goals of social development, economic growth, and long-term environmental impact. It considers the needs of both current and future generations. Therefore, developing a long-term Sustainable Marketing mix should include product planning and development, upgrading pricing policies, managing distribution channels and logistics, and activating promotional tools and marketing communications campaigns that address Social Responsibility, wealth creation, and protecting biodiversity and the Ecosystem from Pollution.

Moreover, one of the issues that arise in this context is the fundamental differences between Sustainable Marketing, on the one hand, and green or

eco marketing, on the other. Although the two terms are often used interchangeably, there is a difference between Green Marketing and Sustainable Marketing. Undoubtedly, Green Marketing is both part of the whole and a branch of the root. It is a component of Sustainable Marketing, rooted in Sustainability from the perspective of environmental practice and responsibility, and from the perspective of a commitment to offering greener goods and Eco-Friendly services, focusing on brand pricing based on Environmental Partnership, planning promotional and advertising campaigns that raise Environmental Awareness and tone, and finally, engaging with environmentally responsible intermediaries and distributors.

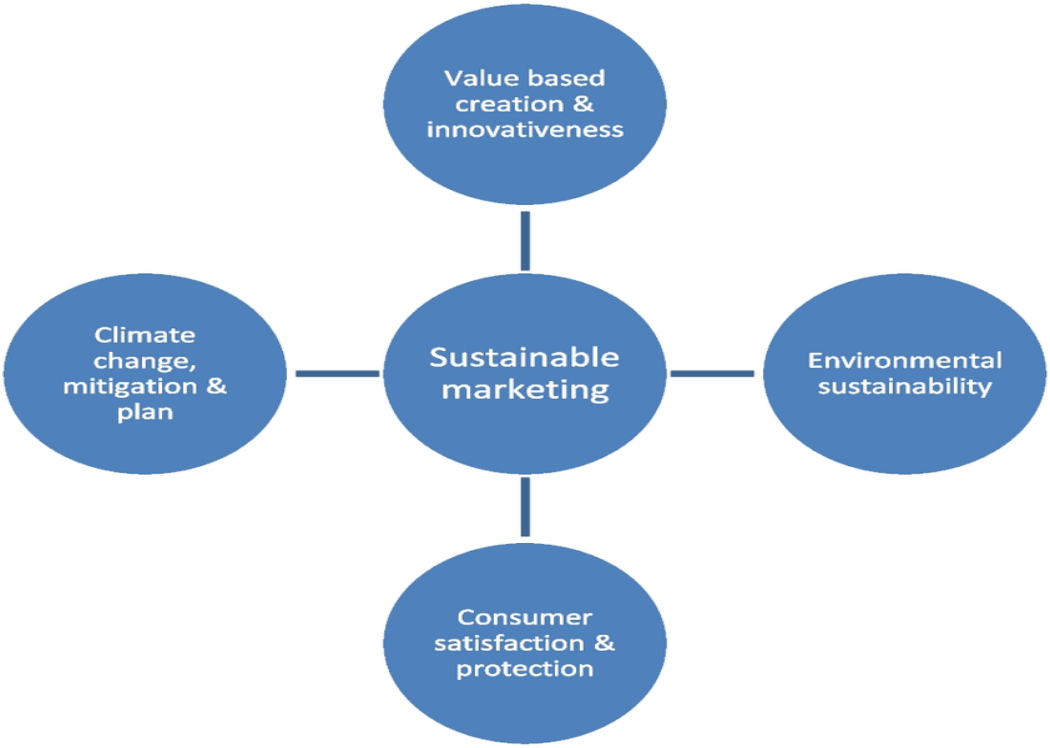
Sustainable Marketing topics and approaches are diverse and evolving. Key among these is studying and understanding consumer behavior and lifestyle from a Sustainability perspective to gain trust and satisfaction, increase customer engagement, and raise retention rates. Environmental Quality begins and ends with analyzing the influences and determinants of sustainable consumption. Furthermore, a large portion of Environmental Feasibility studies and research on new projects and products consider green purchasing habits as a fundamental pillar of evaluation. Moreover, Environmental Ethics are influenced by the buyer's Environmental Awareness, especially considering the widespread phenomenon of greenwashing, a false marketing campaign aimed at environmental misleading and deceiving. Therefore, to build a competitive reputation and a strong brand prestige, Sustainable Marketing must take off from the premise that Sustainability is a commercial driver and a strategic necessity. A prerequisite for excellence and consistent success is alignment with local, regional, and global environmental and climate issues.

