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Towards a Greener Future: Sustainable Development and Green IT

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***Abstract*—In recent years the green computing concept is becoming more popular. In addition to the broad sensitivity to environmental issues, this concern also arises from economic needs, since both energy costs and electrical requirements for the IT industry around the world exhibit an ever-increasing trend. The main purpose of this paper is to discuss the various approaches that can be taken by all the sectors of the society to establish sustainable development and to lessen the detrimental effect of IT on nature. After going through different approaches, it can be observed that each approach focuses on different aspects of the IT field which is to be modified for greening the IT like by reducing the emission and e-waste etc. This paper talks about the contributors to the environmental damages and gives an idea on how to maintain environmental sustainability.**

Keywords—Green IT; Environmental Sustainability; Power Consumption; E-waste Disposal.

I. INTRODUCTION

Addressing environmental problems and embracing environmentally best practices have become a prime agenda of governments, societies and enterprises. Innumerable scientific studies and reports corroborate climate change and its prospective detrimental consequences. The number of climate disasters is increasing. About 70% of natural calamities are now climate-related. These result in a higher human toll and a higher price tag. The progressing amassing of Green House Gases (GHGs) is disturbing the global climate and weather patterns. A consistent ascent in the normal temperature of the world's air is alluded to as Global Warming. Global warming is usually ascribed to the greenhouse effect - the trapping of sun's warmth that would otherwise be reflected back to space - caused by rising levels of GHGs as they trap the heat and reflect it back on to the Earth. Carbon dioxide, nitrogen, nitrous oxide, and fluorinated gases are by far the most significant GHGs in lieu of emission rates. The accumulation of GHGs causes destructive sudden heavy rains, violent tropical storms, repeated flooding, and droughts in some countries. Along with global warming, disposing of solid waste has numerous environmental impacts and can lead to serious problems. Contamination of soil and surface water by chemicals, air pollution which in turn leads to acid rain are the impacts of improper disposal of solid waste.

India is a country with population diversity and a serious and developing economy. Equilibrium and concordance between the nation's monetary, social, and natural necessities are needed for maintainable and all-encompassing turn of events. It is necessary to find a steadiness between the protection of the environment and the growth of the economy. Sustainable development is portrayed as progress that meets current problems without jeopardizing people's ability to meet their own in the future. Sustainable Development Incorporates environmental, economic and social dimensions. With collective partnership of stakeholders, mainstreaming the essence of sustainable development and environment protection is possible [1]. The Characteristics of Information technology (IT) are speed and a lack of boundaries. The advancement of IT has an impact on all of us and changes our lifestyles. For a long time, the focus of IT development was mostly on the physical components, such as computers, network connectivity, and mobile technologies. Now the emphasis is on the content of the various parts. This means that the question of IT's contribution to sustainable development will go much beyond the products direct environmental impact.

IT components have no direct, major impact on society's energy consumption or the spread of environmental contaminants, it is the applications that result from these items that raise or decrease environmental effect.[2]. The influence of IT is rising rapidly and is integrated into more and more products. This means they will play an increasingly important role in sustainability. Unless greater consideration is given to energy consumption and environmental impact when designing IT products and applications, their direct environmental impact could be significant [2]. The sustainability of technology is important, for example, in energy use and equipment disposal (also known as e-waste). Electronic waste is landfilled for disposal and contains toxic substances including lead, mercury and brominated flames. Some elements, such as cadmium, can get into the soil and taint the water we consume, the flora, and the animals that inhabit our surroundings. Other impacts include, global warming, greenhouse gas effect due to carbon emission etc.

Green information technology as outlined in the official journal of the French Republic on July 12, 2009 is that part of information and communication technology, whose development or usage can bring down the negative impact of human activities on the environment. Green IT helps in effective material management and waste management and facilitates the design of an IT product or service by considering every effect it has on the environment from the beginning till its disposal. It contains all of the activities and efforts that embrace ecologically friendly technologies and techniques [3]. Green IT ensures sustainable development. Some of the steps that can be followed for greening IT include reduced use of hazardous materials for manufacturing, efficient and environmentally friendly

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recycling, utilizing renewable and cleaner sources of energy, and many others. Thus, green IT includes the aspects of environmental sustainability, the economics of energy efficiency and the total expense of proprietorship, which comprises the cost of disposal and reutilization. This paper discusses the different approaches that can be taken by all the sectors of the society to ensure sustainable development and to decrease the detrimental effect of IT on the environment.

