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The Role of Internet of Things in Advancing Sustainable Consumption

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Abstract: Rapid environmental degradation in recent years has sparked considerable interest in sustainable consumption. As a result, many researchers are currently investigating the impact of Internet of Things (IoT) on sustainable consumption. In current years, interest in the IoT has skyrocketed. The phrase "Internet of Things" describes the practice of interconnecting various non-traditional devices, such as those used in manufacturing, healthcare, and the home, with the web. Controllers based on microprocessors are now widely used in anything from toaster ovens to aircraft. This study looks at how sustainable consumption has evolved in light of the IoT. Numerous reports have highlighted the importance of energy savings and the IoT in developing eco-friendly metropolises. For sustainable consumption to flourish, smart cities are essential.

Keywords: *IoT, Sustainability, Sustainable Consumption*

1. Introduction

The concept of sustainable consumption pertains to the use of commodities and services that fulfil the fundamental requirements of the current generation while safeguarding the capacity of future generations to fulfil their own needs. In recent years, there, there has been an increasing awareness of the need for sustainable consumption, as the world population continues to grow and natural resources become increasingly scarce [1]. The IoT possesses the capability to fundamentally alter the manner in which we engage with and utilise goods and services, hence fostering sustainability. The term "IoT" pertains to the integration also interconnection of many physical items, including smartphones, appliances, and cars, facilitated by the internet. This technology allows for the collection and analysis of data, which can be used to improve efficiency, reduce waste, and promote sustainable consumption [2].

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1.1. Sustainable Consumption

Sustainable consumption refers to the use of goods and services that have a minimal impact on the environment and natural resources, while also meeting the basic needs of individuals and society. This includes reducing waste and pollution, conserving natural resources, and promoting fair trade and labor practices. It also involves considering the entire lifecycle of a product, from its production and transportation to its disposal or recycling. The goal of sustainable consumption is to create a more sustainable and equitable world by changing the way we consume goods and services [3]

Sustainable consumption (SC) is encouraged in order to limit harmful environmental and social externalities and to provide markets for environmentally friendly goods. The term "sustainable" is used to describe product characteristics that are both ecologically (pollution, waste, resource consumption) and socially (health, welfare) responsible [4,5]. Standards, levies, subsidies, and educational initiatives are all used as administrative tools and techniques to support SC. Additionally, a number of strategies are proposed to safeguard consumers against false sustainability information in numerous fields relating to corporate reporting and promotion.

The tendency to take into account the social aspects of SC focuses on how the items are produced. The main concern for consumers is the pollution or health effects that may result from using the items, as well as how this use would

affect the production components, such as laborers and resources. Therefore, it is crucial to increase SC enterprises and policies in order to take into account and establish services as well as product and procedure holdings. Governments typically use a variety of ways to target their policies to certain consumer groups based on their superior knowledge of social and economic behavior [6,7]. Due to the complexity of the created technologies, sustainable development strategies also call for more integrated programs and efficient sustainable consumption [8].

Technology's emergence as a life-enriching tool has come at a significant cost. While businesses grow and cultures advance, pollution and climate change harm the environment. Hence, it is imperative to embrace a more conscientious way of living that mitigates the adverse impacts of consumerism and technology on the natural world. Sustainable consumption has been a successful strategy for reducing this environmental impact without sacrificing consumption quality or quantity. The field of sustainable consumption has had a notable surge in research activity in recent years [1], attracting attention from scholars and practitioners alike. As a result, it is usual to find a number of literature reviews that critically assess the state of the art in this specific field of academic study.

1.2. Internet of Things (IOT)

IoT is a platform in which the advancements of sensing, MC (mobile computing) and cloud server technologies and platforms are put together, and it has aroused great influence on the present era. IoT technologies are applicable in various applications [9]. Therefore, the fundamental focus is on considering the specific sectors having diverse requirements. In general, these applications are responsible for generating a huge volume of data, whose storage is done frequently in unreliable storage in permanent or temporary way. This technology has capacity to collect and transmit the enormous volume of data. For this, the advanced communication technologies are exploited, and an analysis is performed on them to make an intelligent decision. There is necessity of vast storage, CC (cloud computing), and large bandwidth to transmit the data for making IoT feasible to fulfil the big data requirements of IoT.