Products and brands made from environmentally friendly, low-carbon materials represent a vital and fertile field for green and Sustainable Marketing, reducing and limiting environmental concerns and benefiting the planet and society, especially as consumers increasingly prioritize environmentally conscious brands in their daily choices. Examples include: electric cars, bioenergy, biofuels, organic foods, plant-based products, food wraps made from natural beeswax, clothing and handbags made from organic cotton, furniture made from recycled or reclaimed wood, electronics made

from recycled materials and energy-efficient components, public and garden lights powered by renewable energy sources, such as solar or wind power, green building materials, such as low-VOC paints and recycled insulation, products and services that responsibly use Natural Resources and reduce waste, stainless steel water bottles, Eco-Friendly cleaning products and phone cases, recycled stationery, organic skincare products, compostable plant pots, reusable kitchen storage bags, reusable coffee cups, Eco-Friendly home decor, etc..

See: Rastogi, T., et al. 2024; Richardson, N. 2024; Vijayalakshmi, M., et al. 2025; Yadav, M., et al. 2024; Proszowska, A., et al. 2024; Pellegrino, A. 2024; Kemper, J. A., & Ballantine, P. W. 2019; Hurth, V., & Whittlesea, E. 2017; Peterson, M., et al. 2021; Diez-Martin, F., et al. 2019

Fig.4. Sustainable Marketing as the Result of the Dynamic Interaction Between Marketing Objectives and Sustainable Development Goals



Source: Adewole, O. 2022

3. The Results of Harnessing Sustainable 3D Printing Technology in the Field of Green Marketing of Eco-Friendly Products

3.1 The Rise of Green Technologies amid the Gradual Transition from

Industry 4.0 to Industry 5.0

It can be said that Digital transformation and Environmental Sustainability are two sides of the same coin. The adoption of electronic tools and cyber innovations from the perspective of a clean environment, pristine nature, and even human health is an increasingly urgent and critical requirement due to dangerous, harmful, and sometimes fatal Carbon Emissions. Therefore, scientists and researchers in the field of environmental policies, supported by computers and databases, have worked hard to find computational solutions, create, develop, and implement smart systems to reduce Emissions, remove pollutants, and promote the use of renewable energy in line with the United Nations Sustainable Development Goals. Scientific and knowledge efforts are ongoing to develop effective revolutionary technologies for the green recovery of global economies, to maintain the balance of Ecosystems and Natural Capital, and to support a more sustainable and greener future in the long term. This is achieved through carbon capture, storage, utilization, and removal to mitigate and reduce greenhouse gas Emissions. Accordingly, Eco-Friendly Technology refers to harnessing enabling technologies to conserve Natural Resources and biodiversity, mitigate the adverse effects of Climate Change, and curb the negative impacts of human activities on the environment. This, in turn, contributes to achieving Sustainable Development goals and the well-being of human society.

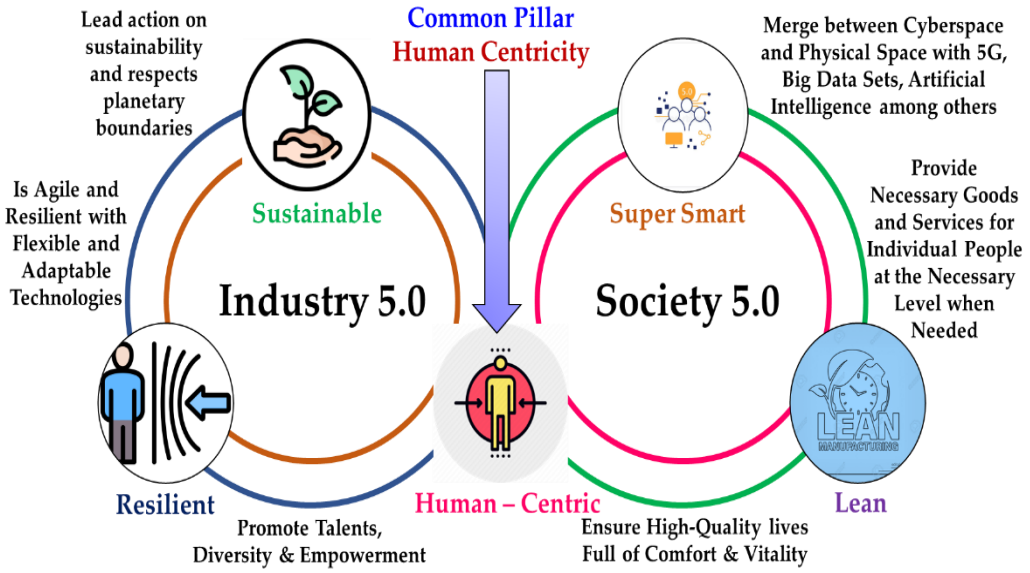
Industry 5.0, also known as the Fifth Wave of the Industrial Revolution, has positive implications for Environmental Sustainability. Indeed, its emergence was a reaction to correct the course of the Fourth Industrial Revolution, which was harshly criticized by green advocates and Sustainable Development experts. Industry 4.0 has had disastrous environmental consequences and has led to the exhaustion and depletion of Natural Resources due to massive production and intensive manufacturing, fueled by innovations in information technology and the internet. Therefore, the emergence of the fifth generation of the industrial revolution has begun to give a positive impression regarding the protection of the planet and Environmental Safety, considering the worsening global Climate Change crisis. Industry 5.0 is characterized by structural reform based on digital

networks and harmony between humans and machines, or what is known as collaborative robots. This has enabled the integration of these tools and methods to achieve Environmental Sustainability, enhance resource efficiency, and reduce and limit waste. This is an important turning point and inflection point in embodying Environmental Responsibility, and a decisive turning point that has caused a global uproar in achieving the goals and initiatives of sustainable development.