II. LITERATURE SURVEY

Ujjwal et al. describes a power and energy consumption monitoring system in different parts of the industry using a wireless environment [4]. Not only is the system cost-effective, but it's also a manageable option for real-time monitoring and energy management. Sensex, which determines a company's performance in the marketplace, may have to do with its contribution to the global green revolution. If possible, this can lead to a commitment to employ 'go-green' mechanisms in all industries. The scalable and acceptable use of the monitoring is through the Green Sensex Credit system, in which energy savings can be linked to the company's stock price, providing a link between the industry's green efforts and market value. The approach encourages industries to adopt green processes as a business decision rather than a regulatory requirement. The future isn't that far away. Sensex closes at 16764 with a loss of 875 points, while Green Sensex closes at 17915 with a gain of 249 points. The diversification of technology through the energy and integration of Sensex will lead to a green (power) revolution.

Donald et al. The Waste Electrical and Electronic Equipment (WEEE) management strategies of the European Union (EU) and China have been analysed in order to find discrepancies and similarities between approaches and to identify current best practices [5]. The general approach was derived from the 1989 Basel Convention and the EU Directive on WEEE and Restriction of Hazardous Substances (RoHS). It is used as the basis for global management policy. General guidelines, such as increased environmental responsibility and producer accountability goals, are considered as best practices that ensure adequate working conditions of WEEE by providing direction and inspiration. The Practical End-of-Life (EoL) treatment process including recycling, recycling, repair, recycling, reinstallation, reuse and disposal of e-waste associated with mobile phones are investigated and studied. In the phone disassemble exercise, component material, weight, contact method, closure function, and disassembly damage were discovered and noted down for each component removed. The disassembly gave an insight into how the EU's WEEE control system can be applied to improve component manufacturing. The proposal suggests implementing an open-access EU component database that provides component data from Original Equipment Manufacturer (OEM) and updated component performance information. Thus, the quality and identification of the components are improved, which aids in the restoration.

Paul et al. performed an analysis which shows that most of the energy consumption for most Information and Communications Technology (ICT) data has occurred due to local devices, with the most important exception being Peer-to-peer file sharing and online video [6]. Online video in particular requires a lot of power, and most of it comes from the network. Given the current internet traffic forecasts, it is not surprising. Desktop data consumes a lot of energy and the majority of it is overhead. The recent advent of cloud computing, a computer model that outsources data to server farms, along with new portable networking products where data accesses these resources, is positive for energy consumed by consumers as these mobile gadgets use a fraction of the energy that desktops and laptops do. It remains to be seen whether this effect will be offset by continuously increasing energy consumption in the server network infrastructure. The exercise highlights the benefits of a top-down strategy. Examining particular tasks reveals the environmental benefits of that action performed, but the final impact of the action can only be inspected collectively.

Herrmann et al. have addressed more layers of Green IT. How to deal with the entire life cycle of information technology is demonstrated [7]. The entire life cycle of the technology, the equipment, the infrastructure, the facility management, and most importantly it optimizes the effectiveness of the first level, that is, the entire IT system, and borrows the substitution effect, using the second level of effectiveness, that is, IT instead of obsolete systems. Examples and methods for assessing and evaluating the sustainability performance of IT, mechanisms and methods for doing them effectively, and proving the results related to Green IT planning and implementation activities are discussed. Equipment and infrastructure can summarize these three areas, along with the focus at the deployment stage. It can be identified as a world-class impact or overall IT performance related to the life cycle. Thus, it reduces the impact of this first level effect, namely Green IT. Finally, IT trends and trends tend to significantly increase the impact. Few argue that IT can never go green because it grows rapidly and sustainability is affected. But defenders also know the benefits and opportunities of IT. This is known as a second-level effect, which includes recognition and benefits, or at least rewards for IT actions.

M. A. Albreem et al. have provided a generalist of wireless communications with information on green IoT implementations, activities, knowledge, and challenges [8]. Different energy productive equipment plan standards, server farms, programming-based information traffic executive procedures are discussed as empowering influences of green IoT. Different viable behavioural change models and methodologies to provide alertness about energy preservation amid clients and specialist organizations of IoTs were presented. Edge registering presents a stage that broadens cloud administrations at the edge of organization and hence lessens inertness, decreases power utilization, provides improved versatility, transfer speed, information protection, and security. So, the energy utilization model of a fog-based administration under different situations was presented. Also, future examination objectives towards

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energy productive equipment plan standards and a need for coordination between strategy creators, IoT product makers alongside specialist co-ops were introduced.

