Digital Technologies and the Environment: a Synergy for the Future

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Digital Technologies and the Environment: a Synergy for the Future
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1. Executive Summary

Environment and digital technology are two pillars at a turning point of humanity's future. Recent alarming reports on the state of the environment emphasizing the urgency to mitigate climate change have included digital technologies as one of the ways to accelerate environmental efforts. With the onset of digital technologies and their potential for disruptive transformation and positive change, the link between digital developments and the environment is now becoming part of international and national policies. Most global policies from the international bodies, the European Union (EU), the new administration in the U.S. or China, reflect substantially on the issues related to the nexus of environmental and digital policy developments and will remain on the agenda for the years to come.
On national levels, digital and environmental issues are intrinsically connected, influence each other and have impacts in all areas of people's lives - from sustainable cities and communities to economic prosperity and human rights.

The European Union in its European Green Deal interlinks policy efforts on digital technologies and the environment. Among other things, it highlights that the European Commission "will explore measures to ensure that digital technologies such as artificial intelligence (AI), 5G, cloud and edge computing, and the Internet of Things (IoT) can accelerate and maximize the impact of policies to deal with climate change and protect the environment"[1]. The EU has also reached a climate deal to begin being "climate neutral" by 2050, with member states and parliament agreeing on binding targets for carbon emissions.

In the US, the Biden administration has introduced renewed efforts to combat climate change, including a commitment to reduce US greenhouse gas emissions by at least 50% by 2030, and urging global cooperation to address the climate crisis at the Climate Summit 2021. Biden's US$1 trillion infrastructure bill includes funds for high-speed broadband, technology to address the climate crisis, and clean energy. According to the Biden administration, climate change will be at the center of the US national security and foreign policy.

Germany also launched its Digital Policy Agenda for the Environment last year. Should the EU and the US combine efforts in this area, it could have a global impact. With big tasks ahead on both sides of the Atlantic, policymakers would benefit from deepening their knowledge of the impacts of digital technologies on the environment to promote effective policy and decision making.

This report provides an overview of the impacts of current digital technologies on the environment and explores the potential of digital technologies in addressing climate change and negative impacts on the environment. From Artificial Intelligence to 3D printing and from space to deforestation, the study maps the interactions between the environmental and digital issues and identifies areas of development.

It further outlines the main issues and considerations, as well as policy tools in the setting of circular economy, focusing on three main areas: Greenhouse gas (GHG) emissions and energy, raw materials (rare earth) and e-waste.

Greenhouse gas (GHG) emissions and energy are the most pressing concern that needs to be addressed in order to achieve climate change mitigation goals. Recently discussed at the COP26 in Glasgow, the countries set the global agenda for the next ten years - from reducing GHG emissions, phasing out coal, and gradually eliminating subsidies that artificially lower the price of coal, oil, or natural gas. This report explores main issues related to the energy-demanding tech sector, related CO2 emissions and the possibilities of technologies to address these issues. In addition, it maps policies on international, EU, and national levels aimed to address the interplay between GHG emissions and digital technology.

Having major strategic importance on both sides of the Atlantic in the production and development of the digital technologies, **raw materials (rare earths)**, their mining and securing the supply chain are addressed in specific national policies both in the US and in Germany. The report looks at the possible convergence of these policies and fora where a shared approach in addressing the issues of rare earths could be addressed.

E-waste is intrinsically connected to the end-of-life cycle of digital technologies and is an up and coming topic on the policy agenda. The report identifies the main issues related to e-waste and maps out policy tools on the international level, in the EU, Germany and the US that deal with the issue of e-waste.

Throughout, the report identifies relevant fora where US and Germany could deepen their understanding and cooperation on policies related to environment and digital developments, from the ITU's 5th study group to U.S. - German Climate and Energy Partnership.

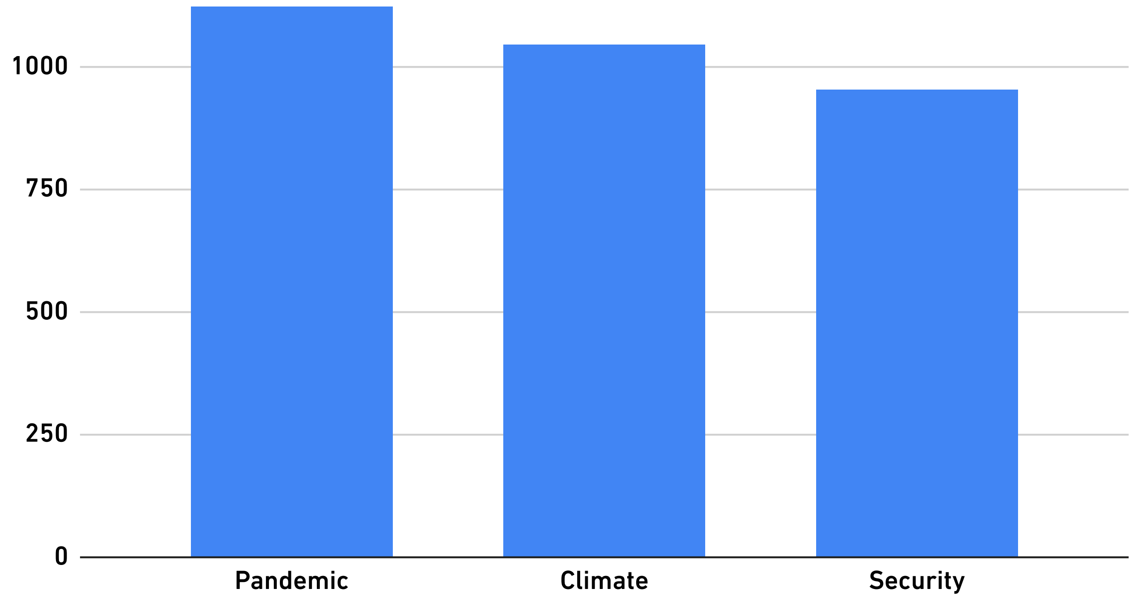
It is evident that the policy alignment on the environment and digital issues between the US and Germany and the EU, based on shared values, has room to grow and that this dynamic field will bring policy developments in the coming years.

2. Introduction

Environment and digital technology are two key pillars of the debate on the future of humanity. Most global policies from the international bodies, the European Union (EU), the new administration in the U.S. or China, reflect substantially on the issues related to environmental and digital policy developments.

Environment and digital technologies will play a key role in navigating another turning point - the point of breakthrough or breakdown described in the UN Secretary General's report "Our Common Agenda"[2] The report makes a pressing appeal stating that: "The choices we make — or fail to make — today could result in further breakdown and a future of perpetual crises, or a breakthrough to a better, more sustainable, peaceful future for our people and planet." The Secretary General also pointed out the need for a green and digital economy, the role of technologies and their deployment to achieve rapid reductions in emissions, while also calling for revisiting patterns of unsustainable consumption and production.

Environmental and digital issues have resonated through all the speeches at the 76th UN General Assembly, with member states pointing out the connections between their digital advancement and recovery from the COVID-19 crisis and the climate change challenges. The issue of global climate change has been the second most discussed topic at the 76th United Nations General Assembly[3]. It is clear that the nexus of environment and digital will remain on the international agenda for years to come. The relevance of environmental and digital issues is becoming even more acute.



Topics by dominance in the speeches at the 76th UN General Assembly, September 2021.
Source: https://www.diplomacy.edu/blog/xray-of-unga-speeches/

This agenda reverberates on national levels - digital and environmental issues are intrinsically connected, influence each other and have impacts in all areas of people's lives - from sustainable cities and communities to economic prosperity and human rights.

While there are many policy initiatives focusing on either digital or environmental developments, not enough work was done on mapping the interplay between the two. Exactly this interplay between digital and natural ecosystems is central for the current search for social contracts from the macro-level of world politics, down to the level of individuals' well-being, lifestyles, work, and ultimately our existence itself.

With the onset of digital technologies and their potential for disruptive transformation and positive change, the link between digital developments and the environment is now becoming part of the international and national policies.

Our study maps this environment-digital nexus and dives deeper into the discourse on the topics in the United States and the European Union, including relations on this issue between them. Special reflections are offered on the position and role of Germany. Given the breadth of topics, this report focuses on the interactions of digital and environmental issues in the setting of a "circular economy", looking specifically at three areas:

- greenhouse gas (GHG) emissions and energy as the one discussed most internationally
- raw materials with the emphasis on rare earths as the topic of most strategic interest for the U.S., EU and Germany
- and e-waste, an up and coming topic on the policy agenda

3. Dictionary of Environment and Digital Technologies

In order to understand the close connections and interplays between the digital world and the environment, we mapped interactions between 10 main digital technologies and 10 environmental issues.

There are a few patterns in this environment/digital interplay.

First, the impacts of digital technologies on the environment are fast increasing as the world moves further into the digital space. These impacts are a double-edged sword, on one side digital technologies and big data can provide much-needed solutions for environmental issues, and on the other side, they themselves are a major contributor to environmental damage. While it is certainly true that emerging technologies such as artificial intelligence, block-chain, and others have the potential to help mitigate negative environmental impacts associated with the sector – and the economy as a whole – this trend has not materialized yet, as these emerging technologies are far from a widespread application.

Second, conflicting interests and dynamics must be mediated via carefully balanced and informed trade-offs between environmental and digital considerations.

Third, most environmental/digital interplays are happening in two realms - the use of digital tools for dealing with the environment, such as the use of AI and big data, and in policies mitigating the impacts of the digital technologies on the environment.

3.1. Digital Technologies

Digital technologies can be understood as **electronic tools, systems, devices, and resources that generate, store or process data for various purposes**.

