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<u>The Future of Green Computing:</u> <u>Emerging Technologies and</u> <u>Trends</u>

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#### Introduction

Computers have a negative effect on both the environment and users because of the toxic chemicals present in hardware waste and the high level of electronic cost and carbon dioxide emissions generated by long term usage of computers. Also, the huge global production of computing equipment has a direct negative impact on the environment. As a result, scientists are conducting extensive research to solve this issue and minimize computing technology's adverse impacts on natural resources. To address these matters, hardware developers should adopt eco friendly practices and learn about green computing.

Green computing is the practice of designing, developing, using, and disposing of computing resources in an environmentally friendly manner. Green computing has gained huge attention due to rising energy costs, the potential for savings, and environmental concerns. It involves managing computing resources in a conscious manner, which includes decreasing the use of hazardous materials, enhancing energy efficiency throughout the product life cycle. By adopting green computing practices, businesses can offer customers robust, versatile, secure, and cost effective solutions that are also environment friendly.

Green computing is a vast field that encompasses diverse subjects, its primary objective is to minimize the environmental impact of industrial processes and innovative technologies, which have become increasingly pressing due to the planet's expanding population and to fulfill societal requirements without depleting natural resources, which involves creating products that are fully recyclable, mitigating pollution, exploring alternative technologies in variety of fields, and fostering economic activity centered on environmentally beneficial technologies.Green computing is now gaining massive attention despite years of limited recognition. Companies are competing with each other to achieve the highest level of "greenness" as the trend of associating technology with environmental friendliness has become popular.

This report offers a brief overview of green computing, with a focus on it's history and development, the importance and benefits of green computing, a major issue in green computing and solutions for it, and future directions. As green computing continues to gain traction, the future looks bright for those who adopt it.

### Green Computing: From Concept to Reality - A Journey Through Its History and Development

Green computing, which is also referred to as green IT or environmentally sustainable computing, is a concept that originated in the late 1990s and early 2000s as a reaction to the increasing worries regarding the ecological influence of computing technologies. This is an emerging field that aims to minimize the environmental impact of computer systems. The history and development of green computing can be traced back to several key areas with respective timelines.

- 1992- The Energy star program, is a program launched by the U.S. Environmental Protection Agency (EPA), to promote energy-efficient computing equipment. With this program, computer hardware manufacturers began to produce components such as processors, memory, and hard drives to consume less power and generate less heat which helped reduce the environmental impact of computing. The term "green computing" was probably formulated shortly after the Energy Star program began.
- 1997-The Kyoto Protocol, the international agreement signed by 192 countries sets targets for reducing greenhouse gas emissions. This results in heightened consciousness regarding the environmental effects of computing. The growth of eco-friendly computing has been prompted by the necessity to curtail the release of harmful gases and alleviate the ecological consequences of the information technology sector.
- 2001-The formation of The Green Grid, a group of IT businesses dedicated to the advancement of energy-efficient data centers, has started to take place. They were designed to minimize energy consumption and reduce carbon emissions with a variety of technologies and techniques like energy-efficient cooling systems, and renewable energy sources. Some of its key initiatives are Power usage effectiveness (PUE), Water usage effectiveness (WUE), Datacenter maturity model (DCMM), and energy-efficient technologies.
- 2005-With reducing the requirement of several physical machines, Virtualization technology becomes more widely adopted, which allows multiple virtual machines to run on a single physical machine. This allows organizations to consolidate their IT infrastructure. It led to significant energy savings.
- 2007-The EPA introduced the Energy star specification for data center storage. It sets energy efficiency standards for storage devices. They established energy efficiency standards for storage devices such as solid-state drives, hard disk drives, and networkattached storage devices. The objective of these guidelines is to encourage the creation and management of energy-saving systems and to contribute to the mitigation of the IT sector's carbon emissions.

- 2008-The European Code of conduct for Data Centers was introduced to enhance the energy efficiency of the data center industry which is experiencing a surge in energy usage.
- 2011-Facebook initiates the Open Compute Project, which aims to create energy-saving computing equipment and data center blueprints.
- 2014-The EPA introduced the Energy Star specification for data center infrastructure. It establishes guidelines for designing and operating data centers with efficient use of energy.
- 2018-The Global e-Sustainability Initiative (GeSI) has published the Digital with Purpose report, which outlines a plan for enhancing the sustainability of the ICT industry and curbing its carbon emissions. The advancement of intelligent power networks, which utilize IT to regulate the dispersal and usage of electricity, has the potential to curtail energy usage and carbon footprints. Correspondingly, the adoption of virtual meetings and other collaborative technologies can diminish the necessity for physical travel and the consequential carbon emissions.
- 2020-The outbreak of COVID-19 has resulted in a surge in telecommuting and virtual engagement, underscoring the significance of energy-saving computing and ecofriendly IT protocols.

Overall, the development of green computing is a crucial move in the direction of establishing a future that is more sustainable and environmentally conscious. Through the reduction of energy usage, the minimization of electronic trash, and the encouragement of information technology as a means to lower carbon emissions, eco-friendly computing can make a substantial impact in the battle.