Bobby. S discussed the consumption of energy at various stages of computing and also as to how it impacts the end users [9]. In computing systems, the management techniques can be classified as static and dynamic where the methods involved at the design time falls under the static power management technique and involved at the run-time falls under the dynamic power management. The green computing methods for power management in computer systems were presented. The techniques presented were categorized at different levels such as the firmware level, the hardware level, the operating System level, the virtualization level and the data centre level.

Piotr Nowakowski et al. research looks at a photo-based image recognition method for identifying and classifying useless electronic and electrical tools [10]. Its key goal is to provide awareness about collection of waste as simple as possible, taking advantage of the global usage and adoption of smartphones. Individuals would take a picture of the waste object and submit it to the server of the waste collection company. It would then be identified and grouped automatically, improving waste collection planning. The system that is proposed can be run either on a mobile application or on a server. For image analysis, a new way of classification and recognition based on neural networks is proposed. The chosen e-waste categories' identification and classification was between 90 to 97 percent accurate.

Abul Bashar reviewed numerous papers relating to sustainable green Internet of Things (IOTs) in the devices for enhancing their energy efficiency in [11]. The relative applications in the hope that the future applications will be greener were discussed. The information about which components and layers in the IOTs cause high power consumption were provided. The goals of green technology and the things that need to be achieved for reaching the fundamentals of green IOT were tabulated.

Das et al. have discussed the realization of green IT for the need of a safe environment [12]. Green IT is primarily used for technologies that reduce carbon dioxide emissions and minimizes environmental impact. Computers can be managed by using computers and scheming algorithms efficiently. Green IT is used in design, production and disposal of servers, computers, monitors, printing devices and other storage devices. Green computers can significantly reduce energy consumption and create value for customers and businesses. The usage of green computing, methodologies that can be implemented by organizations which in turn enhances the procedures for building up a safe and healthy atmosphere is mainly contributed. Business leaders can contribute to safeguarding the atmosphere by implementing green IT practices. Green IT is the best practice for dealing with global warming.

Shenoy et al. have suggested a method where harm towards the environment is reduced by changing a few techniques in current Systems development Life Cycle (SDLC) and aiming towards a greener and sustainable software development [13]. Separating the software development process to systematically implement and maintain software is the main motto of the software development life cycle. The most important barrier is that some important decisions are made at the stages, such as paper use, e-waste production, and energy use. Many of them cause enormous environmental damage. There are a variety of methodologies to do the same in an eco-friendly manner. An important role in software development in an environment friendly is played by the infrastructure. It includes conference rooms, firmware, software, hardware, travel assistance, special hardware, electricity, and more. There are several standards and important processes to follow, which will focus on improvement of the quality of the software. To achieve a greener environment, customer performance, reliability and satisfaction are more important and must be strengthened. The ideas presented will help in reducing energy consumption, paper use, pollution, or fossil fuel use from unnecessary travel, etc., if exercised properly. E-waste can be gradually reduced. It also decreases the additional cost of the software development process of the organization. When implemented, it will certainly provide key benefits such as increased responsibility for environmental protection, support for environmentally friendly measures, and entrepreneurship on behalf of the organization and its customers. It also helps organizations design and for building of green software development centers, processes, products and technologies.

Biswajit Saha summited the practices and the tactics concerning the use of computing sources in an surroundings pleasant manner at the same time as keeping general computing overall performance is not anything but the Green Computing [14]. The continuous upward thrust withinside the common temperature of the Earth's weather has resulted withinside the Global warming. But there were theories placed up for the motives which are inflicting international warming. Climate extrade and related influences in a different way from area to area throughout the globe. However, climate behaviour has turned out to be extraordinarily unpredictable throughout the world. Apart from international warming, there are numerous different motives that are inflicting extrade in behaviour of the surroundings, one in all that's IT equipment to fulfill diverse strength requirements. Green computing is a properly balanced and sustainable method closer to the success of a greener, more healthy and more secure surroundings without compromising technological desires of the modern and destiny generations. The significance and utilization of inexperienced computing for pleasant and sustainable surroundings around us is emphasized. It may be located that inexperienced computing is the want of the hour to shield the surroundings. As time skip through, we're greater in want of and established of era instead of guy strength and for this reason it will become greater crucial to pay attention at the waste which can be being produced through the IT waste and different sort of wastes that are installed to surroundings withinside the manner of growing technological surroundings. So, laptop penetration is growing globally at

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a high-quality rate. It makes it all of the greater vital to keep inexperienced computing tactics at some stage in the existence cycle of a laptop from production until the give up of its operation. Thus, it could be adequately concluded that there can be wholesome and easy surroundings. All stakeholders should contribute for healthier and greener surroundings for our destiny generations.