In this analysis, the term "digital technology" refers to a wide range of such elements, ranging from the internet itself to artificial intelligence and quantum computing. These are some advanced and emerging digital technologies we refer to in the report:

> **Artificial intelligence (AI) & Data** systems rely on a combination of data and algorithms to perform certain tasks or replicate certain specific behaviors that normally require human intelligence, such as visual perception, speech recognition, and decision-making. AI is used in internet services such as search engines, social media platforms, e-commerce, manufacturing, transportation, agriculture, healthcare, and many other areas. AI has significant potential for good and in the ability to scale up environmental protection efforts, but it also comes with risks related to human rights, safety and security, disruptions in the labor market, etc.

Augmented and virtual reality (AR/VR) enables users to view the real-world environment with augmented (added) elements generated by digital devices (e.g. smartphones). **Virtual reality (VR)** goes a step forward by replacing the real world entirely with a simulated environment, created through digitally generated images, sounds, and even touch and smell. AR and VR are evolving fast with applications expanding into fields such as health, development, education, and defense. AR and VR have also proven to be a breakthrough in environmental education and environmental communication.

Blockchain technology is built around a decentralized record of transactions in the form of a ledger, copies of which are distributed among users (or nodes). Through distributed technology and cryptography to verify transactions, blockchain relays trust from a traditionally single central authority to the entire community involved. Transactions are validated by all users simultaneously, and the transactions are protected against tampering and revision.

Biotechnology, as a convergence between digital technologies and different biology fields, can be seen in many areas: use of AI and big data to discover new drugs; 3D printing is used in cellular agriculture for the production of meat in labs, i.e. cultured meat; gene editing (CRISPER), which is the insertion, deletion, modification or replacement of DNA in the genome of a living organism, has the potential to correct defects in a gene to fight certain medical syndromes; Brain-machine interfaces (also called brain-computer interfaces) allow direct communication between the human brain and external devices, powering brain-controlled prosthetic limbs or neuroprosthetics dedicated to restoring damaged hearing and sight. Agricultural biotechnology has major impacts on food production and land use.

Hardware and infrastructure include devices, transmission media, and physical infrastructure to connect people to the internet - everything from mobile phones to undersea cables. It also includes 5G, the fifth-generation mobile network, and potentially will include the 6G network, as a key to unlocking the potential of some of the technologies described above. Compared to previous generations of mobile networks, 5G comes with significant improvements in speed, latency - which is virtually eliminated, enabling real-time remote control of automated processes and bandwidth, allowing greater optimization of network traffic. The 6G technology is expected to facilitate large improvements in imaging, presence technology and location awareness. Working in conjunction with AI, the computational infrastructure of 6G will autonomously determine the best location for computing to occur; this includes decisions about data storage, processing and sharing.

Internet of things (IoT) are new connected devices and have a lot of potential to be used in environmental monitoring, agriculture, disaster recovery, as well as in developing smart cities and communities, and emergency response. IoTs include consumer electronics (Internet-connected smart devices and automated or connected home appliances); city infrastructure ("smart cities" and "smart houses" which connect together in wide systems); medical devices, energy supply networks, etc.

Quantum computing provides advanced computational power. While classical computers rely on individual bits to store and process information and binary 0 and 1 states, quantum bits (qubits) can represent 0 and 1 at the same time, reducing the time needed to process a data set. Today's computing systems, although having significantly improved decade after decade, can only solve problems up to a certain size and complexity. Larger and more complex issues require higher computational capacity of quantum computing.

Nanotechnology is an area of research and innovation that focuses on developing materials and devices on very small scales, e.g. those of atoms and molecules. Nanotechnology is applied in the following fields: hardware infrastructure (smarter sensors, more efficient chips, and enhanced memory storage devices, etc.); medicine and healthcare (nanoparticles used to deliver drugs to specific cells, nanotechnologies allowing better imaging and diagnostic tools); environmental protection (the technology can be used to rapidly detect impurities in water and to clean pollutants).

Space technology encompasses, among others, microsatellites, launch vehicles, and robots. These technologies in combination with AI and quantum computing can change the nature of space exploration. The practical uses of AI, for instance, include automation of repetitive tasks in the manufacturing of satellites and spacecraft, image recognition of satellite data, and assistance to astronauts in task and behavior management. Similarly, quantum computing could help improve space travel research methods as well as planning and scheduling of missions. Space-based technologies, such as remotely sensed data, provide enhanced scientific understanding of water cycles, air quality, forests, and other aspects of the environment.

3D printing enables the fabrication of objects – as simple as a plastic cup or as complex as a house or a human organ. 3D printing opens new economic possibilities for automated manufacturing and health products. New security risks - such as the possibility of printing weapons - are also emerging. However, 3D printing reduces manufacturing waste and lowers the carbon footprint.

3.2. Environmental Issues

Looking at the current major environmental issues, one cannot stress enough the importance of addressing them to secure our survival. Digital technologies may help to assess, mitigate and prevent future environmental decline.

Atmosphere - a thin layer of the gas mixture around the Earth, it has a major impact on life. The gas composition of the atmosphere is changing since the carbon dioxide (CO2) is increasing. It lets sunlight pass through the atmosphere but traps the heat produced by the sunlight thus causing warming. Other gases, such as sulphur and nitrogen oxides, as well as particulate matter are emitted and distributed in the atmosphere.

Biodiversity or biological diversity refers to the multitude of species of flora and fauna in all ecosystems. It is vital for water, food, shelter, energy supply and helps regulate climate through carbon storage and regulating rainfall. It filters air and water and mitigates the impact of natural disasters such as landslides and coastal storms.

Climate change is a long-term global increase in temperature and changes in weather patterns caused by burning fossil fuels like coal, oil and gas generating greenhouse gas (GHG) emissions, such as CO2 and methane. Energy, manufacturing industry, transport, buildings, agriculture and land use are among the main emitters.

Energy - The energy sector is a key contributor to climate change, accounting for more than two-thirds of global greenhouse gas emissions.[4] It is also directly impacted by climate change. Digital technologies are a major consumer of electrical energy. Implementing renewable energy sources, optimization of energy distribution and consumption are the areas where digital technologies, especially IoT could have a major positive impact.

Food/Agriculture The production of food for the ever-growing human population, while conserving the natural resources and ecosystems on which food systems depend, is vital. The food systems rely on natural resources, which are vulnerable to rapidly changing climatic conditions. Food production itself has caused wide-scale changes in ecosystems, being responsible for water shortages and a significant driver of deforestation and loss of biodiversity.

Land and deforestation is the permanent removal of trees to make room for something besides the forest. This can include clearing the land for agriculture or grazing or using the timber for fuel, construction, or manufacturing. It can cause climate change, desertification, soil erosion, fewer crops, flooding, increased greenhouse gases in the atmosphere, and a host of problems for indigenous people.

Oceans and seas are covering more than 70% of the Earth's surface. Oceans provide food, regulate Earth's climate, and generate oxygen. Oceans are threatened by human activities such as plastic waste, overfishing, nutrient pollution creating dead zones, and untreated wastewater. Oceans are also impacted by climate change which damages coral reefs and other ecosystems.

Pollution and waste caused by exhausts and irresponsible disposal of solid and liquid waste manifests itself in many different environmental problems. It can result in air pollution, land pollution and could also cause numerous different health conditions. Regarded as the fastest-growing waste stream in the world, e-waste such as outdated electronic equipment including computers, smartphones, and TVs constitutes a significant ecological issue.

Water has been hit hardest by human activities. Impacts of farming and industry, pollution, waste, flood prevention engineering and climate change all have an impact on the freshwater ecosystem. The freshwater systems are at the forefront of implementing digital technologies, such as data analytics, cloud computing, augmented intelligence, blockchain and IoT.

3.3 Interplay Between the Digital World and the Environment

The interactions between the digital world and the environment offer a wide spectrum of interdependencies. These span from technology being able to map, monitor, predict environmental issues and impacts, as well as to propose, simulate and implement mitigation of negative impacts on the environment.

Digital technologies in general collect, process, and analyze large quantities of data to identify issues and possible solutions, provide modelling of future developments, streamline processes, making them less resource dependent - whether on natural resources, human efforts, or finances. Some of the digital technologies are already widely implemented in environmental protection. This is the case in big data analysis and use of artificial intelligence to find sustainable solutions for environmental issues, use of augmented and virtual reality for modelling and education, IoT for smart cities, smart grids, and in traffic regulation. Additionally, decades of experience in space technology are now used in the renewable energy sector. Others, like blockchain, nanotechnology or quantum computing are just starting to be studied on their possible implementation in environmental protection.

The table below illustrates some of the interactions between digital and environment.

