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Green IoT: A game-changer in Sustainable Development: An Investigation

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Abstract

There has been a boom in information sector in the 21st century and the sector is heavily infused with technical innovations. These results in a multitude of possibilities that can help accomplish the United Nations Sustainable Development Goals (SDGs) if used wisely. The study's major objective is to derive conclusions about the relevance of the Internet of Things in carrying out the global goal of sustainable development. For this purpose, an online survey was undertaken among 250 respondents comprising of industry experts, researchers, and academicians of Central Universities in India. The primary objective of the study is to trace out the gaps, muddles, and roadblocks in achieving the goals of SDGs. The majority of the respondents firmly believe that Green IoT can be a crucial game-changer in achieving goals of SDG. Crucial areas where these technologies can bring about a massive change include productive and optimum utilization of raw materials along with preserving natural resources and reducing the emission of greenhouse gases and other waste. A sustainable environment is in need of planned and organized usage of IoT and G-IoT concepts which can significantly transform traditional development into sustainable development. Developing goods and services for enhancing renewable energy sources, energy-conserving computing and modulation of power sources, green metrics, assessment tools, and methodologies assist this process.

Keywords: Green IoT, Sustainable Development, Economic Growth, Technological Innovations.

INTRODUCTION

State-of-the-art technologies and the upheaval of Internet of Things (IoT) has added spark to research in almost all areas related to human beings, disseminating anytime, anywhere, any device information access to human beings in a multitude of ways. This outstanding research in recent decades aims to synergise humans, data, processes and things, organisations, places, services and facilities together in unprecedented ways. Although IoT offers abundant of benefits to human society, still the process of manufacturing, utilisation, implementation and distribution of IoT services and devices requires mammoth energy ad resource ultimately producing never ending toxic electronic waste. To achieve the target of sustainable development, plans are being implemented at national and international levels keeping in consideration the environmental, social and economic aspects. Even though there has been a revolution in Green Internet of Things (G-IoT), there is very low indication of IoT advancements in many developing countries.

Green Internet usually means “planning and investing in a technology network that serves the needs of today as well as today’s needs while conserving energy and saving money.” The Green Internet of Things revolves around the energy efficiency and the reliability of the IoT concepts. “Green IoT” is defined as the energy-efficient way in IoT to either diminish or eradicate the green-house effect caused by currently running applications. Green IoT is the

process of efficiently producing, developing, disposing of computers, servers, using and associating subsystems (i.e., printers, displays, communications equipment and storage devices), with a much reduced negative impact on society and the environment.

Need of Green Internet of Things

Kevin Ashton, for the first time used the term 'Internet of Things' as title of his Power Point presentation. Kevin had come up with an idea of using "RFID (Radio Frequency Identification)" chips on consumer goods for automatically tracking the stock levels in the storehouses. Soon after, Internet of Things (IoT) became an emerging concept and revolutionized the world by joining billions of IoT devices together. The IoT devices work by sensing, collecting, and transmitting the vital information gathered from the its surroundings. Like a coin having two sides, IoT has also brought some of the obstacles to the Environment, the most important being the increase in the volume of e-waste, energy consumption and CO2 emissions.

To counter the potential negative impacts of latest scientific developments in area of IoT on human society and environment, it has become the need of the hour to effectively deal with the threats and challenges posed by IoT. These challenges mainly comprise of enhanced energy consumption, generation of electronic waste, emission of greenhouse gases mainly CO2, utilization of non biodegradable materials for IoT devices, usage of non-renewable and natural raw materials. This situation has called for a need for using Green IoT (G-IoT), a future technological enhancement of IoT associated with green technology and economy. Green IoT aims to bring about notable improvements in environmental and human wellbeing so as to shrink the world using sustainable technological developments. G-IoT has become mandatory and it carries the potential to completely transform the human society along with boosting environmental health. G-IoT is the latest technology that also cares in eliminating or mitigating the negative influences on the people's health and the environment. Green IoT (G-IoT) basically focuses on two aspects. The first aspect is slanted towards "designing IoT computing devices, communications protocols and networking architectures" that are energy efficient. The second aspect is oriented towards leveraging IoT technologies to reduce the rate of emissions of greenhouse gases, radiations and pollution. Using the technological advancements in IoT, Green IoT has great potential to strengthen environmental and economic sustainability. Thus green technologies and green processes form the pillars in sustainable development and building a smart world.