The environmental program and sustainable resource management occupy a prominent and pioneering position at the heart of contemporary Society 5.0, known as the era of the Super Smart Society. It is enhanced by technological advancements, digital transformation, and computer advancements. The latter aligns with the contexts of Industry 5.0 and the dynamics of QoL 5.0, which are human-centered. From an ecological perspective, this smart society means a commitment to a pivotal role in green Sustainability issues, reducing environmental waste, and preserving nature from Carbon Emissions and Greenhouse Gases. This is achieved by activating panoramic, Eco-Friendly initiatives and programs aimed at achieving a sustainable future based on combating Ecosystem Degradation. Advanced and transformative technologies such as Artificial Intelligence, Internet of Things, Big Data Analytics, and all digital innovations are integrated to address air and water Pollution issues. In precise terms, the Smart Society's efforts and plans are to establish the foundations for QoL through optimal exploitation of emerging CPSs and renewable energy sources. This will ultimately overcome environmental challenges and contribute to societal well-being in various aspects of life: clean air, clean cities, healthy food, and pure water.

See: Ivanov, D. 2023; Ghobakhloo, M., et al. 2023; Aheleroff, S., et al. 2022; Rame, R., et al. 2024; Daoud, A. O., et al. 2025; Zengin, Y., et al. 2021; Alimohammadlou, M., & Khoshsepehr, Z. 2023; Smuts, H., & Van der Merwe, A. 2022; Lesmana, J. 2025; Sanjaya, V. F. 2025

Fig.5. Achieving Environmental Quality of Life and Super-Smart Societies Through the Clean Technologies of the Fifth Industrial Revolution



Source: Mourtzis, D., et al. 2023

3.2 Examples of Green Disruptive Technologies, Clean Digital Innovations, and Eco-Friendly Cyber-Physical Systems (CPSs)

Rising levels of environmental concerns and losses, as well as societal harm, on the one hand, and the proliferation of climate-polluting or dirty technologies, on the other, have led to significant developments, including a compelling need for environmental concern and serious consideration of harnessing disruptive technology as an enabler and enhancer for protecting and preserving the environment before it's too late. In this regard, clean CPSs refer to the development of a combination of seamlessly integrated digital innovations, such as automation, robotics, and environmentally efficient machine learning. The applications of these innovative virtual-physical systems encompass a wide variety and a broad network of progressive and synergistic technologies, reinforced by 5G and satellite networks. These technologies are gaining increasing importance for promoting Eco-Friendly coexistence. They are a rapidly growing field, particularly with the widespread adoption of green and circular economic approaches aimed at decarbonizing the environment. Real-time monitoring and predictive maintenance enabled by Internet of Things and Artificial Intelligence technologies are key to managing, improving, and conserving resources, and suppressing and containing pollutants, for a more balanced and sustainable

future. Such as renewable energy, waste management, water conservation, environmental marketing, green architecture and construction, energy-efficient buildings and structures, sustainable supply chain and transportation systems, smart city urban planning, e-healthcare, and digital infrastructure.