	AI & Data	AR/VR	Blockchain	Biotechnology	Hardware and infrastructure
Atmosphere	Contributes to improving weather forecasts by providing better accuracy in identifying weather events, such as tropical cyclones, weather fronts and atmospheric rivers. Processing of big data contributes to air pollution.	Visualisations of the unseen (vapors, UV and its reflections in the environment) contribute to understanding how atmosphere works and its impacts. Use of AR/VR allows for access to places without travel, contributing to cleaner air.	Allows for decentralised monitoring of air quality and help shape policies on combatting air pollution. Processing of big data contributes to air pollution.	Implemented in direct carbon capturing to dicrease CO2 in the atmosphere.	Applied in monitoring and assessment of air pollution, in forest fire management and in various meteorological applications.
Biodiversity	AI-enabled devices, applications, and analysis or monitoring systems are used to keep track record and understand the behavior of species, helping to make right predictions for conservation of species.	AR/VR have the abilitiy to digitally 'resurrect' certain animal species or keep extinct ones in digital form, provide visualisations of conservation efforts, increase empathy and can influence people toward pro-environmental behavior.	Cryptocurrency can be used for investments in habitat restoration and species conservation, tracking geographic reach and movement of endangered species, insentivisation of farmers to protect natural habitats.	Assists in the conservation of plant and animal genetic resources through new methods for collecting and storing genes (as seed and tissue culture), detection and elimination of diseases in gene bank collections; identification of useful genes; improved techniques for long-term storage, safer and more efficient distribution of germplasm to users.	Expansion of human activities, including through ICT infrastructure has reduced natural habitats. ICTs can contribute to protecting biodiversity by implementing new technologies - GPD, sensing technology (remote sensor), measurement technology, mobile terminals, infrared tech, etc.
Climate Change	Data processing and its infrastructure contribute of GHG emmissions by running on energy from non-revewable resources. Implementation of AI technology could reduce worldwide GHG emissions by 4% in 2030.	AR/VR models that can be used in visualisions of impacts of policies in the future and serve as a sandbox for new policies.	Blockchain could provide shared system for disaster preparedness and humanitarian relief improving efficiency, effectiveness, coordination, and trust of resources. It can be utilised through smart contracts to better calculate, track and report on the reduction of the carbon footprint across the entire value chain.	Biotech crops decrease GHG and therefore mitigate climate change, can be used for direct CO2 capture technologies. Gene sequensing such as CRISPR leads to developing soltions in new resources such as biofuel, bioplastics, etc.	Dematerialisation and online delivery, reduction in the need to travel, tools to help cut GHG emissions by making electricity load and energy management more efficient, or modernizing mass transit. Instrumental in providing information on climate change and disaster management.
Energy	AI, data processing are major consumers of energy, often from non-renewable resources. AI can design more energy-efficient buildings, improve power storage and optimise renewable energy deployment, create flexible and autonomous electric grids.	Visualisations and training of personell on remote renewable energy structures without the need to be physically present, such as windturbines.	Application of blockchain, especially on cryptocurrencies is energy demanding.	Biofuels produced from crops have become an increasingly common alternative to fossil fuels. However, these crops are starting to compete for agricultural land, which can contribute to deforestation and rising food prices.	High energy consumption in use (directly and for cooling); works towards greater energy efficiency in production and use, and recycling.
Food/Agriculture	AI impementation can Increase in yields by providing information on preparing the land, applying fertilizer, and choosing sowing dates, etc.	"Tool for improving food process efficiencies, food decision-making, food marketing, food training, and food safety."	Enhancing agrobiodiversity and agricultural best practices through trusted sharing.	Biotechnology has the potential for improving the quality and increasing the productivity of agriculture, forestry and fisheries. Biotech crops (salinity resistant, drought resistant) allow farmers to use less energy and fertilizer, and practice soil carbon sequestration.	"ICTs are used to improve the supply chain of food products and thereby enhance food security. Manufacturers, as well as farmers, can make use of ICTs to boost food output and monitor inventories. The tracking of food supplies and inventories can be improved with the use of radio frequency identification (RFID) tags."
Land and Deforestation	Predict deforestation and land deterioration impacts, identify hotspots and the ways to remedy, help to protect indeginous population.	Visualisations allow for greater understanding of the issues of deforestation and can simulate different scenarios for the future.	Decentralized and sustainable resource management: blockchain can underpin a transition to decentralized utility systems at scale.	Supports sustainable land management through finding new solutions - biofertilisers, biopesticides, etc.	Aids management and monitoring of soil through remote sensing, contributes to increase in the efficiency and effectiveness of forest management through use in logging, raw material procurement, logistic and production processes. The ICT penetration can also increase deforestation through the need to convert land use to accomodate for ICT structures.
Oceans	Collection and processing of fragmented oceanic data, analysing chemosynthetic life and geologic activity and identify path for protection.	Provide accessible medium for engagement with public, allows to experience undersea remote places virtually.	Blockchain-enabled geospatial platforms, which enable a range of value-based transactions, could monitor, manage and enable market mechanisms that protect the global environmental values.	Marine biotech helps unlock access to biological compounds and provides novel uses for them, advances improving our understanding of marine life and facilitating access to, and study of, marine organisms and ecosystems.	Improved monitoring and reporting which leads to increased accountability. Satellite-based monitoring delivers timely and accurate data on a global basis, while local sensors deliver on the spot updates in real-time.
Pollution and waste	Implemented in fight with ocean plastics, efficient recycling, improve manufacturing processes to achieve zero-waste.	Improves production processes in the area of efficiency and reducing the amount of pollution and the use of natural resources.	Changes how materials and natural resources are valued and traded, incentivizing individuals, companies and governments to unlock financial value from things that are currently wasted, discarded or treated as economically invaluable, it can also can underpin a transition to decentralized utility systems at scale.	New materials developed using biotech can contribute to more sustainable solutions and reduce pollution and waste (bioplastics, enzymatic detergents, construction materials).	Short product life-cycles and e-waste, production and distribution of ICT equipment has negative effects on waste and pollution. Undersea cables contribute to marine pollution.
Water	Allows for data-driven, intelligent management of water systems, better management of water and wastewater systems, predicting emergency events, optimises energy use in water and wastewater treatment	Improves management of water cycles, quality of water, allows for remote solutions.	Facilitates efficient allocation of water resources and provide a clear measure of the value of water to incentivize conservation.	Water industry could to take advantage of the biotech research in the fields of nutrients in wastewater, fouling of water treatment systems, energy production and specific pollutants.	Manage water demand in agriculture through drip and advanced irrigation technologies.

	IoT	Quantum Computing	Nano Technology	Space Technology	3D Printing
Atmosphere	Can provide tools to monitor air pollution in real-time, identify sources of air pollution quickly and accurately. It can be utilized to reduce harmful emissions released into surroundings in the first place, via implementations through 'smart cities'.	To be explored	To be explored	Allows for monitoring of atmospheric pollutants and their movement around the globe -- nitrogen dioxide (NO2), ground-level ozone, carbon monoxide, particulate matter, and sulfur dioxide.	To be explored
Biodiversity	IoT is used to remotely monitor wildlife behaviour and habitat changes, and give timely warning of dangers, such as habitat destruction, poaching, pollution.	To be explored	To be explored	Source of monitoring biodiversity status, especially over large areas. Space technologies can gather and analyse data on landscape structure, ecosystem properties , and threats to the protected areas.	To be explored
Climate Change	IoT is transition enabler in how buildings, appliances and the energy systems of buildings can be synchronized to optimize energy flows and reduce emissions. Once fully operational, IoT has been projected to reduce global carbon emissions by around 20%.	Rapidly developing quantum technologies in computing, sensing, and communication could become useful tools through simulating physical systems, combinatorial optimization, sensing, and energy efficiency.	To be explored	Satellites and other space technologies could be used to help mitigate the effects of climate change by predicting weather and act as early warning systems for extreme weather events. The technology is also key for documenting environmental changes and informing decision making by measuring sea levels, atmospheric gases and the planet's changing temperature.	Reduces manufacturing waste, lowers the carbon footprint and supports the circular economy, lowers the need for remote manufacturing and shipping.
Energy	Implemenation of IoT is energy intensive, contributing to CO2 emmissions and climate change. IoT platform integration provides solutions in energy harvesting, operational optimization in wind farms and power plants, to scenarios for deploying energy management systems. IoT sensors reduce energy consumption, generate renewable energy on-site, and measure carbon consumption plus waste.	To be explored	Nanotechnologies provide the potential to enhance energy efficiency across all branches of industry and to economically leverage renewable energy production through new technological solutions and optimized production technologies	The space sector possesses decades of experience in non-carbon power systems – historically serving as a lead market for solar cells, for example. Space sector has decades of experience with energy storage, hydrogen power, and thermal control.	Requires large amounts of energy to run. Laser of heat technology to fuse materials need large amounts of power.
Food/Agriculture	IoT is in place in monitoring crops and soil conditions, screening and treating farm animals, as well as reducing GHG emissions.	To be explored	To be explored	Global satellite data can be used to help farmers improve agricultural yield, thereby reducing hunger; tackle unregulated mining and its side effects; and identify new opportunities for economic growth.	To be explored
Land and Deforestation	IoT is being used to combat illegal logging and aid in reforestation efforts.	To be explored	To be explored	Satellites are able to map the world's forests in unprecedented detail by penetrating the forest canopy to capture data on the density of tree trunks and branches. They will be able to track how much land a forest covers, how much wood is in it, and help identify grassland degradation and better inform wildfire management.	To be explored
Oceans	Early adoption of IoT monitoring and rerouting for oceanic cargo shipping can reduce fuel consumption by up to 15%. Predictive maintenance can extend the life cycle of existing fleets and minimize the need for fleet rejuvenation.	To be explored	To be explored	Satellites are able to map the Earth's ice sheet and provide data on the amount and speed of melting oceanic ice. Information from next-generation satellites such as ICESat2 – which takes measurements every 85 centimetres along its ground path – could improve forecasts for rising sea levels, as well as global weather and climate patterns.	To be explored
Pollution and waste	IoT can help cities boost efficiency and reduce waste. IoT devices make it possible to extract data, analyze it and develop insights into how the city, using fewer resources, can both gather waste and carry out recycling as efficiently as possible.	To be explored	Improving quality of materials and aiding sustainable consumption. The production of nanomaterials today often still requires large amounts of energy, water and environmentally problematic chemicals such as solvents.	Measure and track air pollution as it moves round the globe.	Manufactures zero-waste once models are established.
Water	IoT-enabled irrigation systems optimize water consumption and minimize waste.	To be explored	Nanotechnologies require large amounts of water to be developed.	Can be used to locate water bodies and delineate river networks, to quantify and/or estimate water related variables such as precipitations, soil wetness, water levels, water storage, to monitor water balance of large river basins on time scales ranging from weeks to years.	To be explored

Digital technologies have an impact on the environment as well. The main impact is the high energy use of digital technologies. Energy is used for manufacturing of digital tech, but also for big data processing, AI, blockchain, and IoT implementation. Globally, the quasi totality of energy resources is fossil (81% from oil, coal, and gas), with only 11% from renewable sources[5], contributing to CO_2 emissions and exacerbating climate change. Other negative impacts include the use of rare materials in the manufacturing of devices, the unsustainable model of "fast consumption" in consumer tech, as well as insufficient recycling contributing to e-waste and plastic pollution.