Green IoT in layman's terms means "planning and investing in a technology network that serves the needs of today as well as tomorrow's needs while conserving energy and saving money." The Green Internet of Things focuses in attaining energy proficiency and the trustworthiness of the IoT concepts. "Green IoT is defined as the energy-efficient way in IoT to either reduce or eradicate the green-house effect caused by existing applications. Green IoT is the process of efficiently producing, developing, disposing of computers, servers, using and associating subsystems (i.e., printers, displays, communications equipment and storage devices), with a reduced negative impact on society and the environment". Shifting to green IoT requires new resources to reduce the negative impact of IoT on human health and climate. Green IoT's primary goal is to reduce rate of CO2 emissions and waste, harness environmental conservation and cover high costs of operating stuff and power consumption. Reduction of the energy consumption of IoT devices is required to make the world healthy and greener. Green IoT offers a great possibility/opportunity to reach new economic heights and highly sustainable environment through the advancement of greening ICT technologies.

The objectives of Green IoT are;

1. Energy efficient procedures adopted by IoT.

2. Reduce green house effect of existing IoT applications.

3. Reduce energy consumption and CO2 emission.

4. Electronic waste management.

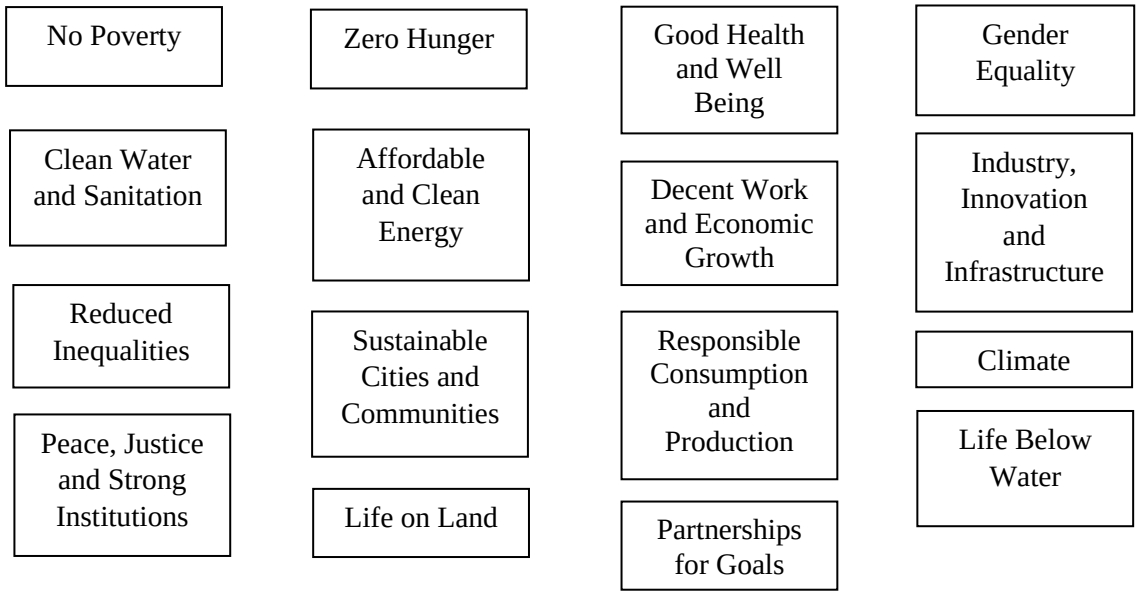
5. Usage of surrounding environment to assist in generating power supply.