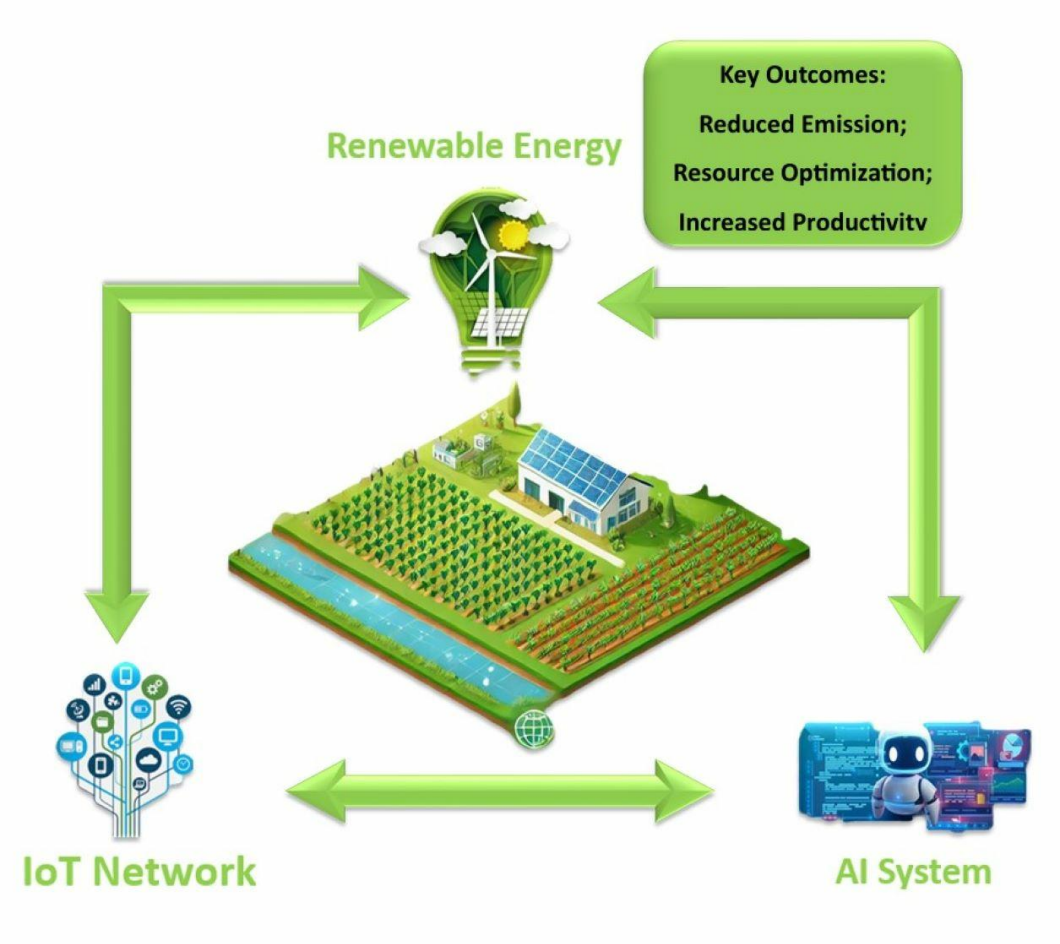
In a related context, in an era of highly complex Climate Change and increasingly severe global environmental challenges, promising scientific discoveries and pioneering computing and cloud innovations have emerged, highlighting the emergence of what is known as Green AI, with its innovative and immediate algorithmic solutions to promote sustainable, planet-friendly practices. Real-time environmental performance, enabled by algorithms and AI robots based on data science, programming models, machine and deep learning, and natural language processing, leads to more stable Ecosystems. It works to reduce Carbon Emissions that cause Global Warming, address the Degradation of Natural Capital, and address the depletion of non-renewable raw materials as a top priority. This, in turn, ensures the promotion and improvement of effective Sustainability in societal development. This significant positive impact on Environmental Quality is due to machine intelligence mimicking the capabilities and abilities of the human mind and brain for causal reasoning, logical analysis, accurate prediction, and informed decision-making. Other essential features reveal transformative horizons and gains, with strategic consequences, that avoid introducing long-term threats to governance, welfare, and environmental health.

In addition to the fundamental pillars of revolutionary information and communication technologies that influence environmental strategies and policies, and the urgent need to transition to a green and sustainable future, a new contemporary trend is Internet of Things, a cornerstone and reflection of what is known as digitization and modernization. IoT, with its advanced, interconnected sensors, networks, and systems, without human intervention, helps conscious and environmentally vigilant management achieve Sustainability and operational efficiency targets that are green in color. Indeed, IoT, with its smart sensors and applications, and its superior ability to sense the surrounding environment and collect, analyze, transmit, and share data in real time, helps drive sustainable growth and accelerate Sustainable Development and QoL from the perspective of monitoring and

Environmental Safety. This has become a more tangible reality than ever before. Industries, communities, cities, farms, and homes benefit from this powerful digital innovation in multiple ways, including improving transportation, logistics, and traffic systems, enhancing resource and energy management, and rationalizing their consumption in a smarter and more efficient manner. Undoubtedly, IoT, responsible for greening and Cleaner Production processes, offers significant advantages, bringing unique benefits in the areas of low-carbon products, reducing toxic waste, enhancing recyclability, managing air, water, weather, and soil quality, detecting pollutants, malfunctions, and waste, and mitigating all other harmful impacts on human well-being and Environmental Sustainability in the short and long term.