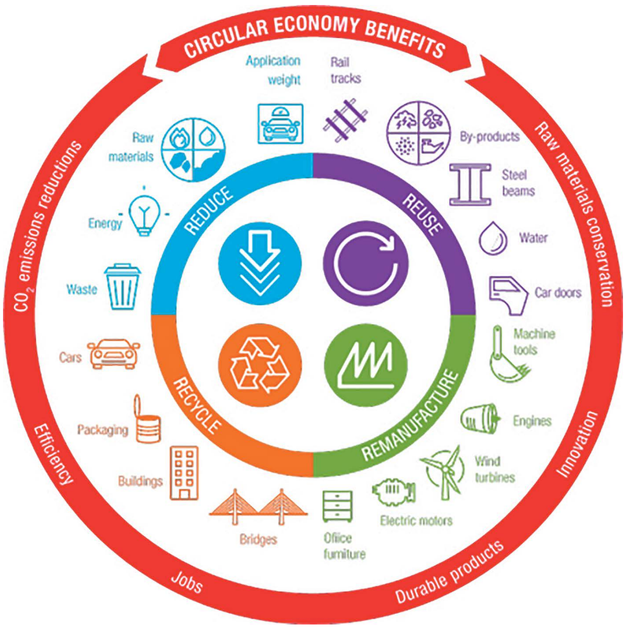
The main challenge in environmental protection, however, remains with changing human behavior and industries to adopt sustainable lifestyles and business models. The linear industrial model used until now should be, according to the policy makers on both sides of the Atlantic, replaced by the circular economy.

4. Circular Economy

> Looking beyond the current take-make-dispose extractive industrial model, a circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. It is based on three principles: design out waste and pollution; keep products and materials in use; regenerate natural systems.
>
> *Ellen McArthur Foundation's definition of circular economy*

The linear economy of extraction, transformation, utilization, and disposal also dubbed as 'take, make, dispose" while using non-renewable resources[6] has underpinned the expansion of the global economy since the industrial revolution. However, this approach is coming under increasing pressure because of its environmental and economic disadvantages.

The transition to circular economy, based on reusing products with all forms of waste being returned to the economy and using renewable energy sources comes with wide-ranging benefits[7], such as reducing pressure on the environment, improving the security of the supply of raw materials, increasing competitiveness, stimulating innovation, boosting economic growth, or creating jobs.



Source: https://unctad.org/topic/trade-and-environment/circular-economy

Digital solutions for the transition to a circular economy have the potential to leapfrog the adoption of the new economic model. With the potential for providing greater efficiency of all processes, identifying issues to be addressed, modelling future scenarios, and scaling up responses throughout, with automated identification of products, potential to connect stakeholders across value chains, and evaluating the impacts of stakeholders throughout the life of the physical products, digital technologies could have an invaluable contribution to the implementation of a circular economy.

Namely AI and data[8], as well as IoT and other emerging technologies could facilitate the transition from the current linear economic model towards a sustainable one. For instance, augmented reality[9] can help repair rather than replace damaged products while AI can accelerate the development of new circular products that are free of dangerous chemicals and materials, and optimize infrastructure, thus ensuring a circular flow of products. In other words, digital technologies can help boost the economy and increase resource efficiency, while reducing waste.

4.1. Digital Technologies and Environment in the Circular Economy

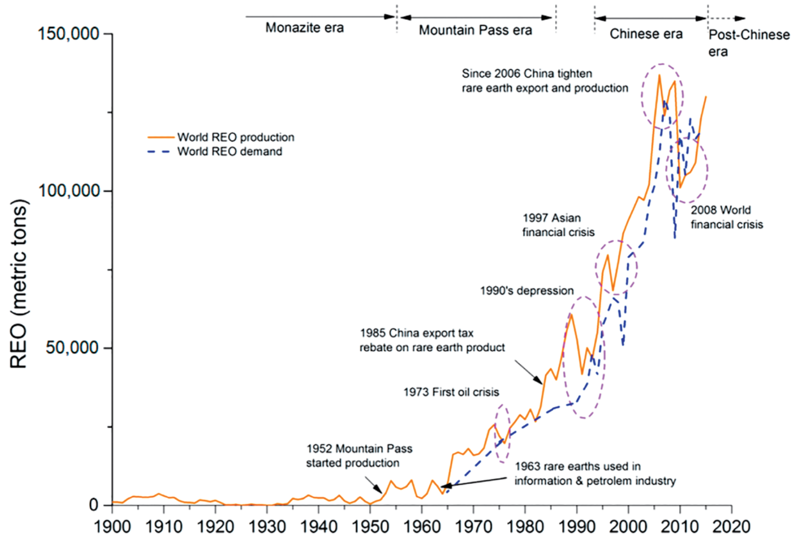
The impacts of digital technologies on the environment are fast-increasing as the world moves further into the digital space. These impacts are a double-edged sword, on one side digital technologies and big data can provide much-needed solutions for the environmental challenges, and on the other side, they themselves are a major source of environmental pollution.

While it is certainly true that emerging technologies such as AI, blockchain, and others have the potential to help mitigate negative environmental impacts associated with the sector – and the economy as a whole – this trend has not materialized yet as these technologies are far from widespread application. The entire lifecycle of digital products, from the resources used in their production to the energy consumption in their operation to poor disposal practices at their end-of-life has considerable impact on the environment.

Looking closer through the lens of a circular economy and the positive and negative interactions between the digital sphere and the environment, we will focus on three major areas - from the inception and manufacturing of the digital technologies (natural resources - rare earths), through their lifespan (GHG emissions and energy) to their retirement (e-waste).

4.2. Raw Materials

Raw material extraction and use is where the digital economy starts. Many devices, as well as physical digital infrastructure require a wide range of metals, plastics, and glass[10]. A smartphone can contain up to 62 different elements, including 16 of 17 rare earth elements[11]. The term "rare earths" is somewhat misleading given that these resources are plentiful. These minerals are critical components of electronic devices such as digital cameras, computer hard disks, batteries for hybrid-electric vehicles, flat screen televisions, computer monitors, and electronic displays.



Source: https://www.mdpi.com/2075-163X/7/11/203

That said, the mining process raises serious environmental concerns. The metals needed for digital products – including gold, copper, cobalt, and several others – are mined in energy-intensive operations worldwide, with most of the world's mining operations taking place in countries with relatively lax environmental regulations and high-carbon energy grids[12]. Substandard regulations result in the clearing of trees and fertile land, water contamination, the loss of biodiversity, energy inefficiencies, and inadequate site clean-up, which can further poison natural habitats. In addition, most of the digital technologies are manufactured of parts which have to be transported to the place of assembly, thus contributing to GHG emissions.

The 15 elements in the lanthanide series shown in the periodic table such as cobalt, gallium, indium, and tungsten – also known as the "**rare earth elements**'" (REEs) – are considered the gold of the 21st century[13]. While these elements are available worldwide, the "rare" in their description refers to the fact that their extraction process is toxic and expensive. The mining of REEs is tied to environmental pollution, such as acidified landscapes and water contamination, as well as negative health impacts on people working in these mines, which are often connected to human rights abuses[14].

The demand for REEs has risen sharply with the increased production of digital devices: They are used in the manufacture of cell phones, LED screens, solar panels, energy infrastructure, defense technologies, and other essential high-tech applications. The current size of the global market is US$5 billion and it is projected to grow by 40%[15] over the next 5 years, which has implications for national security and trade policies worldwide.

4.3. GHG Emissions and Energy Use

Powering digital devices worldwide requires an immense amount of energy, as does the actual physical infrastructure that enables the digital space. For example, data centers – forming the backbone of the internet – are directly responsible for consuming 1% of the world's electricity[16]. While the electricity used to produce and power our digital devices and infrastructure sometimes comes from renewable sources such as hydro and wind, much of it is generated via fossil fuels like coal and natural gas, owing to the dominant use of such fuels in many countries' energy grids. The switch to renewable sources of energy and closing the gap in energy production between the fossil fuel energy sector and renewable sources of energy outputs is a part of global discussion.

> Data storage and transmission releases an estimated 97 million tons of carbon dioxide equivalent (tCO2e) every year which is equivalent to the annual carbon footprint of Sweden and Finland[17]. It is estimated that emissions generated by the digital economy totaled 2.1 $GtCO_2e$ in 2020, or about 4% of total global emissions – this can be contrasted with a 2.5% share in 2013[18]. In terms of emissions by sector, digital emits more than the aviation (1.9%), cement (3.0%), and chemicals (2.2%) industries[19]. In fact, The Shift Project[20] estimates that between 2013 and 2020, digital economy emissions have increased by 450 $MtCO_2e$ – equivalent to the operation of 113 coal-fired power plants. This is a direct result of steep increases in energy use associated with digital technologies (i.e. production and use), which is estimated to be rising by 9% annually.

