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Management of Computer and Electronic Waste through the Fifth Industrial Revolution for the Cleaner Environment

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Abstract **-** One major effect of the fifth industrial revolution (5IR) on our lives is the increase of electronic garbage (e-waste). To lessen detrimental effects on the environment and public health, e-waste needs to be treated appropriately. This study reveals how computer and electronic trash can be managed utilizing the 5IR. A literature review was conducted in order to get more knowledge about the potentially hazardous components of e-waste and their effects, the financial advantages of recycling e-waste, and international best practices for efficient e-waste management and forecasting. The results show that a complementary strategy is needed for the best potential e-waste management outcomes. Both technological and policy initiatives should be a part of this strategy. Developing innovative technologies for recycling e-waste and enhancing the current recycling infrastructure are examples of technical measures. Policy initiatives include things like putting laws into place to ensure that e-waste is disposed of securely and supporting public awareness campaigns to educate people about the importance of recycling e-waste. In order to guarantee efficient monitoring and sustainable development, this paper highlights the significance of formal gathering and documentation. E-waste management initiatives can be evaluated for efficacy and the flow of e-waste can be tracked with the aid of formal collection and recording systems. In order to overcome the difficulties associated with managing electronic trash, it was finally resolved by stressing the significance of cooperation between business, government, and civil society. By managing electronic waste sustainably and effectively, we can create a more equitable and sustainable future for everybody.

Keywords: Electronic waste management-waste; Fifth Industrial Revolution; Sustainable waste management; Environmental impacts; Environmental pollution

I. INTRODUCTION

As the world enters the fifth industrial revolution, there is a growing need for effective management of computer and electronic waste. Technological progress at an accelerated rate has resulted in an ever-growing amount of electronic waste. Based on the fifth industrial revolution, we examine the several methods and tactics for handling computer and electronic trash in this study. With technology developing at a rapid pace, managing computer and electronic trash has become a critical concern. Globally, there is an increasing amount of electronic trash produced in tandem with our increasing dependence on electronics. Ingenious and long-lasting solutions are required since inappropriate garbage disposal causes serious threats to the environment and public health. In recent years, the concept of the Fifth Industrial Revolution has emerged from the convergence of advanced technologies such as artificial intelligence, robotics, the Internet of Things, and renewable energy. With the potential to fundamentally change computer and electronic waste management, this revolution ensures a more efficient, environmentally friendly, and long-lasting approach. The combination of digital technology, automation, and artificial intelligence has ushered in the fifth industrial revolution, bringing about profound changes to many aspects of our lives. The amount of computer and electronic goods available has never been higher, from smart houses to networked gadgets. Electronic waste management is a major difficulty posed by this rapid growth, despite its many positive effects.

Electronic waste, or electronic garbage, is a complex issue that requires immediate attention. Because electronic equipment has a shorter lifespan and technology is becoming more and more outdated, the generation of e-waste has reached alarming proportions. Inappropriate methods of managing and disposing of e-waste not only put the environment and public health in jeopardy, but they also waste valuable resources. This paper report's goal is to examine and assess how computer and electronic waste is managed using the Fifth Industrial Revolution as a lens. We want to identify workable solutions to the problems related to electronic waste management by exploring the possibilities of cutting-edge technology and taking a comprehensive strategy that includes industry cooperation, legislation, and public awareness. The present paper aims to explore diverse facets of the subject matter, encompassing the condition of computer and electronic waste management at present, the obstacles encountered, and the prospects brought about by the Fifth Industrial Revolution. Moreover, it will put forth suggestions and a process for efficiently handling computer and electronic garbage in this revolutionary day. In light of the Fifth Industrial Revolution, we hope to clarify the need of implementing sustainable waste management techniques through this inquiry. A more circular and resource-efficient economy can be achieved by putting the suggestions made in this report into practice. Stakeholders such as government agencies, recycling groups, technology companies, and private citizens can collaborate to lessen the negative effects of these waste. The handling of computer and electronic trash is a complicated, multidimensional problem that calls for creative problem-solving and teamwork. Through the optimal utilization of the Fifth Industrial Revolution, we may create a more sustainable future with efficient waste management for greener environment.

II. The Fifth Industrial Revolution

The growing application of automation, artificial intelligence, and other cutting-edge technology is what defines the Fifth Industrial Revolution as a time of technological transformation. Our manner of living, working, and managing computer and electronic trash are all being profoundly impacted by this change.

The Fifth Industrial Revolution, which is the current phase of the Industrial Revolution, is defined by the integration of cutting-edge technologies like artificial intelligence, robots, and the Internet of Things. The amount of e-waste produced has increased due to the rapid growth of technology, which has led to a great surge in the manufacturing of computers and other electronic devices. Better computer and electronic waste management is needed, as the fifth Industrial Revolution (5IR) has brought to light. What distinguishes 5IR is the use of artificial intelligence (AI), machine learning, and the Internet of Things (IoT) to build robust, efficient systems that can handle difficult jobs. But as these technologies are used more frequently, the quantity of electronic trash produced also rises in tandem. This study addresses how to handle computer and electronic garbage using the 5IR, outlining the difficulties encountered and offering suggestions for environmentally friendly waste management techniques. As people become more and more dependent on electronics and technology, managing electronic waste has become a major challenge for governments, businesses, and individuals worldwide. Any electronic device that has outlived its usefulness or reached the end of its lifecycle is referred to as electronic garbage. Improved management practices are necessary because inappropriate disposal of electronic waste presents serious dangers to the environment and public health. In discussing computer and electronic waste management in the context of the Fifth Industrial Revolution, this research emphasizes the significance of implementing sustainable approaches. As the globe grows more dependent on technology, electronic trash is becoming a bigger environmental issue. Electronic and computer garbage, or "e-waste," is becoming a bigger issue. Only 17.4% of the world's electronic waste—more than 53.6 million tonnes—was appropriately recycled or disposed of in 2020 [1, 2].

Many dangerous materials, such as lead, mercury, cadmium, and brominate flame retardants, are present in electronic waste and can have detrimental effects on the environment and public health if improperly disposed of. When materials are not properly disposed of, electronic waste Over time, heavy metal pollution can seep into the groundwater and soil. Environmental issues are made worse by the emission of hazardous gases into the atmosphere during the burning of electronic waste. In addition, recyclable materials like gold, silver, and copper can be found in electronic waste, promoting a circular economy that lowers waste and the exploitation of raw materials [1].