Green IoT for Sustainable Development

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Green IoT focuses around the cross-cutting technologies like "Design technologies, Leverage technologies and Enabling technologies" to support and achieve sustainable development.

- Design Technologies – Helps in generating energy preserving efficient systems, efficient transmission protocols, low power needs for network architectures, and other cross-connections.
- Leverage Technologies applies to bringing down carbon releases and increasing energy conservations.
- Enabling technologies comprise of various technologies such as machine-to-machine networking, sensor and cellular networks, green RFID, energy reaping and communication tools, cloud computing, intelligent radio transmissions and analysis techniques for big data. Using these enabling technologies in the forefront, green IoT offers never ending opportunities to push forward environmental and financial performance. In 2015, the United Nations signed the Agenda 2030 for Sustainable Development (SDG), through 17 Sustainable Development Goals. The meeting of United Nations with Members States in 2015 found the emergent need of the hour is to set up a common blueprint for survival of world population with huge peace and affluence in the future. The blueprint for the same was presented with a Common Agenda for attaining sustainable growth by 2030. The idea behind this was to collaborate the efforts of the nations worldwide towards achieving the 17 "Sustainable Development Goals (SDGs)" by 2030. The success rate for attaining these 7 SDG's globally depends on the level of global association and understating among nations, immediate proactive contribution and implementation by all developing and developed countries.

17 Sustainable Development Goals by United Nations



Objectives of Sustainable Development

Sustainable development is undertaken with the aim of safeguarding sustainable development, social equality and justice, and environmental conservation. While these three variables can operate in harmony, they are often found to cross each other's paths. Economic growth for a better standard of life has been a player in climate change throughout the second half of the 20th century. In recent times, society has evolved to understand that with so much poverty and environmental destruction, a stable society or economy is not on cards. Economic growth will remain the cornerstone of human progress, but it must adapt so that it does not harm the ecosystem. In order to bring this understanding into global effect, the challenge of sustainable development is to turn our inefficient ways into more sustainable ones for a better future.

The main objective of Sustainable development is to create and maintain a balance between the social, financial and environmental requirements of the society so as to enable the prosperity among the current and upcoming generations. Sustainable development talks and focuses on long term effects and consequences of any decisions taken regarding technological, social, financial or social development. The basic idea is to construct a stable and sustainable societal infrastructure by resolving all the possible conflicts in terms of economic, social and environmental developments along with preservation of key natural and man-made resources.

Green IoT for Sustainable Development – An Investigation

To reduce the potential negative impacts of the latest scientific developments in area of IoT on human society and environment, it has become important to effectively deal with the threats and challenges posed by IoT including enhanced energy consumption, generation of electronic waste, emission of greenhouse gases CO2, and utilization of non-biodegradable materials for IoT devices, usage of non-renewable and natural raw materials. This situation has created a need for moving towards Green IoT (G-IoT), a future technological enhancement of IoT associated with green technology and green economy. Green IoT is aimed towards bringing notable improvements in environmental and human well-being to make the world smarter using sustainable technological developments. G-IoT is the need of the hour and it carries the potential to completely transform human society along with improving environmental health. G-IoT is the latest technology that emphasizes on developing solutions towards eliminating or mitigating the negative influences on the people's health and the environment. Green IoT (G-IoT) focuses on two aspects. The first aspect is oriented towards designing IoT protocols, frameworks and devices for conservation of energy. The second aspect is oriented towards leveraging IoT technologies to reduce emissions of greenhouse gases, radiations, and pollution. Using the technological advancements in IoT enabling technologies, Green IoT has great capability to strengthen environmental and economic sustainability globally.

The 2018 WEF (World Economic Forum) report stated that 84% of IoT deployments were addressing or had the potential to address the SDGs. Among the 17 Sustainable Development Goals, the following SDGs as those addressable by most of the IoT projects.