Looking forward, emissions associated with the production and use of digital devices are forecasted to reach 14% of total global emissions[21]. It is not difficult to envision this, particularly as 5G and the internet of things (IoT) are adopted and developed. The advancements are bringing whole new classes of digital products to market and are greatly empowering common devices like smartphones and computers. The energy needs of all these devices is only going to grow, putting more demand on energy grids worldwide. Furthermore, innovations such as blockchain, cryptocurrency, and AI all need significant amounts of energy, highlighting the digital sector's ever-evolving need to reach new technological levels. For instance, it is estimated that the training of certain AI models can generate up to 300 tCO_2e due to their energy intensiveness[22]. If the world's energy mix does not decarbonize in a meaningful way over the next decade or so, the digital sector's emissions – and therefore impact on the environment – will be even more consequential.

At present, digital sector emissions are in large part due to the activities of high-income countries. To illustrate, findings from 2018[23] show that on average, every American owned 10 connected devices and consumed roughly 140 gigabytes of data per month, far exceeding the one device and 2 gigabytes of data consumed monthly in India. This, however, does not mean that such a trend will continue in the future. Lower-income countries will continue to catch up with developed countries in terms of digital sector emissions. Developing countries, in order not to fall behind, aim to increase the access to internet, take up widespread adoption of digital products and greater internet use. This is compounded by the growing populations in these countries, who will increasingly demand digital devices. Significant efforts will be required on the part of developed countries to help lower-income countries in the decarbonization of their energy grids.

Closely connected to this are the GHG emissions, as fossil fuels still make up the overwhelming majority of global energy use, making up over 84% of the mix[24]. The majority of industrial processes – including the production of digital technologies – are nearly fully reliant on fuels like natural gas and coal. Since much of the emissions footprint of the digital sector is a result of electricity use in operation – it is estimated that 60% of the world's electricity grid[25] runs on fossil fuels, making energy-intensive products and applications in turn carbon-intensive.

Most of the energy consumption associated with the digital sector is related to the manufacture of digital devices. In the segment of mobile phones alone, around 80% of each device's carbon footprint is tied to the manufacturing stage[26]. This includes the entire production process – mining of raw materials, refining of these materials, and transporting these materials and finished products across different parts of the world. For example, smart phones do not use much energy to operate, but researchers estimate that it takes roughly 1 gigajoule to create a modern smartphone[27]. That's roughly 278 kilowatt[28] hours, or 73 times the electricity used to charge it for a year. In terms of fossil fuels, it is equal to the combustion of 25.5 cubic meters of natural gas.

Data centers – particularly those in the United States and Europe – are a good example of the practical application of environmental strategies. While data centers certainly use a significant amount of electricity (approximately 1% of electricity worldwide[29]), their energy use has remained more or less flat over much of the past decade even as internet traffic and related workloads increase. This is due to project implementation (new storage solutions and hyperscale data centers) and various energy efficiency improvements[30].

To combat their negative impact on the environment, digital technologies can facilitate greater adoption of renewable energy[31] resources and technologies by improving electricity generation, storage, and transfer. Energy storage includes developing low-cost storage solutions for energy in the form of modern batteries and improved fuel cells – especially lithium-air batteries, hydrogen energy storage, and thermal energy collectors – not only for short term, but also for long term storage. Malta by Google X[32], storing renewable energy in molten salt and BP's Lightsource[33] are at the forefront of solar energy storage.

Digital technologies can be implemented in smart grid and virtual power plants[34], allowing for two-way communication between the utility and its customers, and the sensing along the electric transmission lines to respond digitally to our quickly changing electricity demand. The concept of virtual power plants relies on software and a smart grid to remotely and automatically dispatch and optimize the distributed energy resources.

Algorithms are also being used to increase energy efficiency by monitoring energy consumption patterns and requirements with the aims of reducing electricity usage and ultimately the emission of GHGs. Similarly, blockchain technologies can contribute towards sustainable resource management, including that of water and energy consumption, through traceable and transparent supply chains.

Research conducted by PwC on "How can AI enable a sustainable future"[35] shows that the use of AI technologies in the context of the environment can have a positive effect on the global GDP, CO2 emissions, as well as net employment, as illustrated below. Similarly, a report[36] published by GeSI anticipates that ICTs could reduce GHG emissions by 20% by 2030.

There are numerous other areas where AI solutions are of critical importance. AI technologies[37] are already being employed in early warning against natural hazards such as earthquakes, floods, wildfires and droughts. New technologies can help prevent practices such as poaching, overfishing or deforestation. Data collection and satellite imagery play an important role in monitoring marine ecosystems and ocean sustainability. For instance, eOsphere[38] is a UK-based SME that provides sustainable satellite earth-observation solutions and uses earth-observation data for building climate resilience or hazard monitoring.

Other smart technologies, including IoT, feature largely in smart city strategies. According to a report published by the United Nations Development Programme (UNDP), cities are responsible for 70% of global greenhouse gas emissions. Smart cities can help decrease GHG emissions in the transport sector, which accounts for 14% of global GHG emissions[39]. The adoption of electric transport - whether it is public transport, e-trucks or smart cars leads to lowering local particulates, including SOx, NOx, and CO2, all major issues in most cities today. Additionally, smart cities can contribute to reducing electricity and heat production[40], which make up a quarter of global greenhouse gases.

Lastly, emerging technologies like 3D printing, augmented and virtual reality can also be deployed to address environmental challenges. Virtual reality[41] (VR) technology, for its part, could help raise awareness on environmental issues and in the long run shape pro-environmental behavior. These technologies can also facilitate transition to a circular economy. Augmented reality[42] (AR) technologies can be used to raise awareness of environmental issues, educate consumers about product materials and their lifecycle, and encourage them to recycle more.

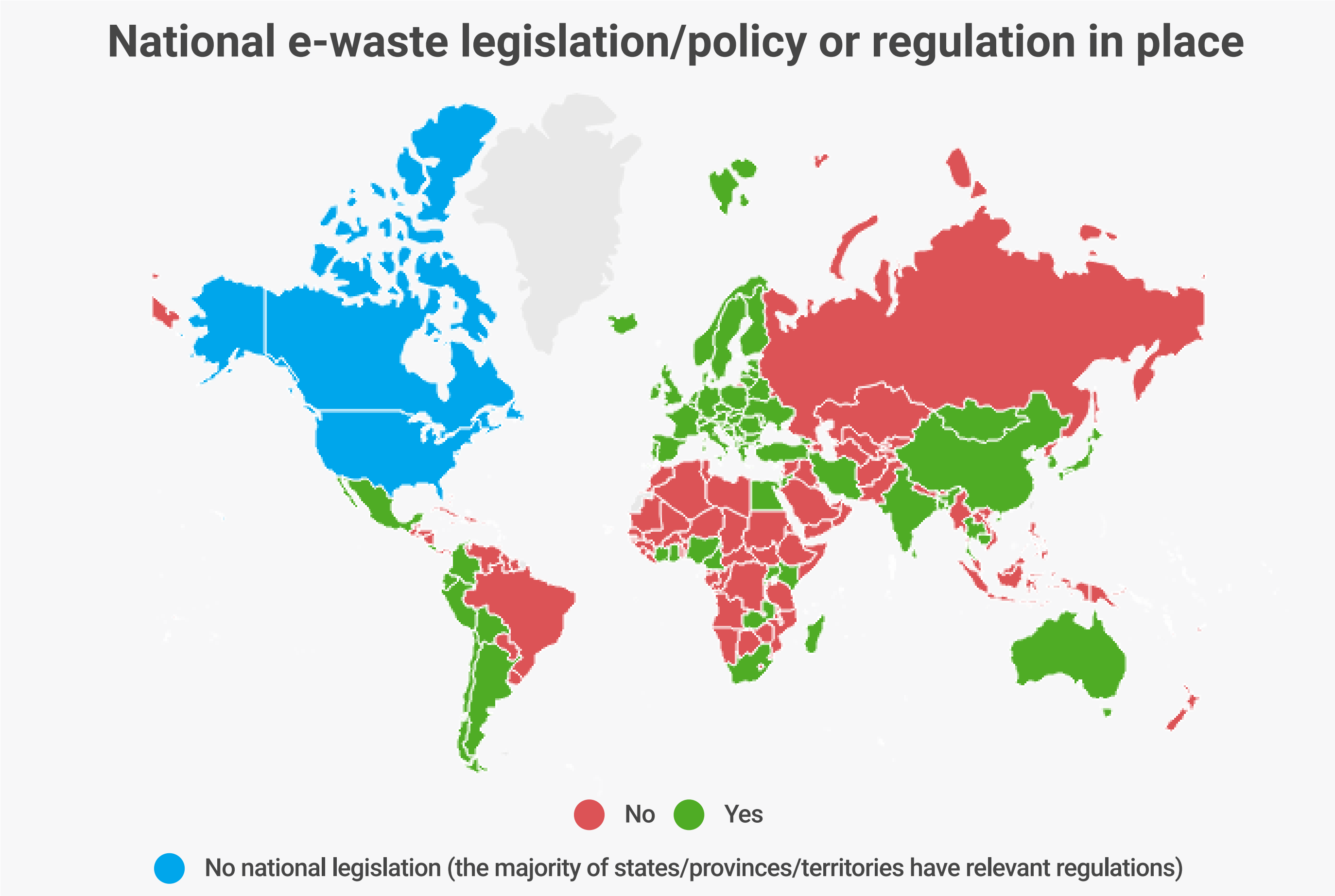
While it is certainly true that emerging technologies such as AI, blockchain, and others have the potential to help mitigate negative environmental impacts associated with the sector – and the economy as a whole – this trend has not materialized yet, as these technologies are far from widespread application. The entire lifecycle of digital products, from the resources used in their production, to the energy consumption in their operation, to poor disposal practices at their end-of-life has considerable impact on the environment.