The e-waste issue is getting worse as a result of the fifth industrial revolution. We are producing an increasing amount of e-waste as we become more and more dependent on computers and other electronic devices.

Furthermore, the fifth industrial revolution's emerging technologies are frequently more complicated and challenging to recycle than their predecessors [2,3,4].

In the Fifth Industrial Revolution, a sustainable approach to waste management is required for electronic trash. The Fifth Industrial Revolution (5IR) is characterized by innovative and ground-breaking technologies such as artificial intelligence (AI), robotics, and the Internet of Things (IoT). These technologies need to be developed and used in a sustainable manner, taking into account the environment and sustainable practices. Achieving a green 5IR requires addressing climate change, responsible consumption and production, and land-based living, among other sustainable development goals. Eco-design, green supply chain management, and the circular economy are just a few of the sustainable management strategies that must be used to handle electronic waste throughout the 5IR. These procedures encourage resource efficiency, reduce negative environmental effects, and develop a long-term, sustainable plan for handling electronic waste. For example, the circular economy emphasizes recycling, mending, and reusing things as a means of cutting waste. Under this strategy, producers would have to stop producing single-use goods and instead create items that are easily recyclable or reusable. Green supply chain management, on the other hand, is concentrated on integrating sustainability into supply chain procedures. Businesses would have to ensure that sustainability is considered at all stages of the supply chain, such as product design, manufacturing, distribution, and transportation, in accordance with this plan [5–11].

A. Electronic Waste Negative Impact

The environment, human health, and society at large are all negatively impacted by electronic trash, or "e-waste." The following are some of the main detrimental effects of electronic waste: Pollution of the Environment Electronic garbage improperly disposed of and recycled can seriously pollute the environment. Lead, mercury, cadmium, and flame retardants including brominates are among the hazardous compounds commonly discovered in e-waste. When these substances penetrate into the soil and water bodies, they can damage ecosystems and put plants, animals, and aquatic life in jeopardy.

B. Soil and Water Contamination

When electronic waste is dumped in landfills or improperly disposed of, toxic chemicals can seep into the soil and contaminate groundwater sources. This contamination can persist for long periods and have detrimental effects on the quality of soil and water, impacting agricultural productivity and posing risks to human health.

Air Pollution

The burning of electronic waste, a common practice in some regions to recover valuable materials, releases toxic fumes and pollutants into the air. These emissions can contain heavy metals, dioxins, and furans, which contribute to air pollution and pose serious health risks when inhaled.

Health Risks

Hazardous material exposure from electronic debris can seriously harm the health of people working in informal recycling procedures and the populations around them. Inappropriate handling of e-waste, direct contact with hazardous materials, and inhalation of toxic fumes can cause cancer as well as skin, neurological, and respiratory ailments.

Depletion of Resources

Electronic waste is a substantial loss of priceless resources. Rare earth elements and valuable metals like palladium, silver, and gold are found in many electronic gadgets. Inadequate recycling of e-waste results in the loss of these resources and a rise in the need for resource extraction, which further depletes natural resources and exacerbates environmental harm.

Energy Consumption

The production and disposal of electronic devices consume a significant amount of energy. Extracting raw materials, manufacturing components, and powering electronic devices throughout their lifecycle contribute to greenhouse gas emissions and energy consumption, contributing to climate change and environmental degradation.

Digital Divide

The improper management of electronic waste can contribute to the digital divide, particularly in developing countries. Inadequate access to proper disposal and recycling facilities can lead to the accumulation of e-waste in marginalized communities. Perpetuating social and economic

inequalities. Figure 1 shows some of the major hazardous materials and emissions from e-waste.

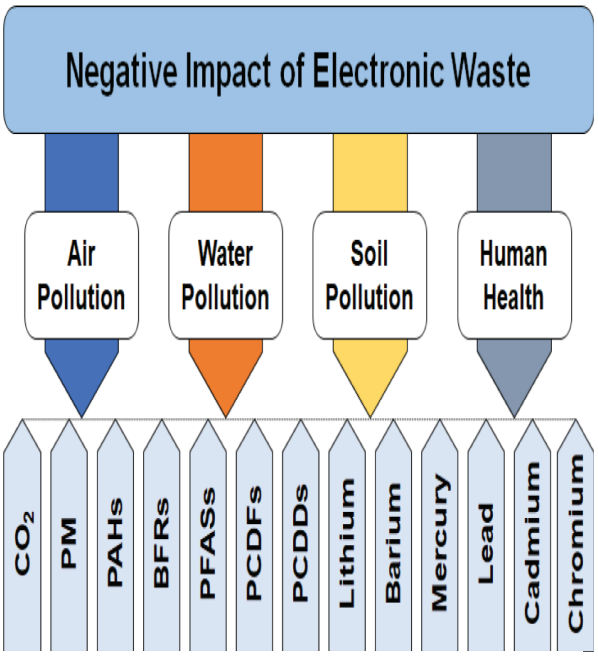

Fig. 1. Major pollutants and hazardous materials that can be generated from e-waste when improperly dumped or managed.

Global Trade and Dumping

The export of electronic waste from developed to developing countries, often for disposal or recycling, can result in the dumping of hazardous materials in regions with weaker environmental regulations. This practice can lead to environmental injustice and health risks for the communities living near these dumping sites.

Data Security and Privacy Risks

Improper disposal of electronic devices can pose data security and privacy risks. If personal or sensitive information is not securely erased from devices before disposal, it can be retrieved and misused, potentially leading to identity theft, fraud, or unauthorized access to confidential data.

Energy Inefficiency

Many electronic devices consume energy even when they are in standby or idle mode. The accumulation of electronic devices and their continuous energy consumption contribute to overall energy inefficiency, leading to higher energy demands and increased carbon emissions.

Addressing these negative impacts requires a comprehensive approach that includes responsible manufacturing practices, proper e-waste management systems, recycling infrastructure, and public awareness. By adopting sustainable practices, implementing effective regulations, and promoting responsible consumption, we can mitigate the negative impacts of electronic waste and work towards a more sustainable future.

