

Environmental sustainability and digitization

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Abstract:

Environmental sustainability has become a pressing global concern, requiring innovative approaches to mitigate the impacts of human activities on the planet. In recent years, the emergence of digital technologies has presented new opportunities and challenges in achieving environmental sustainability goals. This study aims to provide an overview of the intersection between environmental sustainability and digitization, exploring the potential benefits and risks associated with this relationship.

Through a comprehensive review of literature and case studies, this study examines various aspects of the integration of digital technologies in environmental sustainability efforts. It analyzes how digitization can contribute to environmental conservation, resource management, and sustainable development practices. The study identifies several key areas where digitization can facilitate environmental sustainability. Firstly, digital technologies offer new tools for data collection, monitoring, and analysis, enabling more accurate and real-time assessment of environmental conditions. This enhances decision-making processes and enables proactive measures to address environmental challenges.

Secondly, digitization enables the optimization of resource management practices. Through the Internet of Things (IoT) and smart devices, energy consumption can be monitored and controlled, waste management systems can be improved, and water resources can be efficiently utilized. The study explores these applications and evaluates their environmental and economic implications. Furthermore, digitization plays a crucial role in promoting sustainable lifestyles and behavior change. It enables the dissemination of environmental knowledge and

awareness through online platforms, social media, and educational tools. The study examines the effectiveness of digital interventions in promoting sustainable practices among individuals and communities.

However, the study also acknowledges the challenges and risks associated with digitization and environmental sustainability. It discusses issues such as electronic waste generation, energy consumption of digital infrastructure, and the digital divide, which may exacerbate inequalities in accessing digital solutions for sustainability. The research concludes by highlighting the need for a balanced approach to ensure that digitization contributes positively to environmental sustainability. It emphasizes the importance of policy frameworks that encourage the development and deployment of environmentally friendly digital technologies. Additionally, it calls for increased collaboration between stakeholders, including governments, businesses, civil society, and academia, to address the challenges and maximize the potential benefits of digitization for environmental sustainability.

Overall, this study contributes to the understanding of the complex relationship between environmental sustainability and digitization. It provides insights and recommendations for policymakers, organizations, and individuals seeking to leverage digital technologies for sustainable development, while mitigating the associated risks.

Keywords: Global collaboration -Resource Efficiency-Digitalization-Innovative-Energy storage

Introduction:

Data-driven decision-making refers to the practice of using data and analytics to inform and guide the decision-making process. It involves collecting, analyzing, and interpreting relevant data to gain insights and make informed choices. Identifying environmental issues: By collecting and analyzing data from various sources, such as environmental monitoring stations, satellite imagery, and sensor networks, decision-makers can identify and track environmental issues like air pollution, water contamination, deforestation, or climate change. These insights help in understanding the scale, causes, and impacts of the problems. Setting goals and targets: Data analysis allows organizations and policymakers to set specific goals and targets for environmental sustainability. For instance, based on scientific data, governments may establish targets for reducing greenhouse gas emissions or increasing the share of renewable energy in the energy mix. Data-driven insights enable the setting of realistic and measurable objectives.

Optimizing resource management: Data analysis helps optimize the use of resources, such as energy, water, and raw materials, leading to greater efficiency and reduced waste. For example, energy consumption data can identify areas of high energy usage, enabling companies to implement energy-saving measures and reduce their carbon footprint. Water consumption data can be analyzed to identify areas of water wastage and implement conservation strategies. Assessing environmental impact: Data-driven decision-making involves evaluating the environmental impact of various activities or projects. Environmental impact assessments (EIAs) utilize data to predict and assess the potential effects of a project on the environment. This information helps in making informed decisions regarding project approvals, mitigating adverse impacts, and exploring alternative options.