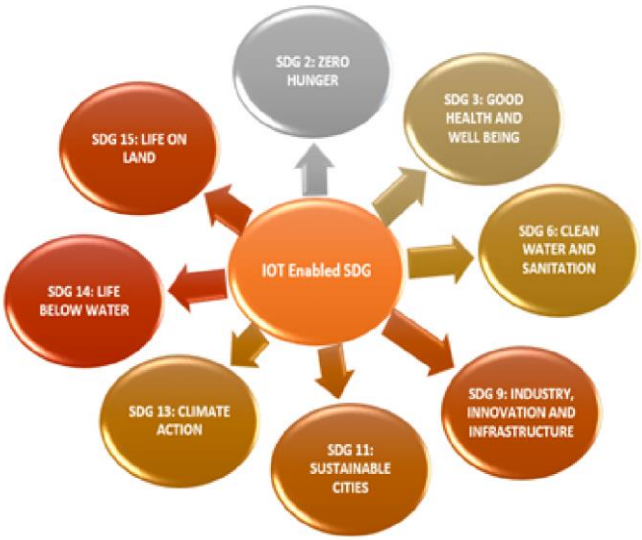


Figure 1:- *IoT Enabled Sustainable Development Goals*

Research Design

An online survey using 'Google Form Questionnaire' was conducted among the IoT industry experts, researchers, professors, educationists of 'A' grade state University in India to study deeper into possible future implications of IoT applicability towards achieving the goal of sustainable development. 250 participants who possessed the domain knowledge of Green IoT, sustainable development and other similar practices were selected. The results obtained have been graphically depicted to easily capture the current need/challenges that need to be addressed with immediate effect at each level namely: government and state level, corporate level, society level, and at the individual level to achieve the Sustainable Development Goals (SDG's) by 2030.

Result Analysis

1. Rate the importance and significance of IoT in successfully implementing the sustainable development goals defined by U N.

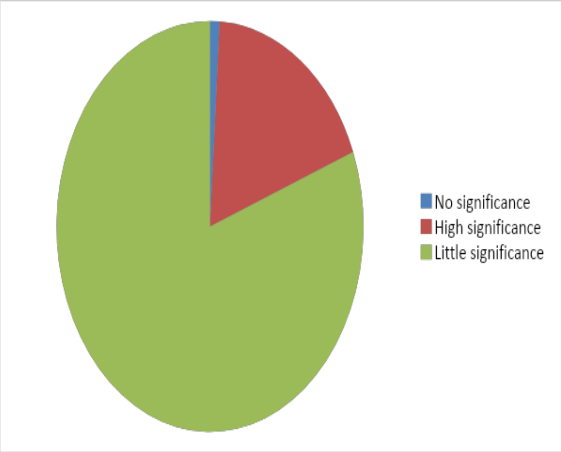


Figure 2: *Significance of IoT in Implementing SDG's*

From the above figure it is understood that, IoT innovations are capable of processing data intelligently, making proficient and successful communication thus converting machines into smarter, efficient and sustainable devices. Reducing the energy usage of IoT devices is needed in order to make the world healthier. Green IoT has a great potential to promote economic growth and environmental sustainability through the advancement of green ICT technologies. 80% of respondents concluded that IoT/Green IoT can play a significant and phenomenal role in achieving the goals of sustainable development.

2. Is IoT essential and indispensable for achieving the Sustainable Development Goals?

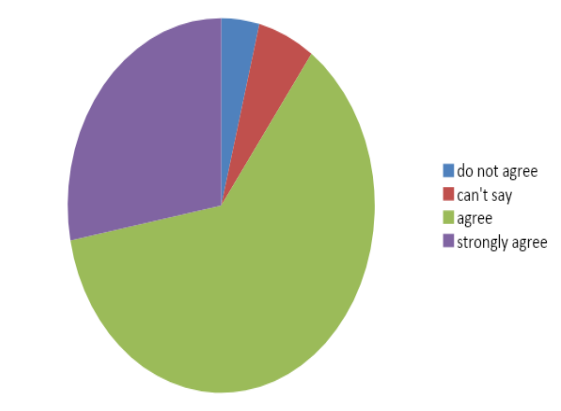


Figure 3: *Essentiality and Indispensability of IoT in achieving SDG's*

It is found that, 28% of the respondents strongly agree and 62% agree that the use of IoT technology/devices/applications is essential and indispensable to attain the target of sustainable growth. This will happen only if global/national and regional efforts are streamlined to accomplish sustainable development. Developed countries must endorse as well as assist and encourage the developing countries to design, develop, implement, share and disperse competent technologies to safeguard the environmental sustainability on flexible terms and conditions.