A. E-Waste Estimation and Prediction

Currently, numerous strategies have been implemented worldwide to effectively and environmentally handle electronic waste (E-waste), particularly in developed countries. Table 1 summarizes the technologies utilized to propose specific interventions. A comprehensive discussion follows the table.

C How we can manage the negative impacts of electronic waste through the Fifth Industrial Revolution:

Advanced Recycling Technologies

The Fifth Industrial Revolution offers opportunities to develop advanced recycling technologies. Innovations such as robotic sorting systems, machine learning algorithms, and automated dismantling processes can improve the efficiency and effectiveness of electronic waste recycling, enabling the recovery of valuable materials while minimizing environmental impact.

Internet of Things (IoT) for Waste Tracking

The integration of IoT technologies can facilitate waste tracking and management. Smart sensors and connected devices can monitor the movement of electronic waste throughout the recycling process, ensuring transparency, traceability, and compliance with regulations. This enables effective monitoring and control of e-waste, minimizing the risk of improper disposal.

Data Analytics for Waste Management

The Fifth Industrial Revolution emphasizes data-driven decision-making. By harnessing big data analytics and artificial intelligence, we can analyze patterns, trends, and forecasts related to electronic waste generation, recycling rates, and resource recovery. These insights can inform policy development, resource allocation, and targeted interventions for more effective waste management.

Circular Economy Principles

The Fifth Industrial Revolution encourages the adoption of circular economy principles, which prioritize resource conservation, product longevity, and material reuse. Designing electronic devices with modular components, standardized interfaces, and easy reparability can extend their lifespan and

facilitate efficient recycling and remanufacturing processes.

Extended Producer Responsibility (EPR)

Implementing robust EPR frameworks can hold manufacturers accountable for the entire lifecycle of their products. By placing the responsibility on manufacturers to manage the disposal and recycling of electronic waste, the burden is shifted away from consumers and local communities, promoting more sustainable and environmentally sound practices.

Collaboration and Partnerships

The Fifth Industrial Revolution encourages cross-sector collaboration and partnerships. Governments, technology companies, recycling organizations, and research institutions can join forces to develop innovative solutions, share best practices, and leverage resources for effective electronic waste management. Collaboration can lead to the creation of integrated waste management systems and the establishment of global standards for e-waste recycling and disposal.

Public Awareness and Education

Leveraging the power of the Fifth Industrial Revolution technologies, public awareness campaigns and educational initiatives can be launched to educate individuals, businesses, and communities about the environmental impact of electronic waste and the importance of responsible waste management. By raising awareness and fostering behavioural change, we can promote a culture of sustainable consumption and disposal practices

Policy and Regulation Governments play a crucial role in enacting policies and regulations that address the challenges posed by electronic waste. Policy frameworks should incentivize sustainable design, impose stricter regulations on waste disposal, and promote recycling infrastructure development, and support research and development in the field of e-waste management.

By embracing the transformative potential of the Fifth Industrial Revolution, we can integrate advanced technologies, data analytics, and circular economy principles into electronic waste management. Through collaboration, education, and policy interventions, we can minimize the negative impacts of electronic waste, promote resource conservation, and create a more sustainable future.

III. Research Methodology

After conducting a comprehensive review of existing literature, research papers, reports, and scholarly articles related to electronic waste management, recycling technologies, circular economy principles, and the application of Fifth Industrial Revolution technologies in waste management. This step helps establish a theoretical foundation and identify knowledge gaps in the field. After a thorough review, relevant articles were selected for inclusion in this systematic review. This approach was used to understand the creation of e-waste in different nations, like Nigeria, and link it to regional and worldwide production, all the while highlighting how important effective e-waste treatment is to preserving a sustainable environment. The methodology that was chosen for estimating and forecasting in order to improve e-waste management is also highlighted in this study. Along with the impact on customer behavior, societal awareness, and the supply chain network, it also covers the economic, environmental, and social aspects of sustainable management. The study's findings underscore the significance of recording the creation, acquisition, and handling of electronic trash in order to create more effective E-waste management plans. The overview of e-waste in several nations, such as Saudi Arabia and Nigeria, together with the associated difficulties and chances for sustainable management, is given in this article.

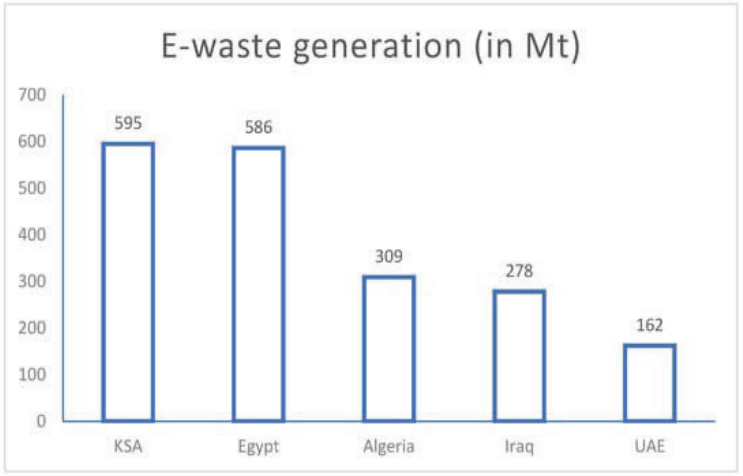

Fig. 2**: Global E-waste generation (in Mt).**

American homes utilize over 20 electronic devices on average. Europe, on the other hand, processes 42.3% (5.1 million metric tons) of its E-waste in a suitable manner, making it the region with the greatest rate of sustainable and formal E-waste treatment. With 24 million metric tons of e-waste produced, Asia is the region with the highest recycling rate (2.9 million metric tons). Europe generates 16.2 kg of e-waste per capital, the most in the world, followed by China with 10.1 million metric tons and India with 3.2 million metric tons. Nevertheless, with 2.4 kg per

person, India contributes less than the global average of 7.3 kg. The generation of e-waste has surged by 58% in the last nine years and is still growing.