Monitoring and evaluation: Data-driven approaches enable ongoing monitoring and evaluation of environmental initiatives. By continuously collecting and analyzing data, decision-makers can assess the effectiveness of implemented measures, identify areas for improvement, and make necessary adjustments. This iterative process helps in refining strategies and achieving better environmental outcomes. Predictive modeling and scenario analysis: Advanced data analytics techniques, such as predictive modeling and scenario analysis, can help decision-

makers understand the potential future impacts of different actions or policy choices. By simulating various scenarios, decision-makers can anticipate the consequences of their decisions on the environment and make choices that minimize negative impacts and maximize positive outcomes. Overall, data-driven decision-making in environmental sustainability empowers stakeholders to make evidence-based choices, optimize resource utilization, monitor progress, and achieve targeted environmental goals. It enables a more informed and proactive approach to addressing environmental challenges and supports the development of effective strategies and policies for a sustainable future.

Smart grids and energy management:

Smart grids and energy management are integral components of modern energy systems that leverage digitization and advanced technologies to optimize energy generation, distribution, and consumption. Here's an overview of smart grids and their role in energy management: Improved monitoring and control: Smart grids incorporate sensors, meters, and advanced communication systems to monitor and collect data on energy production, consumption, and grid conditions in real-time. This allows utilities to have a better understanding of energy flows, identify areas of high demand or potential disruptions, and proactively manage the grid for optimal performance.

Integration of renewable energy sources: Smart grids enable the integration of renewable energy sources, such as solar and wind power, into the electricity grid. By leveraging real-time data on energy production from these sources, grid operators can balance supply and demand, manage fluctuations, and ensure a stable and reliable energy supply. This integration promotes the use of clean energy and reduces reliance on fossil fuels, contributing to environmental sustainability. Demand response and load management: Smart grids facilitate demand response programs that incentivize consumers to adjust their energy usage during peak demand periods. With the help of smart meters and real-time data, consumers can monitor their energy consumption and receive signals or price incentives to reduce or shift their energy use to off-peak hours. This helps balance the grid, avoid blackouts, and optimize the utilization of existing energy infrastructure.

Enhanced energy efficiency: Smart grids enable advanced energy management systems that promote energy efficiency. By providing real-time data on energy consumption, consumers can identify areas of wastage and make informed decisions to reduce their energy usage. Additionally, utilities can identify inefficiencies in the grid and optimize the distribution of electricity, minimizing losses during transmission. Grid resilience and self-healing capabilities: Smart grids are designed with self-healing capabilities to automatically detect, isolate, and restore power in case of outages or disruptions. This improves grid reliability, reduces downtime, and enhances resilience to natural disasters or other incidents. With real-time monitoring and control, utilities can identify and address issues more quickly, minimizing the impact on consumers and the environment.

Electric vehicle integration: Smart grids play a crucial role in the integration of electric vehicles (EVs) into the energy system. By managing charging infrastructure and coordinating EV charging patterns, smart grids can optimize energy distribution and ensure efficient charging during off-peak hours. This reduces strain on the grid, supports the increased adoption of EVs, and contributes to the transition to cleaner transportation. Smart grids, driven by digital technologies and data analytics, offer numerous benefits, including increased reliability, improved energy efficiency, integration of renewable energy, and enhanced grid resilience. By optimizing energy management and reducing energy waste, smart grids play a vital role in promoting sustainable energy systems and mitigating the environmental impacts of energy production and consumption.

Internet of Things (IoT) for environmental monitoring:

The Internet of Things (IoT) refers to the network of interconnected physical devices embedded with sensors, software, and connectivity capabilities that enable them to collect and exchange data. IoT technology has significant applications in environmental monitoring, allowing for more comprehensive and real-time insights into various aspects of the environment. Here's how IoT is used for environmental monitoring: Air quality monitoring: IoT devices equipped with sensors can measure air pollutants such as particulate matter, ozone, nitrogen dioxide, and carbon monoxide. These sensors can be deployed in urban areas, industrial sites, and even wearable devices to gather data on air quality. The collected data provides valuable

information about pollution levels, helps identify pollution sources, and supports the development of strategies to improve air quality.