3. Agreement towards Government or Industrial Policies like Research Promotion, Encouraging the Development and Implementation of IoT Technologies can highly influence the results of utilising IoT for achieving SDG's.

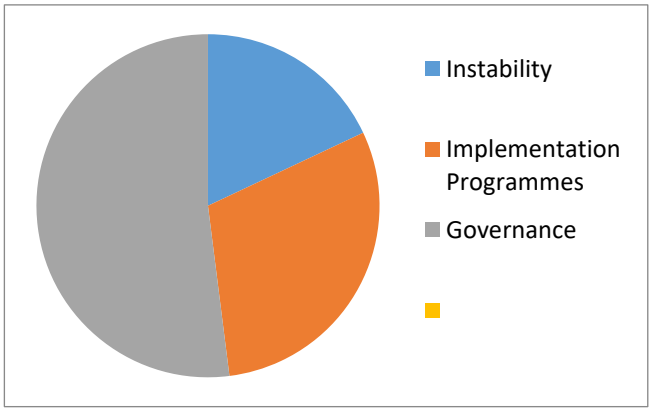


Figure 4: *Respondents Agreement towards influence of Government Policies in SDG's*

As it is stated from above survey results, it is evident that researchers and educationists are well aware that the IoT projects/applications main objective is to counter the challenges and threats posed for sustainable development, while prioritizing the sustainability goals inside commercially driven projects in Industries. Approx. 90% of respondents agreed that industrial research promotion and encouraging policies of government for development and deployment of IoT applications can play a predominant role in this.

4. Need for IoT for Sustainable Development Goals in Education

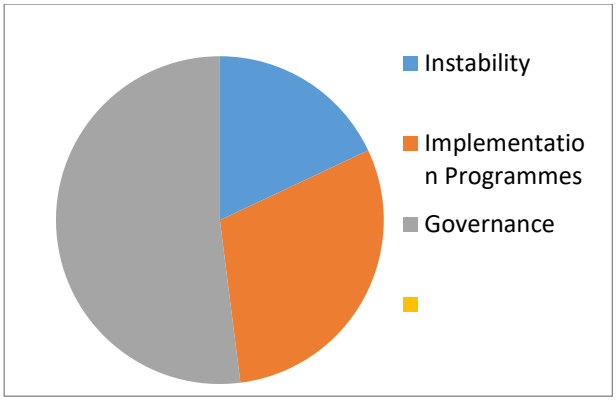


Figure 5: *Need for IoT for SDG's in Education*

Embedding sustainability awareness into culture is also crucial About 90% of the respondents believe that the education system urgently needs to infuse "IoT for Sustainable Development Goals (SDGs)". Knowledge and awareness among the students regarding responsible resource consumption and sustainable environment along with logical capacity and ability of technology based problem-solving will help in achieving sustainable goals.

5. Extent of adopting new and innovative IoT applications to deal with challenges associated with hunger, water supply, and food security through resource monitoring to cope with the increasing consumption needs of a global population can assist in achieving Sustainable Development Goals (SDG's).