Pyrometallurgy, Hydrometallurgy, Biohydrometallurgy, and Pyrolysis are the best physical pre-treatment methods for recycling e-waste and recovering metal.For treating e-waste, non-chemical techniques are becoming more practical than chemical ones. In contrast to hydrometallurgy, which uses chemicals, biohydrometallurgy, which uses microorganisms for metal abstraction and is said to be a more environmentally friendly technology. When compared to alternative resources, using microbes to recover noble metals is both economical and environmentally beneficial. Thermogenetic and initiation energy constraints and yield hinder the large-scale application of another promising developing technology: thermal cracking or pyrolysis of e-waste.

These cutting-edge technologies are necessary for improved recycling and environmental sustainability, helping to lessen the financial and risky load while promoting the restoration of natural resources [94]. Electronic parts are sorted, crushed, and separated using mechanical separators as part of the recovery process. Non-ferrous metals are then treated with pyrometallurgical treatment to separate metallic and noble elements. Acidic wastewater is treated and neutralized before being released, and metallic items are recovered using electrometallurgical procedures.
In the context of the Fifth Industrial Revolution, the following approach is suggested for managing computer and electronic waste: To acquire a thorough grasp of the existing situation regarding computer and electronic waste management, a thorough investigation and analysis must be done in the first stage. This includes reviewing existing literature, identifying key challenges and issues associated with waste management, and analyzing the potential benefits and opportunities that the Fifth Industrial Revolution can offer in addressing these challenges.

Stakeholder engagement plays a crucial role in this methodology. Identifying and involving relevant stakeholders, such as government agencies, recycling organizations, technology companies, and environmental NGOs, is essential. By conducting interviews, surveys, and focus groups, valuable insights and perspectives can be gathered regarding current waste management practices and the potential impact of the Fifth Industrial Revolution. Collaborating with stakeholders helps identify their roles and responsibilities in implementing sustainable waste management strategies.

Next, a technological assessment is conducted to evaluate emerging technologies associated with the Fifth Industrial Revolution that can be utilized for computer and electronic waste management. This assessment focuses on the feasibility, effectiveness, and environmental impact of these technologies in waste reduction, recycling, and disposal. Additionally, innovative solutions and best practices from around the world that leverage advanced technologies for sustainable waste management are identified.

A critical aspect of waste management is the development of a policy and regulatory framework. Policy recommendations aligned with the principles of the Fifth Industrial Revolution and promoting sustainable waste management practices are proposed. Collaboration with policymakers and regulatory bodies is essential to advocate for the adoption and effective implementation of these recommendations. Pilot projects and implementation are key components of this methodology. These projects are designed to test and demonstrate the feasibility of utilizing Fifth Industrial Revolution technologies in computer and electronic waste management. Collaboration with industry partners is crucial in establishing recycling centres, collection systems, and reverse supply chains that incorporate advanced technologies. Monitoring and evaluation of the pilot projects' performance, impact measurement, and necessary adjustments for scaling up successful initiatives are conducted.

Also, raising awareness and providing education are important aspects of this methodology. Educational campaigns are developed to increase awareness among individuals, businesses, and communities about the significance of proper computer and electronic waste management. Workshops, seminars, and training programs are organized to educate stakeholders on the benefits and methods of utilizing Fifth Industrial Revolution technologies for waste management. Partnerships with educational institutions and research centres.

Monitoring and continuous improvement are integral to this methodology. Establishing monitoring systems to track progress, measure key performance indicators, and identify areas for improvement in waste management is crucial. Continuously evaluating the effectiveness of Fifth Industrial Revolution technologies and strategies and

incorporating new advancements as they emerge is essential. Collaboration and knowledge exchange among stakeholders' foster ongoing learning and improvement in waste management practices.

By following this methodology, it is possible to leverage the potential of the Fifth Industrial Revolution to revolutionize computer and electronic waste management.

IV. Research Methodology

In light of the fifth industrial revolution, the methodology section describes the strategy and procedures utilized to carry out research on the management of computer and electronic trash, or "e-waste." The procedures for gathering and analyzing pertinent data are covered in this part, along with the research design and analytical techniques used. Design of the Research:
1. Goal: In light of the fifth industrial revolution, this study's main goal is to investigate e-waste management practices, legislation, and technology.
2. Review of the Literature: A thorough assessment of the literature was done to compile the body of information and research that already existed on the topic. To learn more about the state of e-waste management today, a thorough assessment of academic journals, conference papers, reports, and pertinent publications was conducted.

There have already been three industrial revolutions (IRs) that have had a big impact on the world [26]. Using water and steam to produce textiles and metals in large quantities was the focus of the first industrial revolution. In the Second Industrial Revolution, the idea of industries was explored. In this era, the usage of gas, oil, and electricity was prevalent, and new transportation and communication networks helped to build the steel and synthetic industries. The third industrial revolution focused on automation and modern nuclear energy [26]. The environment was severely impacted by the majority of these revolutions, though. Both the earth and human lives were severely harmed by them. Thus, employing recyclable bio-based materials and renewable resources [13-24]. The material recovery process still uses energy- and resource-intensive technology, which raises the electrical electronic life cycle's total environmental effects as well as its carbon footprint. In order to achieve a circular economy in Nigeria, sustainable waste management is required, and appropriate techniques must be implemented.

A practical, environmentally responsible, and sustainable manufacturing approach is IR 4.0. Industry 5.0 refers to automated and robotic systems that work with people and incorporate resilience and sustainability. Industry 5.0 seeks to reintegrate social, environmental, and human issues into the equation, while Industry 4.0 focused on large data and technology such as the Internet of Things [24-26]. Figure 3 presents Industrial Revolution and its impact on Textile industry.