Water quality monitoring: IoT sensors can be used to monitor water bodies such as rivers, lakes, and oceans for parameters like temperature, pH levels, dissolved oxygen, and pollutants. These sensors can provide real-time data on water quality, enabling early detection of contamination or changes in aquatic ecosystems. This information is crucial for managing water resources, ensuring safe drinking water, and protecting aquatic life. **Soil and agriculture monitoring:** IoT devices can monitor soil moisture levels, temperature, and nutrient content in agricultural fields. Farmers can use this data to optimize irrigation, fertilizer application, and crop health management. By providing real-time information, IoT-enabled soil monitoring systems help farmers make informed decisions, conserve water, reduce chemical usage, and increase agricultural productivity.

Wildlife monitoring and conservation: IoT-based tracking devices, such as GPS collars and tags, can be attached to wildlife to gather information about their behavior, movement patterns, and habitat preferences. This data aids in wildlife conservation efforts, including species preservation, habitat management, and understanding the impacts of human activities on ecosystems. **Weather monitoring:** IoT weather stations equipped with sensors for temperature, humidity, wind speed, and precipitation can provide localized weather data. This information is valuable for weather forecasting, climate studies, and disaster management. By collecting and analyzing weather data from IoT devices across a wide geographical area, more accurate and localized weather predictions can be made.

Forest fire detection: IoT sensors and cameras can be deployed in forested areas to detect and monitor signs of forest fires. These sensors can detect changes in temperature, humidity, and smoke levels, triggering alerts and enabling rapid response. Early detection of forest fires is crucial for minimizing their spread and damage, protecting biodiversity, and preserving valuable ecosystems. IoT-based environmental monitoring systems enable real-time data collection, analysis, and decision-making, facilitating proactive management and conservation efforts. By providing a deeper understanding of environmental conditions, IoT technologies

support sustainable practices, resource conservation, and the protection of ecosystems and human health.

Virtual collaboration and telecommuting:

Virtual collaboration and telecommuting, also known as remote work, have become increasingly prevalent in today's digital age. These practices leverage digital technologies to enable people to work from any location, reducing or eliminating the need for physical office spaces. Here's how virtual collaboration and telecommuting contribute to environmental sustainability: **Reduced commuting and transportation emissions:** One of the primary environmental benefits of virtual collaboration and telecommuting is the reduction in commuting-related emissions. By eliminating or minimizing the need for daily travel to and from the office, remote work reduces carbon emissions from vehicles, alleviates traffic congestion, and helps improve air quality in urban areas. This has a positive impact on climate change mitigation and public health.

Energy savings in buildings: Remote work significantly reduces the energy consumption associated with traditional office spaces. With fewer employees working in centralized offices, there is a reduced demand for lighting, heating, cooling, and other energy-consuming systems. This results in lower energy usage and associated greenhouse gas emissions. Additionally, virtual collaboration tools and cloud-based storage reduce the need for physical document printing and storage, further reducing resource consumption and waste generation. **Conservation of natural resources:** Remote work reduces the consumption of natural resources associated with traditional office spaces. It decreases the demand for building materials, land use for office construction, and water consumption for office operations. This contributes to the conservation of natural habitats, reduces deforestation, and minimizes the environmental footprint associated with resource extraction and manufacturing.

Sustainable work-life balance: Virtual collaboration and telecommuting provide employees with increased flexibility in managing their work-life balance. This flexibility can reduce stress and burnout, leading to improved well-being and job satisfaction. By promoting employee well-being, organizations can contribute to

sustainability by fostering a culture that values people and their quality of life. Reduced waste generation: Remote work reduces waste generation associated with office spaces, such as paper waste, plastic packaging, and food waste. With digital collaboration tools, electronic documents, and virtual meetings, there is a decreased reliance on physical materials and a shift towards digital workflows. This promotes a paperless work environment, reduces waste sent to landfills, and minimizes the environmental impact of waste disposal.