See: Melnyk, L., et al. 2019; Schuelke-Leech, B. A. 2021; Akkucuk, U. 2021; Ofori-Amoah, B. 2020; Feng, Q., et al. 2024; Yin, S., & Yu, Y. 2022; Mitra, C. K. 2023; Aroonsrimorakot, S., et al. 2021; Saleem, H., et al. 2022; Puangpontip, S., & Hewett, R. 2022; Singh, A. K. 2024; Yadav, H. 2024; Velrani, K. S., et al. 2025; Fraga-Lamas, P., et al. 2021; Alandjani, G. 2023

Fig.6. AI and Internet of Things as Eco-Friendly Disruptive Technologies



Source: Morkūnas, M., et al. 2024

3.3 3D Printing Technology as An Effective Tool for Reducing the Carbon Footprint considering the Rapid Digital Transformation

It has been proven beyond doubt that the rapid and dynamic development of smart and sustainable technologies, which have contributed in unprecedented ways to Sustainability, and environmental protection, and the progress and results achieved to date are extremely powerful. These technological solutions were created for a noble humanitarian purpose: preserving a safe and clean environment, i.e., achieving a sustainable Ecosystem. Efforts continue to be made and directed towards living on a healthy planet enhanced by physical and virtual systems. In this context, 3D Printing is a new technological paradigm and the spark of a transformative industrial revolution in the worlds and environments of the metaverse. Figures and statistics indicate that this technology is being harnessed in the

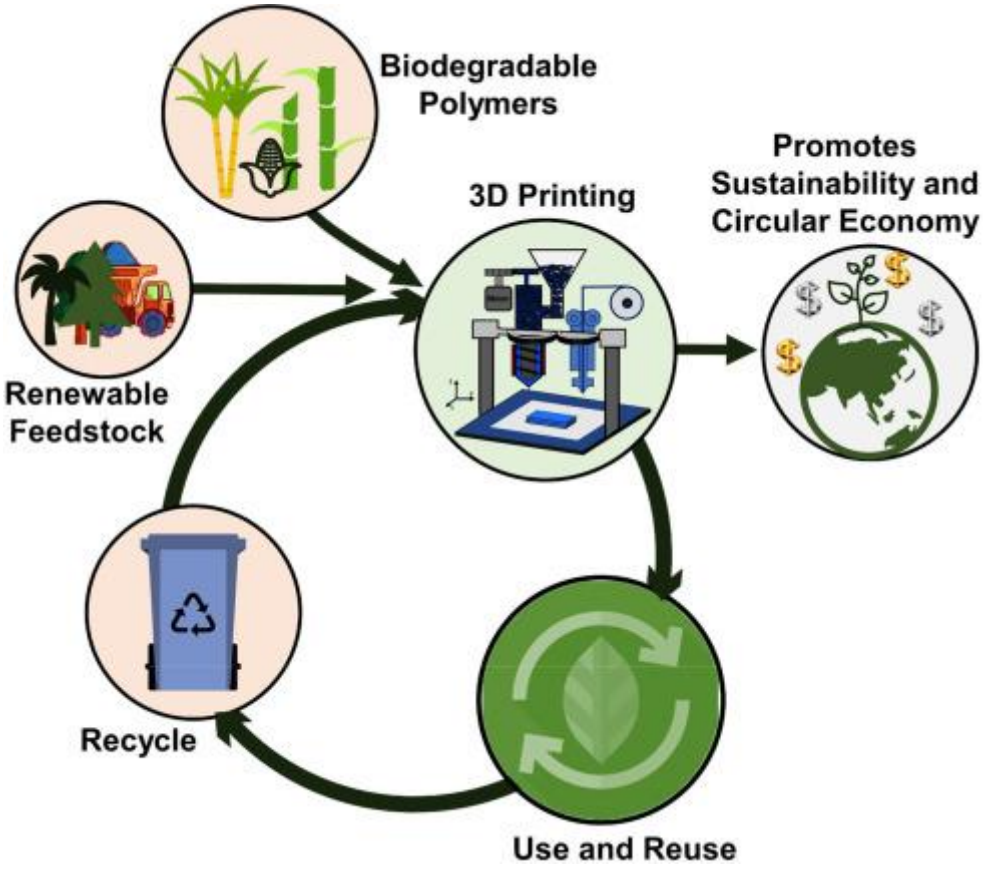
fields of business and is growing at a rapid pace and expanding irreversibly.

3D Printing Technology, also known as Additive Manufacturing, is an innovative digital tool in the fields of industry and production, supported by computer software and hardware, including files and models, and enhanced by advanced computer applications, such as Computer-Aided Design (CAD), where developers create parts, components, blocks, models, three-dimensional objects. The mechanism of action of these adaptive printers is that they have the superior ability to receive instructions from the computer equipped with operating systems to print overlapping, solid parts and complex shapes. They place and stack small, precise, successive layers of printable materials (such as plastics, metals, ceramics, sand, etc.) by printing one layer on top of the other, then combining and assembling them together, and so on. These steps and stages continue over time until the final shape is formed with specific functional, mechanical, and physical specifications, i.e. in terms of thickness, size, length, width, height, color, weight, etc.