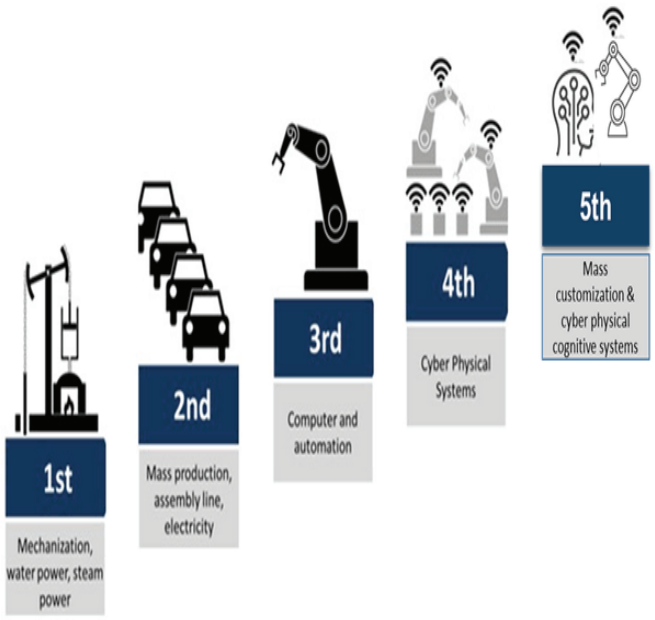

Fig. 3: Textile industry and Industrial Revolution impacts

Data Collection:
1. Primary Data: To obtain primary data, interviews, and surveys were conducted with key stakeholders in the field of e-waste management. These stakeholders included government representatives, industry professionals, recycling experts, and environmental advocates. The interviews aimed to gather qualitative insights, opinions, and experiences regarding e-waste management practices and challenges.
2. Secondary Data: Secondary data was collected from reputable sources, such as research papers, governmental reports, and industry publications. This data covered the management of e-waste and the fifth industrial revolution, including statistical data, case studies, and policy documents. E-waste in Information and Communication Technology is seen in Figure 4.

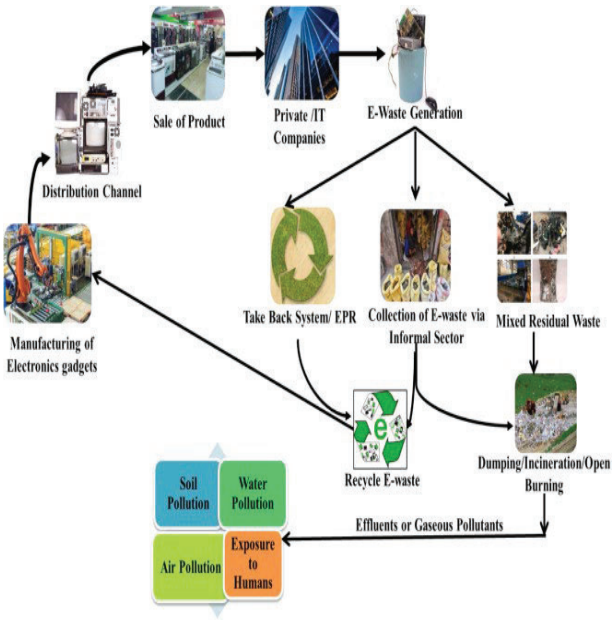

Fig. 4: E-waste in Information and Communication Technology.

Data Analysis:

1. Qualitative Analysis: The qualitative data obtained from interviews and surveys was transcribed, coded, and analyzed using thematic analysis. The key themes and patterns emerging from the data were identified, allowing for a comprehensive understanding of the challenges and opportunities in e-waste management through the lens of the fifth industrial revolution.
2. Quantitative Analysis: Using statistical techniques, the quantitative data from secondary sources—such as statistics and reports—was examined. The amount of e-waste generated, recycling rate trends, and the efficacy of current regulations were all quantified with the use of this investigation. The quantitative analysis procedure is shown in Figure 5. The United Nations Sustainable Development Goals are shown in Figure 7, whereas Industry 5.0 is applied in Figure 6. Industry 1.0–5.0 Industrial Evolution in Figure 8waste

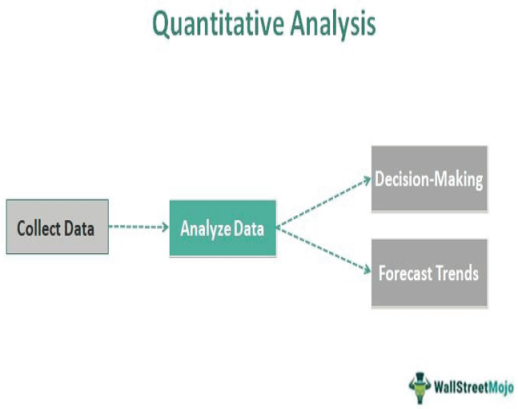

Fig. 5: . Quantitative Analysis Process

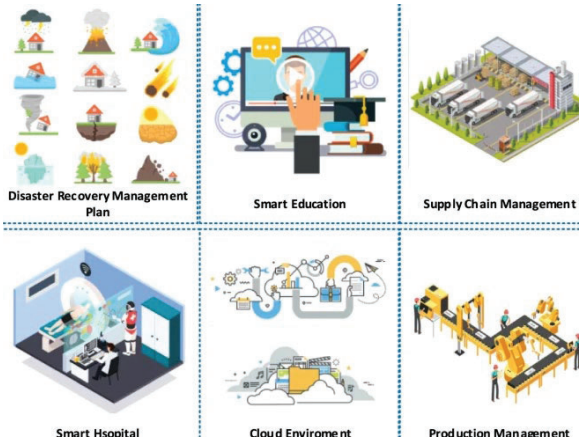

Fig. 6 presents application of industry 5.0

Fig. 7. UN Sustainable Development Goals

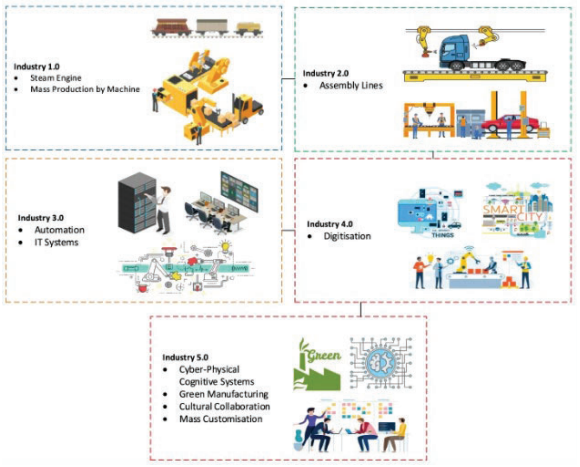

Fig. 8. The Development of Industry from 1.0 to 5.0

The present phase of technological growth known as Industry 5.0, or the fifth industrial revolution, is defined by the use of robotics, artificial intelligence, and other cutting-edge technology into the manufacturing process. The usage of computers and other electronic devices in the workplace has significantly increased as a result of this. To guarantee that these resources are used properly and safely, it is crucial to manage them well. The fact that computer and electronics garbage frequently contains hazardous elements makes it difficult to manage. Another challenge in managing computer and electronic waste is that it is often difficult to recycle. This is because the materials that make up these devices are often mixed, making it difficult to separate them for recycling. For example, a computer monitor may contain glass, plastic, metal, and electronics. It is difficult to recycle all of these materials together, so they are often separated and recycled separately.