Global collaboration and knowledge sharing: Virtual collaboration enables global teams to work together seamlessly, transcending geographical boundaries. This facilitates knowledge sharing, diverse perspectives, and innovation, leading to more efficient and effective solutions. By promoting global collaboration, organizations can leverage a wider range of expertise and reduce the need for frequent business travel, thereby reducing emissions associated with long-distance flights. While virtual collaboration and telecommuting offer significant environmental benefits, it's important to note that there are also potential challenges and considerations. These include ensuring equitable access to digital technologies, addressing social isolation and mental health concerns, and maintaining a sense of organizational culture and teamwork in remote settings. Overall, virtual collaboration and telecommuting present an opportunity to embrace sustainable work practices, reduce environmental impacts, and foster a more resilient and adaptable workforce. By leveraging digital technologies for remote work, organizations can contribute to environmental sustainability while enhancing employee well-being and productivity.

E-commerce and digital services:

E-commerce and digital services have transformed the way we conduct business and engage in commercial activities. This digital shift offers several environmental benefits and opportunities for sustainability: Reduced carbon emissions: E-commerce eliminates the need for physical retail spaces, reducing the carbon emissions associated with brick-and-mortar stores. Traditional retail involves significant transportation, including the shipment of products to stores and customers' trips to make purchases. E-commerce allows for more consolidated and efficient transportation routes, leading to fewer emissions per product delivered.

Moreover, the growing trend of last-mile delivery optimization and the adoption of electric or low-emission vehicles further reduce the environmental impact of e-commerce logistics.

Resource efficiency: Online retail generally requires less packaging materials compared to traditional retail. E-commerce platforms often optimize packaging to fit products efficiently, reducing waste and material consumption. Additionally, digital transactions eliminate the need for printed receipts and paper-based documentation, contributing to paper waste reduction. **Inventory management and waste reduction:** With the help of data analytics and digital tools, e-commerce platforms can optimize inventory management. This reduces excess stock, minimizes product spoilage, and helps prevent the disposal of unsold goods. By aligning supply and demand more precisely, e-commerce can reduce waste along the supply chain. **Sustainable product options:** E-commerce platforms enable consumers to access a wide range of sustainable and eco-friendly products. Online marketplaces provide a platform for small-scale sustainable businesses to reach a broader customer base. This promotes the demand for sustainable products, encourages responsible production practices, and fosters a more environmentally conscious marketplace.

Virtual and digital products: E-commerce is not limited to physical goods; it also encompasses digital services and products. This includes e-books, streaming services, software downloads, and online courses. The distribution of digital products eliminates the environmental impacts associated with physical production, packaging, and transportation. **Consumer education and awareness:** E-commerce platforms offer opportunities to educate and inform consumers about sustainable practices and responsible purchasing decisions. Online marketplaces can highlight eco-friendly products, provide environmental certifications, and offer information about the environmental impacts of various products. This can help raise awareness and empower consumers to make more sustainable choices.

While e-commerce and digital services bring environmental benefits, it's important to consider some potential challenges. These include the energy consumption of data centers powering e-commerce platforms, electronic waste management, and the environmental impact of returns and packaging in the e-

commerce sector. Addressing these challenges requires the adoption of energy-efficient infrastructure, responsible e-waste recycling, and sustainable packaging practices.

Environmental education and awareness:

Environmental education and awareness play a crucial role in promoting sustainability and fostering positive environmental behaviors. By providing knowledge, raising awareness, and inspiring action, environmental education empowers individuals, communities, and organizations to make informed decisions and take responsibility for the environment. Knowledge and understanding: Environmental education provides individuals with a solid understanding of environmental issues, including their causes, impacts, and potential solutions. It equips people with scientific knowledge, ecological literacy, and an understanding of the interconnectedness between humans and the environment. This knowledge enables individuals to make informed choices, evaluate the environmental consequences of their actions, and engage in sustainable practices.