The huge data is processed and forwarded by utilizing a large amount of energy in the IoT devices. The major issue among the researchers is the negative effect of energy usage and emission of Green House Gas of ICT Industry while recognizing the innovative [10] concepts for mitigating the energy utilization for a sustainable and green environment of IoT. There is need to develop more energy sources for meeting the higher requirements of energy consumption. However, the traditional and suggested unit of energy generation sources are ineffective for accomplishing the energy requirements in the near future. Consequently, the renewable energy is effective source to fulfill the demands of energy for IoT devices. The effective and smart methods may result in alleviating the power usage. To overcome this issue, EH (energy harvesting) method is employed, which is a procedure of deriving or generating the energy from the source of energy present in outer location. The external source of energy is also known as an ambient energy source that has no cost for its deployment. The storage and conversion of this ambient energy is done into electrical source [11]. The subsequent stage aims to transmit this energy to the devices. Hence, the IoT systems are integrated with the practical methods for lessening the energy usage to process and transit the enormous sized data and improving the smart cities quality of life. This offers greenery, sustainability and safety to the place.

IoT is utilized to gather and transmit the huge volume of data with the help of advanced communication technologies. An analysis can be done to make the decision intelligently [12]. A large storage and higher bandwidth are required for transmitting the data in IoT. This process utilizes a huge amount of energy. Thus, various integrated methods are employed for lessening the energy utilization. The pollution hazards are diminished, and the energy needs and effective resource consumption are alleviated to establish a link amid green IoT along with big data for constructing sustainable, green, also smart cities. IoT is significant to enhance the smart cities, affected in dissimilar ways through its several applications utilized to enhance the public transformation, diminish the traffic congestion, generate the less expensive municipal services, keep the citizens secure and healthier, lessen the energy utilization, enhance the monitoring systems, and reduce the pollution [13].

2. Role of IoT in Sustainable Consumption: Recent Trends

The goal of sustainable consumption is to create and market goods and services that satisfy consumer needs for quality, effectiveness, and affordability while not negatively affecting the environment, society, or the economy. One of the main ways that IoT can promote sustainable consumption is through the use of smart appliances. Smart appliances, such as washing machines and refrigerators, can be controlled remotely through a smartphone or other device. This allows for more efficient use of energy, as users can program the appliances to run during off-peak hours when energy costs are lower. Additionally, smart appliances can collect data on usage patterns, which can be used to make recommendations for more efficient use [3].

Despite this, the primary focus of the researchers is on a variety of environmental concerns associated with the IoT, like energy utilisation, energy conservation, carbon emission, carbon labelling, and footprint [14]. Therefore, IoT strategies that are based on carbon emission reduction

methods (CER) along with energy efficiency technologies (EE) are essential to sustainable consumption. These tactics are valuable not only for offering a real-time, intelligent environment, but also for gathering and aggregating data during the lifetime of product manufacturing regarding energy consumption. The needs for smart cities and sustainability can be satisfied by utilising green internet of things technology, which is an important technology for lowering carbon emissions and energy usage. Despite their popularity, IoT devices consume a significant amount of power. For Internet of Things devices, for instance, there have been suggestions made for wake-up protocols and sleep patterns as a means of lowering both energy consumption and resource utilisation. Numerous strategies for reducing the amount of energy used by the internet of things have been offered by researchers. In order to accomplish this goal, Internet of Things devices must improve their data communication capabilities while also adhering to applicable EE rules. [15].