The fifth industrial revolution presents new challenges for managing computer and electronics waste. As the use of these devices increases, so does the amount of waste that is generated. This waste can pose a significant environmental and health risk if it is not managed properly.

There are several things that can be done to manage computer and electronics waste more effectively. These include:

- Designing products for sustainability. Manufacturers can design products that are easier to disassemble and recycle. They can also use materials that are less harmful to the environment.
- Providing consumers with information about recycling options. Consumers should be made aware of the different recycling options that are available to them. They should also be encouraged to recycle their old electronics instead of throwing them away.
- Recycling computer and electronics waste responsibly. When computer and electronics waste is recycled, it should be done in a way that minimizes the environmental impact. This means recycling the materials separately and using recycled materials to make new products.

By taking these steps, we can help to manage computer and electronics waste more effectively and protect the environment.

In addition to the above, here are some other things to consider about the management of computer and electronics waste:

The financial consequences of e-waste. Improper handling of electronic trash can lead to substantial financial consequences. For instance, the discharge of dangerous substances into the environment may harm livestock and crops, resulting in financial losses for companies and farmers.
E-waste's effects on society. Improper handling of electronic trash might potentially affect society. For instance, residents who live next to landfills or dumpsites may experience health issues as a result of hazardous material releases into the environment. When devising computer and electronics waste management solutions, it is imperative to take into account all of the aforementioned factors. We can contribute to the preservation of the economy, the environment, and human health by adopting a comprehensive strategy.

V. Result and Discussion

The findings and analysis of the study on computer and electronic waste (e-waste) management in the context of the fifth industrial revolution are presented in this part. The results offer valuable perspectives on the tactics, innovations, and regulations that may be used to tackle the obstacles associated with managing electronic waste and capitalise on the prospects brought about by the fifth industrial revolution.

A. E-waste Generation Drivers:

The study pinpointed some significant factors that are responsible for the production of electronic trash during the fifth industrial revolution.

The rapid pace of technological innovation, coupled with the desire for the latest devices and features, leads to a frequent replacement of electronic products. Planned obsolescence, where

manufacturers intentionally design products with a limited lifespan, further contributes to e-waste generation. Consumer behaviour, characterized by a throwaway culture and a lack of awareness about responsible disposal, also plays a significant role. These findings underscore the need for awareness campaigns, extended product lifecycles, and consumer education to tackle the drivers of e-waste generation.

B. Environmental and Health Impacts:

The study verified the serious consequences that inappropriate e-waste management has on the environment and human health. When not handled appropriately, dangerous materials included in electronic equipment, such as lead, mercury, and brominated flame retardants, can pollute land, water, and air. These pollutants put human health and ecosystems at danger, which can result in a number of health problems. In order to reduce these effects and safeguard the environment and public health, sustainable waste management techniques must be put into place. The results highlight the necessity of strict laws, efficient monitoring programs, and suitable disposal sites in order to reduce the hazards that electronic waste poses to the environment and public health.

C. Policies and Regulations:

The efficiency of current e-waste management laws and regulations was examined in the study. It was noted that several nations had put laws into place to control the recycling, disposal of e-waste, and responsible product design. However, the research also revealed challenges in the implementation and enforcement of these policies, including inadequate infrastructure, lack of awareness, and limited resources. To address these challenges, there is a need for improved coordination between government agencies, industry stakeholders, and international collaborations. The findings emphasize the importance of comprehensive and consistent regulations that align with the principles of the fifth industrial revolution, promoting sustainable e-waste management practices.

D. Emerging Technologies and Innovations:

The research explored the potential of emerging technologies and innovations in managing e-waste in the context of the fifth industrial revolution. Artificial intelligence (AI) and machine learning algorithms were identified as valuable tools for optimizing recycling processes, improving waste sorting, and enhancing resource recovery. Block chain technology was found to offer transparency, traceability, and accountability in e-waste management systems, ensuring proper disposal and recycling. The circular economy model, emphasizing product reuse, repair, and recycling, emerged as a sustainable approach to reduce waste generation and promote resource conservation. These findings highlight the importance of embracing technological advancements and innovative solutions to tackle e-waste effectively.

E. Collaboration and Stakeholder Engagement:

The research emphasized the significance of collaboration among various stakeholders to address the e-waste challenge. Governments, industries, consumers, and advocacy groups need to collaborate. Public awareness campaigns were found to be crucial in fostering responsible consumer behaviour and promoting the principles of the fifth industrial revolution. The research stressed the need for knowledge-sharing, capacity-building, and international cooperation to drive positive change and create a more sustainable future.

VI. Results and Discussion

There are many potential to address the environmental and socioeconomic issues related to electronic waste through the management of computer and electronics trash through the Fifth Industrial Revolution. The main findings are presented in this part along with a discussion of their significance for sustainable waste management techniques.

A. Trends and Generation of E-waste

An alarming rising trend in the e-waste creation rates is revealed by the study of available data. The amount of electronic waste is growing as a result of shorter product lifecycles, increased usage of electronic gadgets, and quick technical breakthroughs. These findings emphasize how urgently efficient waste management plans must be implemented in order to lessen the negative environmental effects of e-waste.

A. Fifth Industrial Revolution Technologies

The integration of Fifth Industrial Revolution technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, offers promising solutions for electronic waste management. These technologies enable improved waste tracking, efficient sorting and dismantling processes, and data-driven decision-making. The results emphasize the potential of these advancements to revolutionize waste management practices.