4.4. E-waste

Raw material extraction and e-waste are intrinsically linked – since so many of our devices end up in landfills, a large number of valuable materials do so as well. Up to 7% of the world's gold is in our e-waste[43]. Other precious metals and rare earth elements are thrown away with e-waste as well. As more and more digital devices are put into circulation – whether through a growing proportion of the world connecting to the internet or through the insatiable demand for faster and more advanced devices and infrastructure (i.e. 5G enabled devices and IoT) – e-waste and its resource inefficiencies will only become an even larger issue. The Global E-waste Monitor forecasts that e-waste will reach 74.7 million tons by 2030[44], which represents a near doubling since 2010.

Every digital device has an end-of-life, and unfortunately, many are not adequately repurposed or recycled. E-waste is an increasingly fraught challenge in today's world. The rate of technological changes over the past few decades has essentially been exponential, with devices often becoming obsolete over the course of a couple of years. The constant climb of software development requires more advanced hardware, necessitating frequent device upgrades to remain at the cutting edge. While some devices are recycled back into the economy via mediums such as second-hand sale, many are thrown out completely. To quantify the issue – over 50 million tons of e-waste is generated every year, and only 20% of this is recycled[45] (with most of the remainder deposited in landfills or incinerated). It is not just the sheer magnitude of e-waste that is the issue – the heavy metals that many devices contain (such as mercury, lead, bromine, and arsenic) seep into soil and groundwater, poisoning the environment as well as humans themselves.

The challenges associated with e-waste will not abate without coordinated intervention by governments worldwide. It is challenging to estimate exactly how many devices there are in circulation globally at present, but the World Economic Forum estimates that there are 25-50 billion internet-connected devices today[46]. Considering the pace of technological advancement, many of these devices will become obsolete over the next few years.



Sources: Regional E-Waste Monitor CIS + Georgia 2021, The Global E-Waste Monitor 2020
Visual: https://infogram.com/e-waste-legislation-1ho16vr9kkdx4nq

5. Digital World and the Environment - Relations and Policies

5.1. International Landscape

The environment has been high on the agenda of numerous international organizations and regional and national bodies for many years. But it was not until a couple of years ago that policymakers worldwide started to discuss the interplay between digital technology and the environment.

On the international level, the discussion on environmental sustainability is focused on achieving environment-related sustainable development goals (SDGs) set by the 2030 Agenda for Sustainable Development[47], commitments of the United Nations Framework Convention on Climate Change (UNFCCC)[48] and its protocols. The Paris Agreement[49] is the most debated one in the international arena, especially its goal to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels and related commitments of countries to achieve net-zero emissions.

While the 2030 Agenda for Sustainable Development tackles the role of digitalization in achieving sustainable development, the relationship between digital advancements and environment is not addressed by the landmark agenda. Only recently has the UN recognized the need to address the dual relationship between technology and environment.

In 2020, the UN Secretary-General in the Road map for digital cooperation[50] pointed out that: "Advancing technology has always been coupled with significant impacts on the environment…the recent advances in technology offer ground-breaking opportunities to monitor and protect the environment, as well as overall planetary health. By harnessing them appropriately, the digital revolution can be steered to combat climate change and advance global sustainability, environmental stewardship and human well-being."

There are several international agencies working on the intersection of environment and digital issues, such as:

United Nations Environment Programme (UNEP) - global authority setting the environmental agenda, implements the environmental dimension of the UN sustainable development. UNEP works on promoting effective use of technology[51] to address environmental goals as well as the development of environmentally sound technologies.

United Nations Development Programme (UNDP) - environmental work focuses on improving the abilities of developing countries to reduce poverty, to develop sustainably, and increase human development[52]. UNDP is mainly involved in water governance, sustainable energy, sustainable land management and biodiversity, and others. UNDP's work includes mapping the potentials and risks of technologies such as artificial intelligence, blockchain technology, big data analytics, robotic process automation, and the IoT.

International Telecommunications Union (ITU) is the UN specialized agency for information and communication technologies. ITUs Study Group 5[53] on environment, climate change and circular economy is responsible for studying the environmental aspects of ICTs of electromagnetic phenomena and climate change. It also develops standards on resistibility, human exposure to electromagnetic fields, circular economy, energy efficiency and climate change adaptation and mitigation. It undertakes studies on how to use ICTs to help countries and the ICT sector to adapt to the effects of environmental challenges, including climate change, identify the needs for more consistent and standardized eco-friendly practices for the ICT sector (e.g. labelling, procurement practices, standardized power supplies/ connectors, eco-rating schemes). It has issued a series of recommendations[54] on ICTs and the environment.

World Meteorological Organisation (WMO), another specialized UN agency is dedicated to international cooperation and coordination on the state and behavior of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate it produces, and the resulting distribution of water resources. WMO runs the Integrated Global Observing System[55] which provides a framework for the integration and sharing of observational data from national meteorological and hydrological services, as well as Information System (WIS)[56] that facilitates the free and unrestricted access to data and information products and services.

International Renewable Energy Agency (IRENA) is an intergovernmental organization that supports countries in their transition to a sustainable energy future and serves as the principal platform for international cooperation. It explores the possibilities of using innovation and technology[57] in transition to renewable energy sources.

UNFCCC Technology Mechanism consists of two bodies. The Technology Executive Committee[58] is the Technology Mechanism's policy body. It analyses issues and provides policy recommendations that support country efforts to enhance climate technology development and transfer. The second body is the operational arm, the Climate Technology Centre and Network (CTCN) hosted by the UNEP and the UNIDO promoting the accelerated transfer environmentally sound technologies[59] for low carbon and climate resilient development at the request of developing countries.

Coalition for Digital Environmental Sustainability (CODES) was initiated by UNEP, UNDP, the International Science Council, the German Environment Agency, the Kenyan Ministry of Environment and Forestry, Future Earth and Sustainability in the Digital Age. It will lead a global multi-stakeholder process and convene a series of events[60] aiming to frame the nexus between environmental sustainability and digitalization, set up a plan for digitalizing environmental sustainability and serve as a platform to unite various environmental sustainability and digitalization tracks.

UN Global Innovation Hub for Transformative Climate Solutions, the latest addition[61] in an array of fora on the intersection of environment and digital issues has been established in November 2021. A wide multi-stakeholder initiative, it is set up to accelerate climate solutions not only through technology, but also through policy, financial instruments, business models, and leadership solutions.

Within the UN system the discussions are also at UN-Energy[62], the Intergovernmental Panel on Climate Change[63] (IPCC), the World Bank, as well as at the Internet Governance Forum[64] (IGF), an open multistakeholder forum, launched a policy network on environment[65] to discuss intersections between environment and digitalization processes.

At the COP26 Summit in Glasgow in November 2021, the parties specifically addressed the role of digital technologies and environment in the outcome document - the Glasgow Climate Pact[66]. The Pact recognizes "the importance of international collaboration on innovative climate action, including technological advancement, across all actors of society, sectors and regions, in contributing to progress towards the goals of the Paris Agreement". In addition, the parties to the Glasgow Climate Pact were called upon to "accelerate the development, deployment and dissemination of technologies, and the adoption of policies, to transition towards low-emission energy systems."

Heeding the call of the Pact for developed countries assist developing countries and to provide enhanced support, including through financial resources, technology transfer and capacity-building, representatives of Germany, Japan, the Republic of Korea, Spain, and the United States discussed expansion of international technology collaboration to implement Article 10 of the Paris Agreement. Germany and the United States announced continuous funding commitments to support the work of the UN Climate Technology Centre and Network (CTCN) "at the rapid speed and massive scale that is urgently needed."[67]

Internet Governance Forum 2021

The environmental sustainability and climate change was an emerging and crosscutting area for IGF2021. The key questions included making digital technology sustainable and energy efficient, and ways to implement digital technology to monitor and combat environmental changes.

This year, the IGF featured a workstream on intersection between environment and digitalization processes, the Policy Network on Environment (PNE). In its report[68], the PNE proposed concrete policy recommendations on environmental data, food and water systems, supply chain transparency and circulatory, and overarching issues.

The main session on environment and digitalization[69] focused on the strong influence the digital world has on environment and vice versa - with digitalization being a driver of positive change and contributor to a green, inclusive, decarbonized economy. The participants from different stakeholder groups also exchanged views and experiences on decarbonization of the digital technology[70], as well as sustainable consumption in e-commerce[71].

5.2. Transatlantic Relations

With the Biden administration taking over at the beginning of 2021, the United States reaffirmed its commitment to the international climate agenda by rejoining the Paris Agreement and World Health Organization, reengaging with the UN Human Rights Commission, or organizing the virtual Leaders' Summit on Climate. These steps were welcomed by the European Union (EU), as well as in Berlin, leading to increased exchanges between the United States and Germany, with Chancellor Angela Merkel noting[72] she was "glad that the U.S. is back in climate policy because it is absolutely indisputable that the world needs your cooperation if we are to meet the Paris Agreement goals."

Focusing on the bilateral level between the United States and the European Union (EU), the newly established U.S.- EU Trade and Technology Council[73] (TTC) provides a wide platform for diplomatic cooperation through which to advance shared values between the two parties, and align their tech and trade policies and regulations. The TTC includes a working group specifically focused on climate and green tech. This cooperation will encompass work on "identifying opportunities, measures and incentives to support technology development, transatlantic trade and investment in climate neutral technologies, products and services, including collaboration in third countries, research and innovation, and to jointly explore the methodologies, tools, and technologies for calculating embedded greenhouse gas emissions in global trade."

At the G7 meeting June 2021, G7 leaders pledged[74] to phase out coal-fired power generation in their respective countries and to end funding for new coal-burning power plants[75] in the developing world. The G7 leaders committed to offering developing nations US$2.8 billion to help them switch to cleaner fuels and resolved to "jointly mobilize US$100 billion per year from public and private sources, through to 2025"[76] to developing countries for a range of climate initiatives. Furthermore, Germany had announced[77] even ahead of the G7 summit that it would raise its federal budget contribution for international climate financing from EUR 4 billion to EUR 6 billion annually by 2025[78].