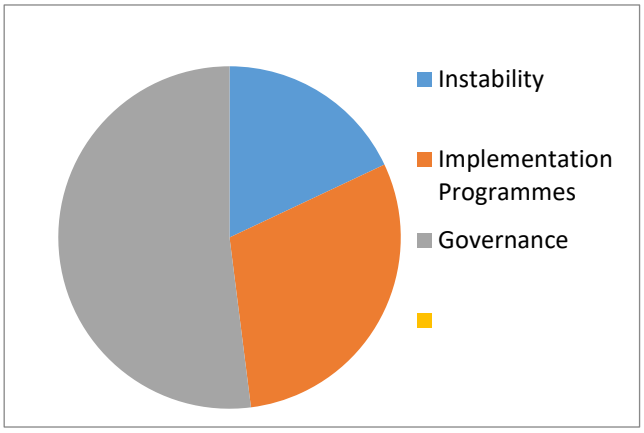


Figure 6: *Adoption of New and Innovative IoT helps in Resource monitoring of SDG's to Global level*

72% of respondents believe that adopting the latest and modern IoT applications can assist in dealing with problems like food and water scarcity. Any kind of water leakage can be detected, monitored and prevented on time using sensors. Similarly, other IoT technologies can easily be implanted to detect humidity of soil, probable water contamination, weather status monitoring, remotely handling the equipment's for irrigation, to name a few. This can greatly enhance the overall sustainability, cost-effectiveness and energy efficacy of agriculture production by enhancing the quality and quantity of crop production.

6. Arguments towards Promoting international dialogue and cooperation on the IoT for sustainable development by bringing the various stakeholders together, especially the academic and research community can play a major role in achieving SDGs?

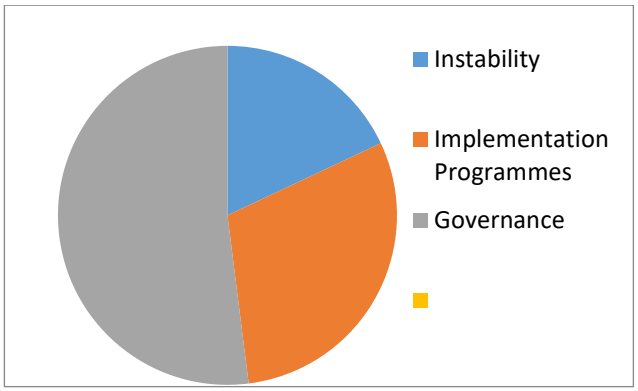


Figure 7: *IoT's role in Academic and Research Community in achieving SDG's*

Every nation's primary responsibility is to achieve social and economic development. There is a great importance of international financial institutions in supporting the policy space of each country in particular developing countries, in accordance with their mandates. Almost 91% of respondents strongly agree or agree that international collaboration industrial, academic and research fronts for specifically designing IoT products prioritized with achieving sustainability goals will greatly help to reach the sustainability targets.

7. Agreement towards sustainable development demands that "humans reduce all sorts of waste including electronic – waste".

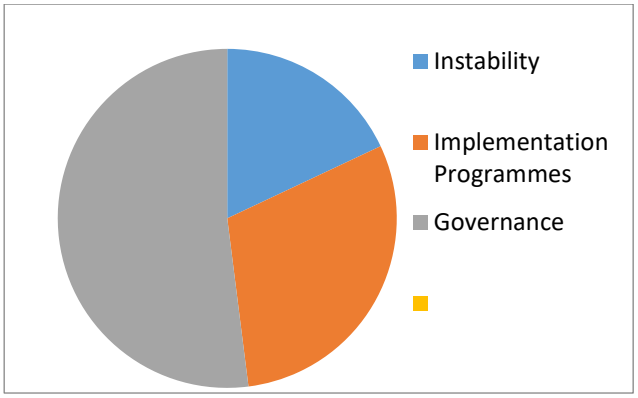


Figure 8: *Arguments towards sustainable development in reducing E – wastes*

A huge source of embodied energy in the production of the IoT and other electronic devices is the use of rare materials which go into their production. E-waste reduction helps to save resources and decreases the amount of energy that we take from nature. Instead of making or extracting more of them alone, recycling/reusing the precious metals and plastics in old mobile phones will save as much energy as flipping off the electricity to 24,000 Indian homes for one year. 51% of respondents strongly agree and 43% agree to the fact that minimizing all sorts of wastage including plastic/metal/other electronic waste in IoT devices can be a game changer in attaining the target of sustainable development.