# Going Green with Technology: Understanding the Importance and Benefits of Green Computing

Green computing has become a vital industry, giving organizations and people a cost- and environmentally conscious method to cut back on carbon emissions and advance sustainability. The subject covers a broad variety of topics, from examining cutting-edge technology to be used in daily living to researching modern power generation techniques. Enhancing energy economy, lowering power consumption, and reducing the release of hazardous chemicals from computer parts are the main goals of green computing. Business expense savings are one of the most important advantages of green tech. Due to the 24/7 nature of the contemporary world, businesses must gather, keep, monitor, and analyze massive amounts of data.

To operate computers and keep them cool, data warehouses and the sizable data centers where they are housed consume a lot of electricity. Businesses have started to handle data center energy usage by utilizing blade servers, storage area networks, virtualization, and more effective cooling systems. Traditional appliance-centric data warehousing methods, on the other hand, can only keep adding gear as data quantities soar. By addressing how much server room and resources their information processing needs in the first place, organizations can reduce their "data footprint." Organizations can save money and go green by using opensource, cost-effective software and new database technologies created specifically for studying vast amounts of data. Green computing supports environmental viability and costcutting in addition to cost-cutting.

Businesses and customers have begun to adopt ecologically friendly goods that offer lowcarbon solutions as global warming and reducing the environmental effect of fossil fuel pollution ascend to the top of the global public policy agenda. Green policies provide organizations that commit to a low carbon emissions footprint with real economic benefits. The main goals of a green computing strategy might be to reduce the amount of energy used by the IT estate, buy green energy, work with green vendors, use less paper and other products, and reduce the amount of equipment that needs to be disposed of. Green computing uses a range of techniques to improve energy effectiveness and reduce power consumption. Information technology becomes "Green" and contributes to cost savings and environmental protection by lowering and removing unnecessary activities. Because of the ability to recycle and use less energy thanks to changing government rules, it also helps to limit the release of hazardous chemicals from computer components. Businesses can greatly reduce their energy usage and lower their energy costs by utilizing energy-efficient technologies like cloud computing and virtualization.

Green computing can reduce electrical trash and boost technological effectiveness. We can lessen the amount of technological trash produced and lessen the environmental effect by utilizing technology that is made to last longer and be readily repaired or recycled. Companies can save time and money by reducing the number of resources needed to complete a job, enhancing efficiency, and reducing downtime, all of which can be accomplished by optimizing software and hardware settings. Furthermore, green tech can help a business's image. Customers are becoming more concerned about how technology affects the ecosystem and are more apt to choose businesses that place a high priority on sustainability.

Employing green computing procedures enables businesses to show their dedication to sustainability and draw in clients who care about the environment. Green computing is an important area that provides a responsible and economical way to lessen the carbon impact and encourage sustainability. Saving money, protecting the earth, and longevity are some of its advantages. New methods and technologies, like virtualization, cloud computing, and green data centers, are constantly being created in the field of "green computing" to decrease the effect of computing on the environment. Green computing is anticipated to grow and develop over the coming years as a result of the rising demand for energy-efficient products and services, providing new chances for businesses to lessen their environmental effect and boost their bottom line. Consequently, utilizing green computing techniques can assist both people and companies in making a difference.



## Green Computing Challenges: The Hurdles to Overcome in Implementing Sustainable Practices

The main problems of green computing are e-waste, energy consumption, limited lifespan of technology, lack of awareness, the cost of devices, issues related to existing standards and regulations. Significant progress has been made in reducing the carbon footprint of computing but there are still challenges that need to be addressed. One of the most pressing and largely uncontrollable issue in green computing is the issue of e-waste.

E-waste, or electronic waste, refers to discarded electronic devices such as computers, smartphones, and televisions. These devices contain hazardous materials such as lead, mercury, and cadmium, which can pollute the environment and harm human health if not disposed of properly. The problem of e-waste has intensified due to the rapid pace of technological innovation, the constant release of new devices into the market and the changes made due to the constant changes in current trends.

E-waste can occur in several forms. Consumers may dispose of old devices improperly by putting them in the trash instead of recycling or proper disposal. Companies can generate ewaste by disposing of equipment that may still be used but to maintain efficiency, or by replacing equipment more often than necessary. In developing countries, e-waste is often shipped from developed countries and dumped in landfills, global environmental and ocean pollution causes food crises health hazards and affecting the survival of living beings.

The consequences of e-waste are significant. Toxic substances from e-waste can leach into the soil and groundwater, contaminating food and water sources. Burning e-waste releases dioxins and other harmful chemicals into the air, contributing to air pollution and respiratory problems. Due to informal disposal of these e-wastes serious health problems, such as cancer and neurological damage.