B. *Circular Economy Principles:* The application of circular economy principles to electronic waste management demonstrates significant benefits. Designing products for longevity, reparability, and recyclability promotes resource conservation and reduces the volume of waste generated. Implementing extended producer responsibility (EPR) frameworks ensures that manufacturers are accountable for the entire lifecycle of their products. The results underscore the importance of embracing circular economy principles to minimize waste and maximize resource recovery.

C. *Policy and Regulation*

Analysis of existing policies and regulations reveals variations in their effectiveness and enforcement. Countries with comprehensive e-waste management policies and strong regulatory frameworks demonstrate better waste management outcomes. However, several regions still lack adequate legislation and enforcement mechanisms, leading to improper disposal practices and environmental hazards. The results emphasize the need for robust and uniform policy frameworks to promote responsible electronic waste management globally.

E. *Environmental and Health Impact*

The improper disposal and recycling of electronic waste pose significant environmental and health risks. Hazardous substances present in electronic devices, such as lead, mercury, and brominates flame retardants, can contaminate soil, water sources, and air if not handled properly. These pollutants have adverse effects on ecosystems, human health, and vulnerable communities. The results highlight the critical importance of adopting environmentally sound practices to mitigate these impacts.

F. *Stakeholder Engagement and Collaboration*

Effective electronic waste management requires collaboration among various stakeholders, including governments, manufacturers, consumers, and recycling organizations. Engaging stakeholders through partnerships, awareness campaigns, and capacity-building initiatives enhances knowledge sharing, resource mobilization, and the development of sustainable waste management Systems. The results underscore the significance of stakeholder collaboration to achieve comprehensive and impactful solutions. The findings of this paper emphasize the urgent need for proactive and comprehensive measures in managing computer and electronics waste through the Fifth Industrial Revolution. Integrating advanced technologies, embracing circular economy principles, strengthening policy frameworks, and fostering stakeholder collaboration are crucial steps towards sustainable waste management. We can lessen resource consumption, lessen environmental degradation, and develop a more sustainable and ethical method of waste management in the digital age by tackling the issues surrounding electronic trash [12].

VII. CONCLUSION

In the context of the fifth industrial revolution, managing computer and electronic trash, or "e-waste," offers both benefits and challenges. In order to harness the transformative potential of the fifth industrial revolution and address the environmental and health risks connected with e-waste, this paper has examined several methods, technologies, and policies that can be implemented. The findings emphasize the need to tackle the drivers of e-waste generation, including rapid technological innovation, planned obsolescence, and consumer behaviour. To address these drivers, awareness campaigns, extended product lifecycles, and consumer education are essential. The amount of e-waste produced can be decreased by encouraging responsible usage and prolonging the life of electronic devices. The effects of e-waste on the environment and human health were brought to light, highlighting the significance of environmentally friendly trash treatment techniques. Ecosystems and public health depend on electronic device recycling and disposal done correctly, as well as a decrease in dangerous materials. Enforcing thorough laws is vital to guarantee conscientious handling of electronic trash. The study has also looked into the possibility of new developments and cutting-edge e-waste management systems. Resource recovery, transparency, and recycling process optimization are all potential benefits of blockchain technology, artificial intelligence (AI), and the circular economy model. By embracing these technological advancements and adopting a circular approach, we can minimize waste generation and maximize resource conservation.

Collaboration among governments, industries, consumers, and advocacy groups is imperative in addressing the e-waste challenge. Knowledge-sharing, capacity-building, and international cooperation are key to developing effective strategies and implementing sustainable e-waste management practices. Public awareness campaigns play a vital role in fostering responsible consumer behaviour and promoting the principles of the fifth industrial revolution.

In conclusion, the management of computer and electronic waste through the Fifth Industrial Revolution presents significant opportunities to

address the challenges posed by these rapidly growing waste streams. The adoption of advanced technologies, collaboration among stakeholders, and the implementation of effective policies are keys to achieving efficient and sustainable waste management. Through this paper, it has become evident that fostering collaboration among government agencies, recycling organizations, technology companies, and environmental NGOs is crucial. Additionally, investing in research and development, strengthening policy frameworks, promoting circular economy principles, and raising awareness through education campaigns are vital steps towards sustainable waste management. By implementing these suggestions, we may make the most of the Fifth Industrial Revolution's promise to transform computer and electronic waste management, lessen our influence on the environment, and build a more sustainable future. Adopting these suggestions and taking proactive steps to guarantee a healthier and cleaner environment for present and future generations is our shared duty. A key component of sustainable development in the context of the fifth industrial revolution is the management of computer and electronic waste. E-waste can be managed responsibly to reduce negative effects on the environment and public health while promoting the growth of sustainable communities. Although excellent e-waste management techniques and prediction methodologies have been used globally, more work needs to be done to get the best outcomes.

RECOMMENDATIONS

Based on the findings and analysis presented in this paper report on the management of computer and electronic waste through the Fifth Industrial Revolution, the following recommendations are proposed:

A. Foster Collaboration: It is recommended to foster collaboration among government agencies, recycling organizations, technology companies, and environmental NGOs. This collaboration can facilitate knowledge sharing, resource allocation, and the development of innovative solutions for efficient waste management.
B. Invest in Research and Development: Allocating resources for research and development initiatives focused on advancing waste reduction, recycling, and disposal technologies is essential. By supporting research institutions, start-ups, and technology companies, we can drive the development of novel approaches that promote sustainability and environmental responsibility.
C. Strengthen Policy Frameworks: To address the unique challenges of computer and electronic waste management, it is necessary to strengthen existing policies and regulations. To guarantee that manufacturers assume accountability for the complete lifecycle of their products, impose stronger waste disposal and recycling legislation, create incentives for sustainable practices, and support extended producer responsibility.
D. Encourage the Circular Economy: Promote the application of the concepts of the circular economy to waste management. Implementing take-back programs, encouraging the use of recycled materials, and designing products with durability, reparability, and recyclability in mind can all help create a more sustainable approach to waste management.
E. Promote Awareness and Education: To raise public awareness of the harm that incorrect trash disposal does to the environment, start educational initiatives. We may influence behavior and advance sustainable practices by teaching people, companies, and communities about ethical waste management techniques and the possibilities of Fifth Industrial Revolution technology.
E. Embrace Technological Innovations:

Leveraging emerging technologies can significantly improve e-waste management practices. Governments and industries should invest in research and development of artificial intelligence (AI), machine learning, and blockchain technology to optimize recycling processes, enhance traceability, and increase resource recovery rates. To increase efficacy and efficiency, technology-driven solutions ought to be incorporated into the current e-waste management systems.