This study looked at ways to make cities smarter, greener, more sustainable, and safer while also enhancing the quality of our lives. We focused on the green IoT in particular for its effective resource use, creation of a sustainable economy, reduction of energy consumption, reduction of pollution, and reduction of e-waste. Anyone interested in learning more about research on eco-friendly and sustainable cities based on cutting-edge IoT technology may use the poll results as a useful resource. The key components of enabling technologies make the smart objects in smart cities smarter so they can complete their jobs on their own. To make the city eco-friendly and sustainable, these objects connect with each other and with people while using bandwidth and energy efficiently, minimizing harmful emissions, and generating less e-waste. In order to create eco-friendly and sustainable smart cities, we also highlighted problems and potential future research directions.

The integration of IoT in sustainable consumption can lead to reduced waste and greenhouse gas emissions through efficient supply chain management. H. Nozari, et.al (2021) developed a model to deploy a green IoT-based supply chain [2]. There were 4 phases in this model and the views of active experts in this field were studied and reviewed. This model was implemented to represent the direct association amid the process of generating the data and its way of interacting with the sectors at which the environmental sustainability laid impact. A clear pathway was presented to make the green decision with sustainability in the supply chain. The developed model was useful for the experts in the supply chain field and provided the way to exploit the green supply chain efficiently with regard to a technology in manufacturing organizations. Similarly, Aytaç, K., & Korçak, Ö. (2021) used Edge computing based IoT technology to reduce waste in Quick Service Restaurants (QSRs) [16]. QSR industry's business accounts for a sizable and growing portion of the international food trade. To optimize service delivery and reduce waste in such a vast field, effective resource management is essential. Edge computing is a crucial technology in an IoT platform since it allows for instantaneous decisions, minimal latency, less redundancy in resources, and increased security. One promising approach to addressing the limitations as well as issues related with current urban waste management methods is the integration of technologies like the "internet of things," "artificial intelligence," "cloud computing," along with "intelligent transportation systems" into the existing waste administration system along with waste collection infrastructure, treatment, transportation, segregation, as well as final disposal. By using automation via cyber-physical systems, waste management procedures can be made smart within the context of the smart city concept [17].

Along with waste management, IoT's role has been pivotal in energy efficiency. F. A. Almai, et.al (2021) emphasized on suggesting schemes and mechanism for providing smartness, greenery, sustainability, and safety [18]. Generally, the major focus was on the green IoT for its effective utilization of resources, creation of a sustainable, energy consumption reduction, reduction of pollution, as well as e-waste reduction. For learning more about research on eco-friendly and sustainable cities, on the basis of cutting-edge IoT technology made the deployment of poll results as a useful resource. To transform the city sustainable as well as eco-friendly, these things connected with each other and with people while utilizing bandwidth and energy efficiently, minimizing harmful emissions, and generating less e-waste. Moreover, A. M. Said, et.al (2021) suggested an IoT-based approach for a green intelligent parking system. For this, a mathematical model of game theory was proposed [19]. The reservation system of the suggested system was modelled using the game theory. Three main issues addressed: parking costs, how far the parking was from the automobile drivers' destinations, and the length of time needed to park. As a result, the reasonably priced parking lots were offered to project a solution for dealing with the parking issues for making the driver capable of selecting and place which was nearer to the destination. The technique that was advised resulted in time and energy savings, reduced the anxiety associated with being stuck in traffic, and as a direct result offered a cleaner environment and an improved quality of life.

More studies on energy efficiency aspect of sustainability have been presented recently. Tiwari et al., (2022) presented IoT based sustainable energy management for tourism sites [20]. The development of long-standing cultural traditions and responsible use of energy resources have been critical factors in the current expansion of tourist destinations. It is argued that the rate of growth must accommodate technical advances while taking into account future generations.