According to a 2020 report by the Global E-waste Statistics Partnership, the world generated a record 53.6 million metric tons of e-waste in 2019, with only 17.4% of it being collected and recycled. In Sri Lanka, E-waste has become a problem that needs to be focused on, which has been gradually growing since about a decade ago, with the country generating an estimated 21,600 metric tons of e-waste in 2019 alone. This figure is expected to rise to 38,500 metric tons by 2030.



https://www.statista.com/statistics/1067081/generation-electronic-waste-globally-forecast/

According to a United Nations University report, the world's top generators of e-waste are the United States, China and India, which recycle or properly manage e-waste at a much lower rate than the rate at which it is generated. If successful solutions are not found and implemented for the problem of e-waste, it is a problem that can have significant global consequences and threaten the existence of living beings both directly and indirectly. By 2050, e-waste may reach 120 million metric tons per year, which the United Nations Environment Program has warned of severe environmental and health impacts.



## Solutions for a Sustainable Future: Best Practices for Implementing Green Computing

There are several solutions that can be implemented to reduce e-waste and promote sustainability in the field of green computing. One solution is for governments to implement regulations that require manufacturers to entrust proper disposal and recycling of e-waste. For example, The European Union's Waste Electrical and Electronic Equipment (WEEE) directive requires manufacturers to collect and recycle a significant percentage of the electronic waste they produce. By implementing and enforcing these regulations, governments can ensure that electronic waste is properly disposed of and recycled, reducing the amount of e-waste that ends up in landfills.

Extended Producer Responsibility (EPR), which is a stricter policy than the (WEEE) Directive mentioned above, is a policy in which manufacturers take responsibility for the whole life cycle of a product. This policy ensures that manufacturers are liable for the end-oflife management of their products, boosting them to design products that are recyclable and more eco-friendly. EPR is currently in place Japan, South Korea, and some European Union countries. As an incentive for those policies, the governments offer benefits such as tax concessions to those companies. Japan has been particularly successful in implementing EPR, with manufacturers required to bear the cost of collection and disposal of e-waste. This has led to high collection rates and improved recycling rates.

One such project as an example of the above solution is Fairphone, a smartphone designed to be environmentally friendly and socially responsible. The Fairphone is designed to be modular, with easily replaceable parts, making it easy to repair and recycle.

Another solution is for people to delay disposing of their devices by using methods such as regularly updating devices for several years instead of buying new ones. This can only be achieved with the commitment of the producers. Companies can buy their products from customers when they are old and provide new products of the same company to customers. For example, Apple istore program offers customers significant discounts on their old iPhones, iPads, and Macs to purchase a new device. The traded-in devices are either refurbished and sold or recycled in an environmentally responsible manner. This program has been successful in reducing e-waste, with Apple recycling over 100,000 tonnes of electronic waste in 2019 alone.

Recycling is one of the most effective ways to reduce e-waste. Recycling facilities can extract valuable resources from old electronics, such as gold, copper, and silver, which can then be reused in new products. This is how the raw materials for the gold, silver and bronze medals of the 2020 Olympics were procured. Many countries have implemented recycling programs. Switzerland has been relatively successful in implementing recycling, with one of the highest recycling rates in the world. Switzerland's recycling program includes a deposit system for

electronic devices that encourages people to return their devices for recycling. Dell's closed-loop recycling program is another example of a company taking steps to address the issue of e-waste. The program involves collecting old electronics, extracting valuable resources such as gold and silver, and reusing them in new products. Dell has set a goal of recycling 100 million pounds of recycled content into new products by 2030. These solutions have been successful in reducing e-waste in various countries around the world. For example, in 2019, the United States recycled over 2.7 million tonnes of electronic waste, while Japan recycled over 18 million mobile phones in the same year.

As more countries implement regulations and individuals become more aware of the environmental impact of their actions, the level of success in reducing e-waste is expected to increase. An example project is the Basel Convention, an international treaty designed to reduce the movement of hazardous waste between countries. The treaty has been ratified by 187 countries, including Sri Lanka, and aims to reduce the dumping of e-waste in developing countries.

The government should compile and implement relevant sustainable regulations and assign the responsibility of recycling their products to the manufacturer. Those companies should be encouraged to install projects like iStore in the country. By encouraging new investors to start new recycling projects, e-waste that remains after several stages can also be disposed of properly.



### Additional assumptions

- Although the implementation of the proposed e-waste recycling and disposal programs may incur high costs but the investors are investing for these programs
- Encouraging consumers to buy eco-friendly products even if they cost more than conventional products
- The demand for these electronic devices does not increase or decrease too much
- Alternative inventions may not enter the market in the next decade
- Government's not reluctant to implement e-waste regulations
- Some people or companies prioritize sustainability over cost
- Absence of regulatory issues between countries



#### Conclusion

In conclusion, green computing has become an essential aspect of the IT industry in recent years, and its development has been significant. The concept of green computing has its roots in the early days of the personal computer transformation when concerns about energy consumption and environmental effect began to arise. Over the years, there have been massive developments in the field, including the implementation of energy-efficient hardware and software, cloud computing, virtualization, and the use of renewable energy sources. In summary, green computing has come a long way since its early days, and its importance in promoting sustainability and reducing the negative impact of technology on the environment cannot be overstated. While there are obstacles to be addressed, such as the proper disposal of electronic waste, the future of green computing looks encouraging, with continued development and a focus on energy efficiency, renewable energy sources. As the Information Technology industry continues to evolve, green computing will play an increasingly important role in shaping the future of technology and the environment.



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