Behavioral change: Environmental education aims to change behaviors and attitudes towards the environment. By raising awareness of the environmental challenges we face, it encourages individuals to adopt sustainable behaviors and make environmentally conscious decisions in their daily lives. These behaviors may include recycling, conserving energy and water, reducing waste, choosing sustainable products, and adopting eco-friendly transportation options. Conservation and stewardship: Environmental education fosters a sense of responsibility and stewardship for the environment. It promotes the idea that each individual has a role to play in protecting and conserving natural resources, biodiversity, and ecosystems. By instilling a sense of connection and responsibility, environmental education encourages individuals to take action to preserve and restore the environment, whether through participation in conservation projects, volunteering, or advocating for environmental policies.

Sustainable lifestyles and consumption: Environmental education encourages individuals to adopt sustainable lifestyles and consumption patterns. It emphasizes the importance of reducing overconsumption, embracing resource efficiency, and

choosing products and services that have minimal environmental impact. This includes promoting concepts such as the circular economy, sustainable agriculture, renewable energy, and eco-friendly technologies. Community engagement and participation: Environmental education fosters community engagement and participation in environmental initiatives. It encourages collaboration, dialogue, and collective action among individuals, schools, community organizations, businesses, and governments. Through environmental education programs, communities can work together to address local environmental challenges, develop sustainable solutions, and create a sense of shared responsibility.

Policy and decision-making: Environmental education plays a crucial role in shaping policies and decision-making processes at various levels. By raising awareness of environmental issues and their implications, it empowers individuals to engage in environmental advocacy, participate in public consultations, and influence policy development. Environmental education also helps policymakers and stakeholders make informed decisions by providing them with scientific knowledge and insights into the social, economic, and environmental dimensions of sustainability. Overall, environmental education and awareness are essential for building a sustainable future. By fostering knowledge, inspiring action, and cultivating a sense of environmental responsibility, it empowers individuals and communities to take meaningful steps towards a more sustainable and resilient world.

Digital technologies and environmental sustainability:

Digital technologies have the potential to significantly contribute to environmental sustainability by enabling innovative solutions, promoting efficiency, and fostering behavior change. Energy management and efficiency: Digital technologies such as smart meters, energy management systems, and building automation systems enable better monitoring and control of energy consumption. Real-time data and analytics help identify energy inefficiencies, optimize energy usage, and reduce energy waste in buildings, industrial processes, and transportation systems. This leads to improved energy efficiency and reduced carbon emissions.

Renewable energy integration: Digital technologies play a crucial role in integrating renewable energy sources into the grid. They enable the monitoring, control, and optimization of distributed energy resources, such as solar panels and wind turbines. Advanced algorithms and predictive analytics help balance energy supply and demand, manage fluctuations, and support the reliable integration of renewable energy into the grid. **Internet of Things (IoT) for resource management:** IoT devices and sensors can be deployed for monitoring and managing resources such as water, air quality, waste, and natural habitats. These devices provide real-time data on resource consumption, pollution levels, and ecological indicators, allowing for more effective resource management, pollution control, and conservation efforts.

Digitalization of processes and workflows: Digital technologies enable the digitization and automation of various processes, reducing the need for physical materials and paper-based workflows. This includes the use of electronic documents, digital communication tools, cloud storage, and online collaboration platforms. By minimizing paper waste, resource consumption, and transportation needs, digitalization contributes to environmental sustainability. **Circular economy and resource optimization:** Digital technologies support the transition to a circular economy by facilitating resource tracking, product lifecycle management, and material reuse. Block chain technology, for instance, can enable transparent and secure tracking of products and materials throughout their lifecycle, promoting responsible sourcing, recycling, and waste reduction. Digital platforms and marketplaces also facilitate the sharing economy and collaborative consumption, reducing the need for new products and optimizing resource utilization.