The areas in which this revolutionary technology has flourished are diverse and renewable from a usage perspective. Some examples of the market sectors in which 3D Printing Technology has excelled include aerospace, weapons, dentistry, medical equipment, consumer goods, food industries (such as sugar and chocolate), coffee cups, plates, decorative furniture, footwear, jewelry, automotive engines, aircraft engines, spare parts, car seats, buildings and construction, architectural planning, tourism, infrastructure, art, heritage, and antiquities, packaging, toys, etc. The global 3D Printing market reached USD 24.61 billion in 2024 and is expected to reach approximately USD 117.78 billion by 2033. It is a rapidly evolving and dynamic industry, expanding at a compound annual growth rate of 19% from 2024 to 2033. It is worth noting that the financial feasibility of harnessing this technology has become available to small and medium-sized enterprises with limited budgets, as well as large enterprises, due to the trend of declining costs.

See: Jiménez, M., et al. 2019; Praveena, B. A., et al. 2022; Lu, B., et al. 2015; Kumar, L. J., et al. 2019; Rahman, Z., et al. 2018; Jadhav, A., & Jadhav, V. S. 2022; Agrawaal, H., & Thompson, J. E. 2021; Kalender, M., et al. 2019; Vora, H. D., & Sanyal, S. 2020

Fig.7. 3D Printing and Additive Manufacturing as Enablers and Enhancers of Environmental Sustainability



Source: Hassan, M., et al. 2024

3.4 Green Competitive Advantages of Sustainable Marketing Based on Eco-Friendly 3D Printing Technology

This section aims to fill this research gap by identifying the causal effects and positive consequences of 3D Printing or Additive Manufacturing Technology on Green Responsibility and Environmental Sustainability in marketing activities. Accordingly, this section of the study also explains how 3D Printing Technology can enable and support business analytics and industrial marketing. It discusses the challenges of providing digital and physical solutions for managing products and prototypes (molds, designs, structures, etc.), and offers insights into how this integration can reshape marketing practices in a highly competitive and intense world. The trends and implications of informed marketing decisions in the context of the impact, importance, uses, and applications of Additive Manufacturing

Technology are looming and worth highlighting. This revolution has left profound impacts on QoL and Sustainability and is undoubtedly a new scientific discovery comparable to inventions and innovations throughout human history, such as the light bulb, the steam engine, and the World Wide Web.

Despite the growing popularity of 3D Printing Technology, marketers have been slow to adopt it. Fortunately, the success of a handful of companies that have harnessed and adapted it has helped them discover that traditional and digital marketing and adaptive 3D Printing can go hand in hand. Therefore, there is a pressing need to answer the research question: How can Additive Manufacturing Technology enhance the Sustainable Marketing of Eco-Friendly brands to reach a more mature and environmentally conscious target audience? In this context, we present to the reader a range of gains from developing automated 3D Printing Technology as a promising tool for marketing in general, and Sustainable Marketing in particular, which bring tremendous benefits to both the marketer and the end user, as follows:

 Sculpting and displaying customized, enhanced, and attractive 3D products and merchandise to meet the expectations, requirements, and aspirations of the target audience.

 Enriching customer experiences with enjoyable and unique purchasing journeys, based on consumer testing to determine preferred, desirable, and comfortable designs.

 Providing cost-effective and efficient marketing solutions, a technology capable of creating marketing and promotional elements quickly and at very low prices.

 Improving the level and quality of service and customer relationships, empowering them through customized and appropriate models and providing more interactive value propositions.

 Enhancing the vitality and effectiveness of rapid innovation and creativity management, so that the development and modernization of production lines proceed smoothly, streamlined, and agilely.

 Increasing production and operational efficiency by rationalizing and rationalizing costs and expenses, shortening lead times, and reducing labor.

 Upgrading advertising strategy to a new level, enabling the

implementation of creative visual campaigns such as Guerrilla Marketing.

 Creating all types of advertisements, mockups, and other display and advertising materials to attract and engage customers who admire brands.

 Encouraging green and Sustainable Marketing, protecting the planet and Ecosystem from Pollution and Environmental Degradation by reducing waste, squandering, and waste.

 Encouraging a commitment to Cleaner Production and the sale of Eco-Friendly products and brands, as this approach saves energy and leaves a smaller Carbon Footprint.

As discussed above, the environmental constraints in the context of the alliance between Sustainable Marketing and 3D Printing services are inherent and critical and should be considered. Undoubtedly, environmental concerns are a fundamental, sensitive, and pressing issue from the perspective of Sustainability, waste reduction, and energy conservation. Therefore, efforts are underway to use bio-based or recycled filaments and materials as an alternative option for printing. These materials are classified as green materials with a favorable environmental impact, avoiding Pollutants such as conventional plastics. Additive Manufacturing remains significantly superior to traditional processes when it comes to building a more sustainable future. Indeed, it is a hallmark of companies that enjoy the advantage of environmentally conscious initiatives and have made a significant difference in reducing their Carbon Footprint and rationalizing energy consumption. A growing number of organizations and consumers are prioritizing sustainable and Eco-Friendly business activities, due to increased awareness of the importance of protecting their Natural Capital.