After the official visit of Chancellor Merkel to the White House, the first European leader to be invited, both leaders affirmed their commitment to a close bilateral cooperation promoting peace, security, and prosperity around the world, as part of the "Washington Declaration"[79]. Specifically, the United States and Germany committed to work together to ensure that rules, norms, and standards that govern emerging technologies are channeled toward freedom and embody democratic values.

The Washington Declaration, as well as the "Joint Statement of the US and Germany on Support for Ukraine, European Energy Security, and our Climate Goals"[80] set the foundation for increased cooperation between the USA and Germany on the policies and technologies to accelerate the global net-zero transition. This included launching Climate and Energy Partnership[81], which aims to deepen collaboration on the policies and energy technologies needed to accelerate the global net-zero transition. Specifically, the Climate and Energy Partnership:

- Aligns U.S. and German push for combating climate change and achieving net-zero emissions through coordinating their policies and agendas on climate and trade in multilateral fora, such as the G20, the G7 and the UN;

- Sets up cooperation on developing and deploying critical energy technologies, such as renewable energy technologies, energy storage, sustainable hydrogen technologies, the adoption of electric vehicles, and many more. Both parties will again coordinate their policies and actions in multilateral fora such as G20, G7, Mission Innovation, Clean Energy Ministerial, International Energy Agency, and IRENA;

- Includes commitment to collaborate to accelerate sustainable energy in emerging economies critical to tackling the climate crisis and preventing the use of energy as a coercive tool.

The roles of the United States and Germany on national levels in addressing environmental challenges is significant due to their impacts on the environment as developed countries, as well as their abilities to develop and implement important technological advances. Their cooperation and alignment could have positive implications globally. However, on both sides of the Atlantic, the nexus between environment and digital issues is in the early stage. Further developments will be shaped inevitably by different approaches and levels of maturity on digital developments and environment in both the US and EU.

5.3. Policies on Digital and Environment

The focus is on three policy areas where digital issues and environment intersect:

- **Climate change** as one of the most pressing and discussed issues in the international fora
- **Raw materials** and related supply chains, as currently the most relevant strategic issue for the U.S., EU, and Germany
- **E-waste and circular economy** as the area with most impact in the future

We will now provide a detailed look at the international discourse, as well as policies in the U.S., the EU and Germany.

a. Climate Change Policies

The climate change agenda has rapidly gained in urgency in the global discourse and is now in the spotlight:

The Sixth Assessment Report[82] of the Intergovernmental Panel on Climate Change (IPCC) approved in August 2021 by 195 member governments sounded the alarm. It found that "unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach."

The World Meteorological Organization (WMO) produced evidence[83] to show that GHG reached a new record high in 2020. Concentrations of CO2 and other heat-trapping gases in the atmosphere had risen faster in the last year than over the previous 10.

A new **UN Development Program (UNDP)** report[84] gave evidence that around half the G20 countries, responsible for three-quarters of global emissions, had not adhered to core principles of the Paris Agreement to ratchet up ambition — and that among those that strengthened their nationally determined contributions (NDC) pledges, much more needed to be done.

And the **UN Environment Program (UNEP)** reported[85] that new and updated climate commitments by UN member states were well below what was needed to adhere to the goals of the Paris Agreement in order to avoid a devastating global temperature rise of at least 2.7 degrees Celsius this century.

Effective carbon strategies and a defined pathway to net-zero are becoming a necessity for corporations and governments alike. On the government level, policies such as carbon pricing and stricter environmental regulations are required to place a price signal on the GHG emissions and to drive private enterprise to adopting and implementing net zero strategies.

In January 2020, ITU study group 5 issued a recommendation ITU-T L.1470 (01/2020)[86] on greenhouse gas emissions trajectories for the information and technology sector compatible with the Paris Agreement, including the accompanying Guidance for ICT companies setting science based targets[87]. The recommendation outlines detailed emissions trajectories for the global information and communication technology sector and sub-sectors for the years 2020, 2025 and 2030, and establishes a long-term aim for 2050.

At the regional level, the EU has positioned itself as a leader in the area by blending policy efforts on digital technologies and the environment. To illustrate:

The European Green Deal[88] adopted in 2019 defines digital technologies as a critical enabler for achieving the objectives of the Green Deal. The document further highlights that the EU Commission "will explore measures to ensure that digital technologies such as artificial intelligence (AI), 5G, cloud and edge computing, and the Internet of Things (IoT) can accelerate and maximize the impact of policies to deal with climate change and protect the environment". In a similar vein, the EU Commission's communication on "Shaping Europe's digital future"[89] stresses that digital technologies can "support the decarbonization of all sectors and reduce the environmental and social footprint of products placed on the EU market".

The European Climate Law[90]**,** passed by the European Parliament as a part of the Green Deal, is setting more stringent and legally binding emission reduction targets for 2030 and 2050. The new targets are for the EU to reduce emissions by at least 55% below 1990 levels by 2030 (compared with the 40% original target), as well as legally binding carbon-neutrality by 2050. After 2050, the EU aims to achieve negative emissions (carbon capture). The European Climate Law acknowledges the importance of digital technologies in energy production and consumption, particularly in relation to emissions levels, transition to renewables, and the efficiency of all these systems. It states the importance of digital transformation, technological innovation, and research and development as important drivers for achieving the climate-neutrality objective. As one of the measures to achieve this goal, the European Commission is to consider the best available cost-effective, safe, and scalable technologies.

The EU strategy for energy system integration[91] (2020) sets out key actions to drive the clean energy transition. One of them is a system-wide digitalization of energy action plan that aims to contribute to the EU energy policy objectives by supporting the development of a sustainable, (cyber)secure, transparent and competitive market for digital energy services, ensuring data privacy and sovereignty, and also by supporting investment in digital energy infrastructure. It further aims to ensure that the digitalization of the energy sector is fully part of the green energy transition and also consistent with the digital targets for 2030[92]. The adoption is expected in the first quarter of 2022.

A New Industrial Strategy for Europe[93], was adopted by the EU Commission in March 2020 to support the twin transition to a green and digital economy. An updated[94] version of the strategy, adopted a couple of months later due to the COVID-19 pandemic outbreak, underlines that "business case for the green and digital transition is stronger than ever". Hence the companies that pursue sustainability and digitalization are more likely to succeed than others[95].

Other important documents, such as the **European Data Strategy**[96], and the recently adopted 2030 **Digital Compass**[97], address the intersection of digital and environment recognizing the critical importance of digital solutions for a climate neutral, circular economy.

At the national level, numerous governments like Switzerland[98], Estonia[99], and Germany adopted strategies, action plans and other policy instruments tackling the impact of digitalization on the environment. Germany is one of the countries that made a critical impact on the policy discussions around digital and climate. Germany has shifted its energy supply from coal and oil to a more diversified system in the last 40 years. The German energy transition to a low-carbon, nuclear-free economy, "Energiewende"[100] foresees the closure of the last nuclear plants in 2022 and coal fully phased out by 2038. Of note is also the German Climate Action Law[101] aligning German national GHG emission targets with those of the EU.

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) published in 2016 a "Climate Action Plan 2050"[102], consisting of principles and goals of the German government's climate policy. The action plan refers to the manifold applications of digital technologies in developing environmentally friendly solutions, such as the energy supply, traffic flows and transport safety, to name but a few. The recently updated "German Sustainable Development Strategy"[103] focuses on the role of digital technologies in achieving sustainable development goals, including those related to environmental sustainability.

The BMU recently presented the Digital Policy Agenda for the Environment[104], the first strategy in Europe that combines digitalization and environment in a consistent way[105]. The aim of the agenda is twofold - to foster environmentally friendly digitalization, on the one hand, and use digitalization for environmental protection. This strategy includes, among others:

- Averting or diminishing environmental impacts of digital technologies and related business models. Software, data centers and end-devices have to become energy- and resource-efficient. In addition, material cycles for the manufacture of digital devices must be closed.
- Making use of the efficiency potential of digital technologies and solutions to yield digital environmental dividends. Resources saved should be invested in future tasks. To this end, a regulatory framework is needed.
- Adopting a cross-cutting approach to digital technologies to include socio-political issues such as gender equality, diversity and demographic change.
- Implementing digital technologies to help modernize environmental policy and environmental administration
- Building the engagement of digital and environment to support sustainability.

According to the Climate Change Performance Index (CCPI) for 2021[106]:

The EU jumped six spots in the ranking from last year, to be ranked 16th in this year's CCPI. The EU, driven by the positive role it plays in international climate negotiations, has a high overall rating on the CCPI, as well as in the underlying Climate Policy category. The EU does not, however, perform as well in any of the other categories.

Germany is ranked 19th rising, from 23rd last year, reflecting its new efforts to reduce emissions. With the exception of the high-rated international Climate Policy indicator, Germany's performance in the CCPI categories is mixed, leading to an overall *medium* rating. The country's high per capita GHG emissions and energy use, the growing emissions in the transport sector and the incompatibility of its 2030 renewable energy target with a well-below-2°C pathway are especially concerning. These indicators continue to receive a *low* rating.

Ranked 61st, the United States maintains its spot at the bottom of this year's CCPI. The US performance on this year's CCPI ranks very low, putting it in the lowest rank. This is driven by its withdrawal from the Paris Agreement and lack of targets at the national level to either reduce national GHG emissions or increase renewable energy deployment.