8. Sustainable development demands that everyone move towards renewable resources.

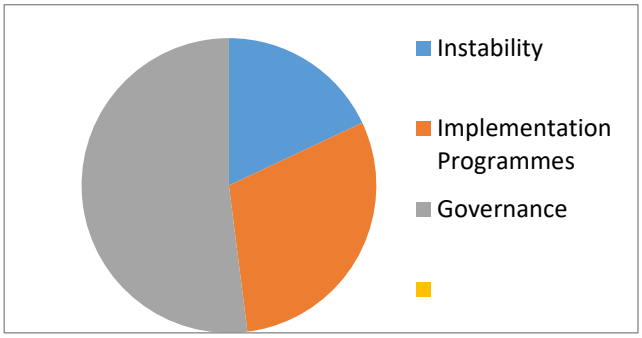


Figure 9: *Sustainable development demands everyone to move towards renewable resources*

Over the last four decades, the world has witnessed an interesting new trend by shifting to alternative energy sources. Technologies have been designed and engaged solely to make the world a better place. Industries have developed/focused around clean energy such as wind and solar energies. Almost 99% of respondents agreed that it is the sprouting demand of the time to step to the renewable energy resources that reduce the negative impact on the environment like CO2 emissions, greenhouse effects, global warming, etc.

9. Challenges in achieving sustainable development goals

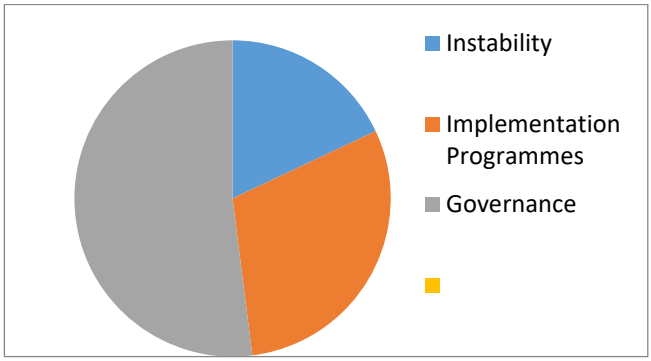


Figure 10: *Challenges in achieving sustainable development goals*

From the above table, it is analysed that IoT is a wave of revolution to achieve sustainable growth and development. However, there is still a slight indication of progressing IoT in developing countries. 47% of respondents believe that “The Governance issue” is a major obstacle in the successful implementation of IoT for sustainable growth. Therefore, making policies for investors/tech-entrepreneurs/officials/administrators is called for to transform the implementation of IoT applications into long term practices.

10. Rank the following based on the needs and significance of IoT practise for Sustainable Development

Rank (in %)	Factors
38	IoT is necessary for biodiversity conservation and ecological monitoring
62	IoT is must for smart and sustainable cities through global initiatives
35	Promoting international dialogue and co-operation on the IoT for sustainable development
44	Promoting the development and adoption of IoT Technologies
47	Supporting the implementation of the IoT in an urban and rural context
70	Adopting new and innovative IoT applications to deal with challenges associated with hunger, water supply and food security

29	Galvanising interest in the use of IoT for risk reduction and climate change mitigation
56	Identifying and incorporating IoT technologies for sustainable development in education

70% of respondents have selected the highest priority to the sixth option of adopting new and innovative IoT applications to deal with challenges associated with hunger, water supply, and food security. 62% of respondents chose second priority that is IoT for smart and sustainable cities through global initiatives. Half of people live in cities today and 5billion people are projected to live in cities by 2030. The world's cities occupy just 3% of the Earth's land but account for 60-80% of energy consumption and 75% of carbon emissions.

The Sustainable Development Goals and Priorities will instigate action over the next ten years in areas where IoT technologies are essential for humanity and the earth. The analysis of survey results concludes that the following points need urgent focus and attention to achieve sustainable development and the goals. Shifting to green IoT requires new resources to reduce the negative impact of IoT on human health and disrupt the climate. Greening IoT's primary goal is to reduce CO2 emissions and waste, harness environmental conservation, and mitigate the costs of operating stuff and power consumption. The reduction of the energy consumption of IoT devices is required to make the world a better place.