Therefore, it is absolutely necessary to implement cutting-edge technology such as the internet of things and to develop a more sustainable approach to tourism. O. Said, et.al (2020) also projected an IoT EMS (Energy Management Scheme) in which 3 techniques were implemented [21]. The initial technique focused on mitigating the amount of data whose transmission was done across green IoT environment. The next one was deployed for scheduling the tasks of the critical energy IoT motes. The last technique was fault tolerant, and capable of tackling the energy issues occurred before the nodes. The projected scheme was computed on NS2. The simulation outcomes indicated that the projected scheme performed more effectively as compared to other methods for alleviating the energy utilization rate, number of failed nodes because of energy loss, and prolonging the duration of network. In addition, H. A. B. Salameh et al. (2021) proposed a workable cross-layer design with the intention of minimizing the amount of energy consumed by CR-based green IoT networks, focus to IoT delay assurances, verified primary radio (PR) channel obtainability, along with PR user actions [22]. This cross-layer design aimed to minimize the amount of energy used by IoT networks. This design utilized JO, which stands for "joint optimization," for both the modulation order as a physical-layer parameter along with the backoff probability as a MAC-layer parameter. The simulation results, when compared to the findings of the comparative study, showed that the strategy that was suggested gave much lower latency needs and energy usage.

Smart grids are tightly intertwined with sustainable consumption. Schappert & von Hauff (2020) presented IoT-enabled smart grids for smart cities. However, ultimately, household use determines the environmental effects of smart grids. Smart grids are most closely associated with the housing sector of energy usage [23]. Clean energy sources are considered integral to the smart grid's vision of sustainable consumption. Smart grids are very useful for renewable energy. For this reason, efforts are made to rise the usage of renewable energy sources in order to cut down on carbon dioxide emissions and the consumption of non-renewable fossil fuels. Also, X. Zhang, et.al (2021) presented an IoT-SGE (Internet of Things based Smart Green Energy) for smart cities [24]. Smart cities were capable of controlling the energy with fine precision by implementing ubiquitous monitoring and secure connections. DRL (deep reinforcement learning) algorithm was utilized for generating an IoT-based smart energy management system for lessening the power wastage because of non-concurrent state switching and power surges. The local energy efficient and decentralized urban supply is utilized in reducing the emissions. The findings revealed the applicability of the presented algorithm to enhance the operational logs, reduce the power necessity, wastage, and failure, to forecast the energy demand in smart cities also to diminish the cost. More on smart cities, P. Chithaluru, et.al (2020) established an I-AREOR (Improved-Adaptive Ranking based Energy-efficient Opportunistic Routing protocol) on the basis of different factors such as regional density, relative distance, and RE (residual energy) [25]. EE (energy efficiency) was enhanced by tackling the issues of FND (first node death), HND (half node death) and LND (last node death). The utilized factors were taken into consideration for generating a solution so that the time of FND was prolonged. The energy metrics were employed on the basis of dynamic threshold for every round. The outcomes validated the reliability of the established protocol in terms of longer duration of network in contrast to other methods.

Moreover, J. Bai, et.al (2021) introduced a general design principle to develop a mechanism called ADCC (Adaptive Duty Cycle Control) for making the networks more efficient and effective [26]. It was proposed that a method might be used to minimize congestion as well as real-time processing, and this method would integrate the dynamic modification of the duty cycle with the complete utilisation of any residual energy. Therefore, the notion of Green IoT was accomplished. The results of experiments indicated that the introduced mechanism assisted in alleviating the data drop ratio by$20.95\% - 77.85\%$ for which the duration of network was not affected. Similarly, P. Chen, et.al (2021) introduced a CRBFT (Credit Reinforce Byzantine Fault Tolerance) consensus algorithm for which RL (reinforcement learning) method was exploited [27]. This method was utilized to adjust the credit of node which resulted in changing the position of nodes. The introduced algorithm was effective for recognizing the malevolent and illegal nodes in automatic way and assisting them to escape for lessening the consensus delay up to 40%, and the traffic overhead up to 45% for saving the energy and reducing the emissions. Hence, the system was made appropriate to generate Green IoT and promote the advancement of smart cities.