Accordingly, there are significant competitive environmental advantages for Sustainable Marketing enhanced by 3D Printing applications, largely revolving around products with added environmental value. This strategic partnership has changed the rules and scenarios of the competitive game in the era of science fiction, digital dominance, and the circular economy. It will achieve further qualitative progress as a smart solution, a proactive approach, and a pioneering technology for clean design and Green Marketing for more efficient and effective brands, with high precision, shorter lead times, and significantly less waste of raw materials, in terms of

cost reduction. Most importantly, it utilizes new and smart materials to appeal to Sustainability. At a time when Environmental Awareness is at the forefront of marketing, commercial, and sales reviews and evaluations, Hyper-Personalization with an environmental footprint, and the retention of customers with green purchasing and sustainable consumption, is gaining steady momentum and is a true benchmark for outperforming competitors in generating additional sales and growing market share.

See: Bai, G., et al. 2021; Albalawi, H. I., et al. 2021; Tabassum, T., & Mir, A. A. 2023; Alotaibi, B. S., et al. 2024; Elessawy, N. A., et al. 2024; Agrawal, K., & Bhat, A. R. 2025; Kumar, V., et al. 2024; Paszkiewicz, S., et al. 2024; Kumar, S. V., et al. 2024; Thorbole, A., et al. 2024; Batwara, A., et al. 2022; Liu, Z., 2016

Fig.8. 3D Printing and Its Role in Achieving a Green Competitive Advantage for The Environmental Marketer Aiming for Hyper-Personalization

Source: Faster Capital Team. 2025

4. Conclusion

This study addressed the issue of marketing under the umbrella of Sustainable Development enhanced by 3D Printing technologies. Which aims to highlight the emergence of the marketing Sustainability system. As a result of the consequences and repercussions of global Climate Change and the risks of Natural Capital Degradation. Where it dealt with the dilemma of Ecosystem Pollution, considering the threats of Global Warming and Carbon Emissions. It discussed the topics of Environmental Responsibility and Cleaner Production for companies as a dynamic tributary and a true touchstone for social commitments. In addition to evaluating the management and performance of Environmental Sustainability as a fundamental pillar and cornerstone of Sustainable Development and the

CCE. This gave birth to Sustainable Marketing as a natural extension of Green Marketing that is aware of protecting the environment, reducing waste and lowering the Carbon Footprint. The research paper concluded that the environmental advantages and benefits of Sustainable Marketing of Eco-Friendly products and brands based on Additive Manufacturing reflect effective digital innovations. This paper shows the upgrowth of green technology, and amidst the rise of Industry 5.0, Society 5.0, as well as Green AI and Eco-Friendly IoT as manifestations of Clean Disruptive Technologies.

Global governments and industrial corporations have wreaked havoc, destruction, and devastation on the Natural Environment, committing flagrant crimes and violations against Natural Capital, particularly in the United States and the People's Republic of China, as well as other G7 countries, the world's most industrialized. Emerging and developing nations cannot be excused. Therefore, protecting the planet is everyone's responsibility, without exception. The problem stems from the conflict, and sometimes contradiction, between the demands of economic growth and industrial development, without a doubt, and the environmental consequences of factories, logistics chains, and other Carbon Emissions. Meanwhile, calls and voices calling for Sustainability, well-being, and QoL in general, and for preserving the health of the planet in particular, have escalated.

With the dawn of the CCE, the Fifth Industrial Revolution, and a Super-Smart Society powered by CPSs, digital, computing, and cloud innovations, this has coincided with the emergence of clean, Green Technologies to combat Global Warming, which threatens the entire Ecosystem. This boom has produced numerous advanced tools for responsible and environmentally conscious marketing performance. Among these invented technologies are applications known as 3D Printing or Additive Manufacturing, which carry long-term marketing benefits that primarily serve Sustainable Development and environmental management.

Here are the most important findings from this study:

 The deterioration and damage to Ecosystems at record levels is evident in the steady and cumulative increases in Greenhouse Gases, which trap heat in the planet's atmosphere. This is primarily due to human activities

and the pursuit of material profit. Industrialization and the combustion of fossil fuels are a major source of Carbon Dioxide Emissions, resulting in a global phenomenon called Global Warming—a rise in the average temperature of the Earth's surface across the globe. Therefore, there is a consensus that environmental issues, particularly Climate Change, are now the most serious and dangerous challenge and concern. Regrettably, despite the enactment of environmental laws, legislation, and regulations, they continue to destabilize and threaten the Ecosystem and biodiversity. They are also expanding and becoming more severe and devastating than ever before.