Summary of Findings and Role of IoT in Sustainable Development

a. Green IoT offers a high potential to support economic growth and environmental sustainability through the advancement of greening ICT technologies.

b. IoT is highly significant in successfully implementing the Sustainable Development Goals as suggested by United Nations.

c. IoT is essential and indispensable for achieving the Sustainable Development Goals.

d. Government or Industrial Policies like research promotion, encouraging the development and implementation of IoT can highly influence the results of utilising IoT for achieving Sustainable Development Goals.

e. Need of an hour is necessary to incorporate IoT for Sustainable Development Goals in the Educational Sector.

f. Adopting new and innovative IoT applications to deal with challenges associated with hunger, water supply, and food security through resource monitoring to cope with the increasing consumption needs of a global population can assist in achieving Sustainable Development Goals.

g. Promoting international dialogue and co-operation on the IoT for sustainable development by bringing the various stakeholders together especially the academic and research community that they can play a predominant role in achieving SDG's.

h. Sustainable development demands that humans must reduce all sorts of waste including E-waste.

i. Sustainable development also demands that all must move towards renewable resources like wind power, solar panels, ethanol, cardboard packaging etc.

j. Governance issues are major challenge in achieving Sustainable Development Goals.

k. Adopting new and innovative IoT applications can cope-up with the challenges associated with hunger, water supply and food security.

Conclusion

The survey conducted in the present research work concludes that "All the research work in IoT sector towards design and development of IoT devices/software's/techniques will not generate long-term benefits to the society unless the research focus do not take Green IoT into consideration, as Green IoT is one of the strongest base for achieving the target of sustainable development." The survey results depict that 65- 80% percent of the researchers/educationists favour transforming the "IoT developments" as "Green IoT developments" for long term benefits. The limitation of the current study is that the survey

results have been calculated using a medium size sample population. Further studies in this course may generalize the results on a larger sample size. The present study will be an added benefit to the IoT/Green IoT body of knowledge as similar studies have not been conducted in this area in past.

In the process of making a sustainable future, accurate decisions regarding technological innovations need to be taken at initial stages of the development. Technology goes in hand with sustainable development as it can be used as a tool for handling assets existing in nature in well planned and well-organized way. This paves way to clean and affordable energy, clean water, possibility to survive in a least polluted environment and also under environmental governance managements.

For sustainable world vision to come true right choices need to be taken at initial stages along with thorough technological research and innovations.

Optimal use of technologies is called for as it can to develop as an obligatory tool for sustainable development. The areas where these can prove beneficial are numerous like maximizing the usage of raw materials and decline of Green House Gas emissions and waste along with preserving natural assets/resources. IoT and G-IoT concept, aided with specifically designed products and services for a sustainable environment can transform traditional development into sustainable development. The focus of implementation of IoT for sustainable development can only provide outcomes when global, national, regional, and individual efforts are placed accordingly to collaborate and co-operate for the promotion of innovatively designing and implementing IoT devices. The green-IoT keeps the environment green and clean by mitigating the negative impact of IoT on nature. This paper through survey probed into the issues/challenges that need to be addressed urgently to attain sustainable development goals defined by the United Nations by 2030. The analysis of survey results affirms that IoT is the need of the hour and a game changer in the path of attainment of sustainable development goals. Hence it is essential and indispensable.

Recommendations

Based on the detailed Literature study and Survey results, the following recommendations can be pointed:

1. Need for management of "Data torrent": Explosion of the huge amount of data collected and exchanged through IoT network devices.

2. There is an emergent need for reaching a "zero level of entropy" where the IoT systems or devices are designed in such a way to harvest its own energy.

3. Need for Miniaturization of IoT device is popping up as an urgent requirement for achieving SDG's.

4. Need for Development of Autonomic Resources that is capable of self-healing, self-management, and self-configuration.

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