S. Devika talks about the environmental impacts caused by computers beginning from the mining stage until its abandonment as e-waste [15]. The waste generated during each stage in the life cycle of the computer – mining, manufacturing, usage and disposal is communicated. The process of how the mines are over-exploited for extraction of metals and its adverse impact on the ecosystem is discussed. Some of the recycling processes such as incineration, open dumping that are carried out by the unorganized sector and its effect on the environment are explained. Some safer methods of e-waste disposal such as recycling, reusing, refurbishing and secondary production are proposed.

V. Agarwal et al. specializes in reviewing the past works for recognising the role of Artificial Intelligence (AI) in e-waste management [16]. The impact and scope of AI in the management of e-waste in the future is illustrated. Two main objectives were mentioned - To contemplate the AI techniques and to explore the challenges of AI in the treatment of e-waste. The computation tools which are being used by other countries in segregation of e-waste were compared. The advantages of utilizing AI in treating e-waste such as the faster treatment process and the prevention of humans from coming in contact with the toxic substances during the processing of e-waste were mentioned.

Gupta et al. mainly focus on the current situation of electronic waste in India [17]. The industry here has a prominent worldwide footprint in recent times mostly due to the software sector. And hence the e-waste generation is increasing compound annual growth of 30%. The causes of electronic waste, various types and sources of electronic waste such as household appliances, IT equipment, tools and medical instruments, the hazardous materials present in e-waste such as lead, chromium, mercury, lithium, arsenic, etc. and their impact on humans and the environment, and the various ways to control the pollution due to e-waste are all discussed.

Pant et al. examine the world-wide and Indian interpretations on e-waste. The government's proposals for electronic-waste control and the impact of e-waste on our environment is reviewed [18]. The countries considered for the research are India, China and South Africa. These countries are evaluated using an assessment indicator system, which considers the organizational framework, the recycling management and its numerous effects on the surrounding environment. The major sources of e-waste in India include PC equipment, media transmission hardware, electrical hardware, and restorative gear and of all these, only 1.5% of the waste is reused.

III. PROPOSED WORK

A. Minimization and disposal of E-waste

As technology is growing, e-waste is also increasing and hence, e-waste management is necessary for sustainable development because the improper management of e-waste causes hazardous effects on the environment and human health. Some of the methods that can be implemented to ensure the proper usage of electronic devices and to reduce the amount of e-waste generated are discussed below.

There is no efficient procedure in place to collect e-waste from both the household and enterprises. Most people tend to dispose of e-waste in the same way as they dispose of normal waste. Hence, it is necessary to spread awareness among people so that they do not dump their e-waste along with other wastes. Also, it would be beneficial if the local municipalities with the help of the non-governmental organizations (NGOs) or other similar organizations would take the initiative and collect the e-waste like they collect the other types of waste from all the localities on a regular basis.

Another common practice in the Indian household is to give away old electronic items to scrap dealers(kabadiwalas). The problem here is that they have much less skill and do not follow the safety measures required to handle the various materials present in e-waste. They engross in open-air burning of wires to obtain copper and use cyanide-based acid to separate metals which causes great damage to themselves and to the environment around them. They extract only those materials which can be beneficial to them and leave the rest of the materials unattended, some of which may still be harmful.

Hence it would be useful if we could set up establishments to collect and examine e-waste in all the major areas where any person can drop off e-waste. People who work there should be qualified to manage all types of e-waste. They must examine the materials and check if they can be recycled. An app or a website can be developed to provide the locations of all these places and also allow the user to search for the places near his location.

Some of the common practices that are in use for disposing of e-waste include incineration and landfills. Incineration leads to the discharge of lethal gases and landfills cause soil contamination. However, this impact on the environment can be minimized by segregating the e-waste into biodegradable and non-biodegradable components. The biodegradable materials can be decomposed safely and the non-biodegradable components can be recycled using chemical processes. Deep learning algorithms can be implemented for the classification of e-waste based on the type or the type of material.

Even though India is the third-largest producer of e-waste in the world, there still are millions of people who are not able to afford some of the common electronic gadgets such as smartphones and laptops due to relatively low income. Hence all individuals and enterprises can donate their old and reusable electronic devices to organizations such as schools, colleges or NGOs who require such equipment. It would help them to teach basic computer skills to people from underprivileged backgrounds. Old phones can provide a new way of communication to many people,

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especially in rural areas.