 The commitments and obligations of environmentally vigilant management and performance are of paramount importance. They stem purely from the ethical conscience and social citizenship of business organizations. CER refers to deepening the meaning of Environmental Quality by broadening the perspectives and understanding of all stakeholders and relevant parties, both inside and outside the organization. This understanding is reinforced by the shift toward a greener future, supporting sustainable initiatives, and promoting cleaner production. This has become a competitive advantage that must be possessed to compete and outperform competitors in gaining the support of environmentally conscious customers. Therefore, CEOs must believe that their companies must act in an Eco-Friendly manner and methodology and must allocate manpower and funds to find optimal solutions to crises and problems directly related to environmental protection.

 Strategically developing more Sustainable Development solutions is an urgent requirement and a dire need for all of humanity, emphasizing the synergy between circular economic practices and sustainable development. The transition from a traditional linear economy to a circular economy has become easier than ever before. People need clean air to breathe, pure water to drink, and healthy living spaces. This is what Environmental Sustainability achieves if properly implemented. Living in such an environment would be impossible if social and environmental issues were ignored and neglected, the consequences of which are becoming increasingly severe. The responsibility no longer falls solely on the UNEP, ISO, or nature conservation groups. These bodies are fulfilling their humanitarian duty to help secure a

livable future, but the responsibility lies with everyone, without exception.

 Modern marketing thought, with its flexibility, agility, and ability to respond effectively to the circumstances, conditions, and realities surrounding business, has been able to seamlessly integrate and engage in sustainable development. This has been achieved by fostering a new approach that embraces Green Marketing, with its creative skills and methods in the field of Environmental Efficiency and has transcended the boundaries of planetary protection to social agendas and economic issues. This philosophy is termed "Sustainable Marketing." One of the roles of the sustainable marketer is to spread environmental culture among the public and individuals who lack awareness of the benefits of purchasing Eco-Friendly products. From a marketing perspective, green Sustainability has manifested itself in marketers' attention to environmental considerations and Climate Change issues. Managing the marketplace requires expending all possible efforts to protect the planet from the effects of environmental Pollution.

 ICTs and CPSs are a rapidly growing field, and one of the most vital areas experiencing rapid progress is Environmental Sustainability. The emergence of Green Technology amidst the rise of the fifth generation of the industrial revolution and the super-intelligent society—all of which are human-centered waves based on collaborative and symbiotic solutions between humans and robots—has yielded significant contributions and innovative collaborations in managing renewable resources, reducing waste, seizing carbon, and rationalizing energy consumption. With clean technology continuing to evolve at an astonishing pace, seizing opportunities and overcoming barriers will be the benchmark for survival in this digitally transformed landscape. Examples include Green AI algorithms and Eco-Friendly IoT sensors.

 3D Printing Technology represents one of the most effective digital innovations for achieving environmental goals. It appears to be a promising alternative in serving Sustainable Development agendas related to environmental protection. Adaptive printing applications possess outstanding potential and practical solutions to address societal and economic problems, including Sustainability. Indeed, this pioneering technology, as an intelligent system, has opened new horizons for the transition to green (Going Green)

and significantly increased environmental efficiency. Given the novelty of this innovative technology, and when comparing Additive Manufacturing techniques with traditional manufacturing, it is likely that 3D Printing will continue to become increasingly environmentally friendly. This means adopting practices and methodologies aimed at reducing environmental impact and embracing the principles of recycling and cleaner production.

 Environmentally conscious marketing, supported by 3D Printing, offers numerous advantages that elevate Sustainable Marketing outcomes and results in exceptional and unique competitive performances. At the forefront of these positive gains is reducing the environmental footprint. This can be achieved by harnessing and adapting this powerful tool. Integrating digital manufacturing and computer science into adaptive printing technology provides more efficient, creative, and Sustainable Marketing strategies, techniques, and tools. Marketers are harnessing the potential of Additive Manufacturing for customized products, known as Hyper-Personalization, and enhancing the experiences of customers who tend to buy and consume sustainable materials and aspire to a greener future.

Last but not least, these research papers emphasize the need for Sustainability-based Green Marketing executives to adopt a proactive approach to reducing Carbon Footprints, minimizing waste, encouraging the use of recycled materials, and other environmentally responsible practices. Green marketers should help improve the environment wherever possible. Addressing the environmental impact of marketing requires a conscientious and ethical effort to explore and adopt Eco-Friendly alternatives and promote a more environmentally responsible approach. Therefore, integrating Environmental Sustainability into business and marketing operations is the best strategic approach to achieving these goals. Finally, Sustainable Marketing, enhanced by 3D Printing or Additive Manufacturing green technology, is becoming a necessity, not just an option. Indeed, marketers urgently need to shift their decisions from simply responding to consumer tastes and market preferences to an environmentally responsible approach that drives audience support for clean products and services and builds sustainable communities.

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