Furthermore, A. Mukherjee, et.al (2020) investigated an effective and green dynamic clustering technique on the basis of power demand and information volume [28]. Any information loss was avoided using ML (machine learning) technique on the basis of forming the dynamic cluster. First of all, the energy necessities helped in splitting the poison distributed nodes into two temporary clusters. After that, a set threshold equalized the energy requirements within these clusters. The amount of information was computed in every cluster to form the dynamic clusters. The simulation outcomes reported that the investigated technique was effective to equalize the networks power demand also further augment the cluster information, for enhancing the energy efficacy of the entire network. Also, Y. Ren, et.al (2021) presented a dynamic in-network caching method for finding the cache of sensed data in brokers or not, at which the encapsulation of the location as well as clients delay requirement, traffic load of the brokers and energy level of

the sensor nodes was done. Subsequently, a case study was conducted for quantifying the presented method [29]. The results exhibited the supremacy of the presented method over other methods concerning energy saving. At last, the future research directions were summarized for attaining in-network caching so that the green IoT was deployed.

2.1. Table Recent Studies towards the role of IoT in Sustainable Consumption

Author	Year	Area of Focus
Tiwari et. al.	2022	Energy Management (Tourism Destinations)
M.M. Razip et al.	2022	Waste management (Households)
K. Aytaç, & O. Korçak,	2021	Waste management (Quick Service Restaurants)
H. Nozari, et.al	2021	Green Supply chain / IoE-based sustainable marketing (Dairy Industry)
F. A. Almai, et.al	2021	Energy Efficiency & Waste Management (Smart Cities)
A. M. Said, et.al	2021	Smart Cities / IoT-based parking system
J. Bai, et.al	2021	ADCC (Adaptive Duty Cycle Control)
H. A. B. Salameh, et.al	2021	Energy consumption in the CR-based green IoT networks
X. Zhang, et.al	2021	Smart Green Energy (Smart cities)
P. Chen, et.al	2021	CRBFT (Credit Reinforce Byzantine Fault Tolerance) consensus algorithm
Y. Ren, et.al	2021	Energy Efficiency
O. Said, et.al	2020	Energy Management
Schappert & von Hauff	2020	Energy Efficiency (Smart Grid)
P. Chithaluru, et.al	2020	Sensor based communication (Smart cities)
A. Mukherjee, et.al	2020	Energy Efficiency

3. Conclusion

More focus on studies regarding IoT-enabled sustainable consumption is on smart cities. Smart cities are dynamically rested upon IoT sensors and actuators to advance amenities and reduce operating costs by automation. Cities can be

made smart by applying any combination of different smart gadgets. Not all components are required for a city to be considered as smart. The number of smart gadgets relies upon cost and accessible innovation. At the place of smart terminals like customer-operated machines for selling or payments, there is the availability of open data. These data accesses come up with the challenges of integrity and confidentiality. Further, the proliferation of connected devices and digital technologies can be leveraged to provide shoppers an edge. A high level of utility and a significant decrease in complexity for clients, however, necessitate an integrated solution. With the help of an IoT decision support system, shoppers can get expert advice and make informed purchases that are good for the environment and promote sustainable consumption [30].

IoT has the potential to revolutionize the way we consume goods and services by making them more sustainable. IoT can be used to promote sustainable consumption in a number of areas, including smart appliances, sustainable transportation, sustainable building design, and smart cities. However, it is important to note that the success of IoT in promoting sustainable consumption will depend on a number of factors, including the availability of data, the ability to analyze it, and the ability to use it to make recommendations for more sustainable consumption. It is also important to note that while IoT has the potential to promote sustainable consumption; it also has the potential to contribute to the problem of e-waste [31]. The improving count of devices connected to the internet means that more and more electronic waste is being generated. To address this issue, it is important to develop strategies for the responsible disposal of e-waste and to promote the use of sustainable materials in the production of IoT devices [17]. IoT-enabled sustainable consumption has the potential to reduce resource consumption, lower greenhouse gas emissions, and improve the efficiency of the economy. However, it is important to consider the potential downsides of IoT-enabled sustainable consumption, including data privacy and security concerns, and the potential for increased inequality if access to IoT- enabled sustainable consumption technologies is limited.

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