An effective way of reducing the generation of e-waste is to prevent the unnecessary purchases of electronic equipment. One must ensure that the products they are buying are really useful and are required in the long run. After purchasing a product, it must be managed properly by following all the instructions provided by the manufacturer for its efficient usage. Hence proper techniques for usage, recycling and disposal of electronic devices can help reduce the amount of waste to a large extent.

B. Reducing Power Consumption in Electronic Devices

Table 1 describes the existing techniques or features that are incorporated in various components of electronic devices to decrease their power consumption.

Popular Approaches from Table I are,

1. Clock Gating:

The most prevalent method for lowering power usage has been to change the architecture of the system. Clock gating is a prominent method for decreasing power consumption. Latch based clock gating is an intriguing solution for protecting designs from dangers that can result in increased power usage. When not in use, the clock can be switched off. It incorporates a level sensitive latch into the circuit. It allows signal transmission from the clock's active edge to its inactive edge.

TABLE I: TECHNIQUES FOR REDUCING POWER CONSUMPTION IN ELECTRONIC DEVICES

Existing Technique/Feature	Description	Applicable Device/Field
Bluetooth Low Energy (BLE)	Instead of frequency hopping, the Bluetooth Consortium developed BLE, which employs Direct Sequence Spread Spectrum to convey data.	Battery-operated devices (eg. iOS, Android, Windows Phone, and BlackBerry are among the mobile operating systems available, as are macOS, Linux, Windows 8, and Windows 10)
Variable Voltage techniques	Parallelism can be used at the chip level due to the nearly "infinite" number of transistors available, resulting in notable power savings by lowering the supply voltage level.	Very large-scale integration (VLSI) Design
Sleep Mode feature of Processors in Integrated Circuit (IC)	Sleep and Deep Sleep modes, as well as sleep-on-exit features in processors, help to cut down on device active life cycles. Tasks are performed faster and the system can stay in sleep mode for longer when project code is compiled using flash memory. As a result, the project's runtime is reduced.	Arm Cortex-M23 processor and Cortex-M33 microcontroller in CPUs
Adiabatic Logic Technique in Integrated Circuits (ICs)	Current ICs run on DC voltage that is converted from AC supply voltage, however the conversion process requires power from an AC adaptor or a battery. Two AC voltages (sine waves) are used as the power supply for the adiabatic logic circuit. It does not misuse energy; instead, it recovers a portion of it as supply power, lowering power usage.	Transistors ,Healthcare Products (Pacemakers etc), Smart Phones, Personal Computers (PCs) etc.
Clock Gating	The main areas of concern for power consumption are the power utilized through device logic change and charging load capacitance. Clock gating based on latches is an intriguing solution for protecting designs from potential power consumption issues. When not in use, the clock can be switched off.	Circuit Design for Processors (eg. Pentium 4)

2. Adiabatic Logic Circuit:

Current ICs run on DC voltage that is converted from AC supply voltage, however the conversion process requires power from an AC adaptor or a battery. Adiabatic Logic Circuit, a novel form of IC, is put into consumer electronics to decrease such power loss. The circuit in the IC system is controlled by digital domain signals of 0 and 1. This computation method has been wasting energy (or electric power) and generating heat unnecessarily till now.

Adiabatic logic uses the concept of switching activities to reduce power consumption by returning stored energy to the source. As a result, in low-power VLSI circuits that incorporate reversible logic, the phrase adiabatic logic is used. Thus, power consumption of electronic devices is reduced by 90% with adiabatic logic integrated circuit.

There are different simple steps which can be followed by the users to decrease the power consumption of the devices they use i.e., personal computers (PC's), laptops,

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mobile phones etc. One such step would be to turn the switch off immediately after charging the device. Leaving the switch on even after unplugging the charger from the system wastes an abundant amount of energy. The next important thing is to make use of the sleep mode provided to our laptops and PC's. Whenever the system is not in use instead of leaving it on we can either turn off the system or we can put it in sleep mode in case we want to use it immediately again. Doing so will lower the screen time which in turn decreases the power usage. Some other steps which can be taken would be keeping the brightness of the screen to a minimum level, closing all the unnecessary applications which are running in the background, using blank screensavers instead of one that displays moving images etc.

IV. CONCLUSION

Most of the harm caused to the environment by the IT industry can be reduced with the help of Green IT. This paper gives a summarization of the various methods used in reducing power consumption in electronic devices and e-waste disposal management systems in order to have a healthy greener environment for the upcoming generations. The IT industries and their consumers can incorporate these approaches as a step towards a Greener Future.

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