Environmental monitoring and data analytics: Digital technologies enable comprehensive environmental monitoring, data collection, and analysis. This includes remote sensing technologies, satellite imagery, and geospatial data analysis, which provide valuable insights into ecosystems, deforestation, climate patterns, and natural resource management. By leveraging big data and analytics, decision-makers can make more informed and evidence-based decisions for environmental conservation and sustainable development. **Environmental education and awareness:** Digital technologies offer new avenues for environmental education, awareness-

raising, and behavior change. Online platforms, mobile applications, and social media enable the dissemination of environmental information, interactive learning experiences, and engagement with a broader audience. Digital media and storytelling can help inspire action, drive behavior change, and mobilize collective efforts towards environmental sustainability.

It's important to note that the production, use, and disposal of digital technologies themselves have environmental implications. Addressing these challenges requires the adoption of sustainable design, responsible e-waste management, energy-efficient data centers, and the consideration of social and environmental factors in the development and deployment of digital solutions.

Innovative solutions and environmental sustainability:

Innovative solutions play a critical role in advancing environmental sustainability by addressing pressing environmental challenges, improving resource efficiency, and promoting sustainable practices. Here are some examples of innovative solutions that contribute to environmental sustainability: Clean energy technologies: Innovations in renewable energy technologies, such as solar power, wind power, and geothermal energy, are crucial for reducing reliance on fossil fuels and mitigating climate change. These technologies continue to evolve, becoming more efficient, affordable, and scalable, thereby driving the transition to a low-carbon energy system.

Energy storage systems: The development of advanced energy storage solutions, including batteries and grid-scale storage systems, is essential for integrating intermittent renewable energy sources into the grid. Energy storage enables better management of energy supply and demand, helps stabilize the grid, and allows for the efficient use of renewable energy resources. Sustainable transportation: Innovative solutions in transportation, such as electric vehicles (EVs), hydrogen fuel cells, and shared mobility platforms, contribute to reducing greenhouse gas emissions and air pollution. EVs, for example, offer a cleaner alternative to traditional internal combustion engine vehicles, while shared mobility services help optimize transportation resources and reduce the number of private vehicles on the road.

Circular economy models: The transition to a circular economy involves rethinking how we produce, consume, and dispose of goods. Innovative solutions that promote product reuse, recycling, and remanufacturing contribute to reducing waste generation and resource depletion. This includes initiatives such as product take-back programs, material recovery facilities, and eco-design principles that encourage the use of recycled materials and promote durability and reparability.

Precision agriculture: Innovative technologies in agriculture, such as precision farming techniques, sensor-based irrigation systems, and data analytics, improve resource efficiency, reduce chemical usage, and minimize environmental impacts. These solutions enable targeted application of fertilizers and pesticides, optimized irrigation based on soil moisture levels, and real-time monitoring of crop health, resulting in higher yields and reduced environmental pollution.

Water management technologies: Innovations in water management help address water scarcity and improve water efficiency in various sectors. This includes technologies like drip irrigation, precision water monitoring systems, and water reuse and recycling technologies. By reducing water wastage, minimizing pollution, and enhancing water resource management, these solutions contribute to sustainable water use and conservation.

Waste management and recycling: Innovative waste management solutions focus on reducing waste generation, improving recycling rates, and converting waste into valuable resources. This includes technologies like advanced sorting systems, waste-to-energy conversion, composting facilities, and decentralized waste management systems. These innovations help minimize landfilling, recover valuable materials, and reduce the environmental impact of waste disposal.

Green building and sustainable infrastructure: Innovative building materials, energy-efficient designs, and smart building technologies promote sustainable construction and reduce the environmental footprint of buildings and infrastructure. This includes innovations like green roofs, passive cooling systems, energy management systems, and building automation technologies. Green buildings contribute to energy and resource efficiency, enhance indoor air quality, and reduce carbon emissions. These are just a few examples of the many innovative solutions driving environmental sustainability. The continuous development and adoption of

such solutions are essential for addressing environmental challenges, promoting sustainable development, and creating a more resilient and regenerative future.

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