REFERENCES

[1] Akram, R., Natasha, Fahad, S., Hashmi, M. Z., Wahid, A., Adnan, M., ... & Nasim, W. (2019). Trends of electronic waste pollution and its impact on the global environment and ecosystem. *Environmental Science and Pollution Research*, *26*, 16923-16938.

[2] Sharma, M., Joshi, S., & Kumar, A. (2020). Assessing enablers of e-waste management in circular economy using DEMATEL method: An Indian perspective. *Environmental Science and Pollution Research*, *27*(12), 13325-13338..

[3] Saha, L., Kumar, V., Tiwari, J., Rawat, S., Singh, J., & Bauddh, K. (2021). Electronic waste and their leachates impact on human health and environment:

Global ecological threat and management. *Environmental Technology & Innovation*, *24*, 102049.

[4] Cole, C., Gnanapragasam, A., Cooper, T., & Singh, J. (2019). Assessing barriers to reuse of electrical and electronic equipment, a UK perspective. *Resources, Conservation & Recycling: X*, *1*, 100004.

[5] Hakami, B. A. (2018). Electronic waste management approaches, Saudi Arabia. *Am. J. Environ. Eng*, *8*, 4-10.

[6] Ikhlayel, M. (2017). Environmental impacts and benefits of state-of-the-art technologies for E-waste management. *Waste Management*, *68*, 458-474.

[7] Rautela, R., Arya, S., Vishwakarma, S., Lee, J., Kim, K. H., and Kumar, S. (2021). E-waste management and its effects on the environment and human health. *Science of the Total Environment*, *773*, 145623..

[8] Sharma, M., Luthra, S., Joshi, S., and Kumar, A. (2022). Developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic. International Journal of Logistics Research and Applications, 25(4-5), 433-453.

[9] Gupta, S., and Singh, R. (2020). E-waste management: a review on technologies, challenges, and future prospects. Journal of Cleaner Production, 265, 121955.

[10] World Economic Forum. (2020). A New Circular Vision for Electronics: Time for a Global Reboot. Retrieved from https://www.weforum.org/reports/a-new-circular-vision-for-electronics-time-for-a-global-reboot

[11] Zhang, D., Ding, L., and Zhang, L. (2020). The challenges and strategies for e-waste management in the era of the Industrial Internet of Things. Journal of Cleaner Production, 275, 123548.

[12] World Health Organization (WHO). (2018). Children and Digital Dumpsites. Retrieved from https://www.who.int/ceh/publications/children-digital-dumpsites/en/

[13] Bradu, P., Biswas, A., Nair, C., Sreevalsakumar, S., Patil, M., Kannampuzha, S., and Gopalakrishnan, A. V. (2023). Recent advances in green technology and Industrial Revolution 4.0 for a sustainable future. *Environmental Science and Pollution Research*, *30*(60), 124488-124519.

[14] Castro, F. D., and Bassin, J. P. (2022). Electronic waste: Environmental risks and opportunities. In *Hazardous Waste Management* (pp. 421-458). Elsevier.

[15] Oyebode, O. J. (2013). Solid waste management for sustainable development and public health: A case study of Lagos State in Nigeria. *Universal journal of public health*.

[16] Oyebode, O. J. Promoting Integrated and Sustainable Solid Waste Management System in A Developing City for Public Health and Cleaner Environment. *Journal of Harbin Engineering University*, *45*(01).

[17] Oyebode, O. J. (2022). Sustainable waste management towards circular economy in Nigerian context: Challenges, prospects and way forward. In *Effective Waste Management and Circular Economy* (pp. 103-110). CRC Press.

[18] Nithya, R., Sivasankari, C., and Thirunavukkarasu, A. (2021). Electronic waste generation, regulation and metal recovery: a review. *Environmental Chemistry Letters*, *19*, 1347-1368.

[19] Fatimah, Y. A., Govindan, K., Murniningsih, R., and Setiawan, A. (2020). Industry 4.0 based sustainable circular economy approach for smart waste management system to achieve sustainable development goals: A case study of Indonesia. *Journal of cleaner production*, *269*, 122263.

[20] Oyebode, O. J., and Abdulazeez, Z. O. (2023). Optimization of Supply Chain Network in Solid Waste Management Using a Hybrid Approach of Genetic Algorithm and Fuzzy Logic: A Case Study of Lagos State. *Nature Environment and Pollution Technology*, *22*(4).

[21] Oyebode, O. J., and Otoko, J. A. (2022). Medical Waste Management and Design of a Low-Cost Incinerator for Reduction of Environmental Pollution in a Multi-System Hospital. *Nature Environment and Pollution Technology*, *21*(4).

[22] Oyebode, O. J., Coker, A. O., Sridhar, M. K. C., and Ogarekpe, N. M. (2022). Biomedical Waste Management Practices in Sub-Saharan Africa: Insights of Its Impacts and Strategies for Its Mitigation. In *Advanced Manufacturing in Biological, Petroleum, and Nanotechnology Processing: Application Tools for Design, Operation, Cost Management, and Environmental*

Remediation (pp. 249-256). Cham: Springer International Publishing.

[23] Masud, M. H., Akram, W., Ahmed, A., Ananno, A. A., Mourshed, M., Hasan, M., and Joardder, M. U. H. (2019). Towards the effective E-waste management in Bangladesh: a review. *Environmental Science and Pollution Research*, *26*(2), 1250-1276.

[24] Premalatha, M., Tabassum-Abbasi, Abbasi, T., and Abbasi, S. A. (2014). The generation, impact, and management of e-waste: State of the art. *Critical Reviews in Environmental Science and Technology*, *44*(14), 1577-1678.

[25] Carvalho N, Chaim O, Cazarini E, Gerolamo M (2018) Manufacturing in the fourth industrial revolution: a positive prospect in sustainable manufacturing. Procedia Manuf 21:671–678

[26] Dogaru L (2020) The main goals of the fourth industrial revolution. renewable energy perspectives. Procedia Manuf 46:397–401