On the U.S. side, reversing the policies of the previous administration, President Biden signed the Executive Order to re-join the U.S. to the Paris Agreement as soon as he took office. Other executive orders followed, directing agencies and departments to enact climate-friendly policies across the government and to review and address the promulgation of the climate rollbacks of the previous administration. The Executive Order 14008[107]" Tackling the Climate Crisis at Home and Abroad" has solidified climate change as one of the priorities of the Biden administration, reaffirming the goal to achieve net zero GHG emissions by 2050, and planning and implementation of climate action at the federal level. The executive order established the creation of the Climate Policy Office[108], the National Climate Task Force[109], the White House environmental justice advisory council[110] (WHEJAC), and the Interagency Working Group on Coal[111].

In April 2021, at the Leaders Summit on Climate, President Biden issued a statement on the 2030 greenhouse gas pollution reduction target and on securing US leadership on clean energy technologies[112]. The United States has set a goal to reach 100 percent carbon pollution-free electricity by 2035 and committed to 50-52 % reduction in US greenhouse gas pollution from 2005 levels in 2030.

The Biden administration has put in efforts to pass regulations on the environment and digital. Currently, the US$ 1 trillion infrastructure investment bill[113] (Infrastructure Investment and Jobs Act) has been passed. It aims to spur economic recovery and update the infrastructure while accelerating climate action. Specifically, on digital and environment, the infrastructure investment bill:

- tasks the U.S. Secretary of Energy to prepare in 2022 a report assessing the use of digital tools and platforms as climate solutions, including AI and machine learning, blockchain technologies and distributed ledgers, crowdsourcing platforms, IoT, distributed computing for the electrical grid, and software and systems.
- provides for implementation of smart manufacturing, i.e. advanced technologies in information, automation, monitoring, computation, sensing, modeling, AI, analytics, and networking throughout the manufacturing and supply chain network, as well as to model, simulate, and optimize the design of energy efficient and sustainable products.
- set out the development of a smart grid to support the adoption or expansion of energy capture, electric vehicle deployment, or freight or commercial fleet fuel efficiency.
- provides for the development, adoption, and integration of light-, medium-, and heavy-duty electric vehicles into the transportation and energy systems of the U.S., including supporting infrastructure.

Other examples of where the executive branch of the U.S. Government has also been active on the intersection of digital issues and the environment include:

The U.S. Environmental Protection Agency undertakes a wide scope of engagement on the intersection of digital and environment. The EPA works on implementing new technological solutions[114] in its work, such as in the areas of water and technology[115], runs the Clean Air Technology Center[116], and partners with stakeholders within the framework of the Federal Technology Transfer Act[117], etc.

The U.S. Department of Energy's Advanced Grid Research and Development[118] aims to accelerate discovery and innovation in electric transmission and distribution technologies and create "next generation" devices, software, tools, and techniques to help modernize the electric grid.

The National Institute of Standards and Technology (NIST) works on embedded intelligence in buildings[119] and on net-zero energy, high performance buildings[120] to develop and implement technology solutions for lesser climate impact.

It is important to note the private sector in the U.S., with big tech and other private companies having developed their own environmental initiatives in recent years. Before Biden's administration took over, over 1,800 US private and financial institutions signed a statement calling for a national climate target that is "ambitious and equitable." In 2021, prior to the announcement of the new U.S. nationally determined contribution (NDC) under the Paris Agreement, the group *"America Is All In"*[121] was launched with a call to at least halve US emissions by 2030 and businesses, universities, scientists, activists, and others declared their support for an ambitious NDC. Similarly, the coalition "We Mean Business" of 408 businesses and investors, signed an open letter to President Biden indicating their support for the Biden administration's commitment to ambitious climate action.

In order to mitigate the environmental impact of their activities, tech giants such as Amazon, Apple, Microsoft, and Google, all of which are headquartered in the U.S., are increasingly positioning themselves as eco-friendly entities.

For instance, in 2019, Amazon[122] made a pledge to fulfill Paris Agreement targets 10 years ahead of the deadline. The company is also expected to operate on 100 percent renewable energy by 2030.

Google, for its part[123], has been carbon-neutral since 2007, and announced recently that it matched 100 percent of its total electricity consumption with purchases of renewable energy. It has also taken measures to recycle equipment[124], including the recycling of older servers into new ones.

Microsoft[125], announced its plan to become carbon negative by 2030. In order to step up its effort, it has set up a Climate Innovation Fund[126] intended for the development of technologies that combat the emission of GHGs, while its AI for Earth[127] program gives actors working on environmental challenges access to AI technology and their cloud. Apple's[128] data centers have operated using 100% renewable energy, which in turn has reduced GHG emissions by its facilities by 54% worldwide.

b. Raw Materials Policies

One of the areas of strategic importance for the U.S., EU and Germany are coordinated policies on raw materials.

As of 2020, China extracted 57.6% of the total rare earth elements (REEs) mined worldwide, making it by far the world's largest source of REEs. China also holds a majority share of REEs and critical mineral reserves, making up 36.7% of global deposits. In addition, China has secured a dominant position across the supply chain, particularly in purifying and processing REEs.

The U.S. currently imports[129] 80% of its REEs directly from China, with its next largest import sources – Estonia (5%), Japan (4%), and Malaysia (4%) – deriving their REE compounds and metals from mineral concentrates and chemical intermediaries produced mostly in China and Australia. According to Real Clear Defense, China's dominance over global critical mineral supply chains presents one of the largest strategic vulnerabilities[130] to the USA.

The need to address this issue resulted in Executive Order 13817[131] in 2017, prioritizing increased domestic extraction of minerals, refinement processes, and supply chain activity, as well as the evaluation of new material sources. On 21 December 2017, following the executive order, Interior Secretary Ryan Zinke signed Secretarial Order 3359 "Critical Minerals Independence and Security"[132] directing the steps to be taken to produce "the first nationwide geological and topographical survey of the United States in modern history" to identify REE sources and necessary processes for their refinement. In 2020, Executive Order 13953[133], declared reliance on critical mineral imports from adversaries (such as China) a national emergency. Also, the Defense Production Act authorized to streamline the construction of domestic mines, while prioritizing the expansion and protection of minerals in secured supply chains.

The Biden administration has continued and expanded on these policies, pledging investment in rare earth extraction, separation, and refinery processes in the recently passed US$1 trillion infrastructure bill[134]. In Executive Order 14017[135] on U.S. supply chains, President Biden announced the formation of a supply chain disruptions task force headed by the secretaries of commerce, transportation, and agriculture to identify improvements in supply chain management.

On the European side, there is similar awareness on the strategic importance of REEs and the impacts of import dependency, as 98% of the EU's REEs supply comes from China. The EU's digital strategy Europe Fit for Digital Age[136] includes the European Industrial Strategy[137], which identifies REEs as critical raw materials with high supply risk. The European Commission has set out various actions to support the development of a resilient raw materials supply chain in the 2020 Action Plan on Raw Materials[138]. It aims to achieve a diversified supply of REEs from both primary and secondary sources, reduce dependencies, and improve resource efficiency and circularity, including sustainable product design. In addition, it set up the European Raw Materials Alliance[139], where Germany is an active participant.

Germany, as the largest economy within the EU and one of the major users of REEs worldwide, has been particularly affected by risks associated with the stable supply of REEs and a free trade regime. The German Raw Materials Strategy[140], first adopted in 2010 and reviewed in 2019, is embedded into European raw materials-related policies and initiatives[141] such as the 2020 Action Plan on Critical Raw Materials, the European Commission's critical raw materials assessments[142], and the European Commission's Action Plan for Circular Economy[143]. Ensuring the supply of raw materials is also crucial for the European Union's Green Deal[144] and an essential element of the EU's industrial strategy[145].

Germany's Raw Materials Strategy[146], much like its U.S. policy counterparts, recognizes the need for the responsible extraction of raw materials and the risks associated with the dependency on imported raw materials. According to the strategy, the German supply of raw materials (REEs included) is currently based on the use of primary raw materials from domestic sources, secondary raw materials from recycling, and the import of raw materials. The German government is striving to make the substitution of primary raw materials with secondary raw materials as broad as possible in the future. The German government is also committed to promoting resource efficiency at the international level, particularly within the G7 and the G20[147].

In the international arena, both the U.S. and Germany have similar objectives – the need to have sustainable and reliable sources of REEs, extracted in compliance with high social and environmental standards, as well as curbing their import dependence on China.

One of the latest developments are the outcomes of the first meeting of the U.S.-EU Trade and Technology Council (TTC)[148]. It has recognized significant mutual dependencies and common external dependencies in raw materials supply chains between the U.S. and the EU. The TTC established ten working groups chaired by relevant U.S. agencies and European Commission services. REEs as critical materials are discussed under the auspices of Working Group 3 on secure supply chains. The working group is tasked to seek to increase the transparency of raw material supply and demand; map respective existing sectoral capabilities; exchange information on policy measures and research and development priorities, and cooperate on strategies to promote supply chain resilience and diversification.

The U.S. and the EU intend to focus on reducing existing strategic dependencies throughout the supply chain, especially through a diversification of the supply chain and increased investment. Additionally, both parties are set to develop partnerships with third countries, in order to progress on their shared goals.

c. E-waste Policies

Regarded as the "fastest-growing waste stream in the world"[149], e-waste such as outdated electronic equipment (e.g. computers, smartphones, and TVs) constitutes a rather significant ecological issue. A report[150] by the World Economic Forum indicates that around 50 million tons of e-waste are produced annually, of which only 20% gets recycled. The remaining 80% of e-waste usually ends up buried underground or incinerated. While the vast majority of e-waste is produced by developed countries, most of it is treated (i.e. dismantled and processed in so-called e-dumps) in developing countries. The amount of e-waste, however, is the result of a wider issue in the digital technology industry –– that of sustainability of both hardware and software.

The UN has addressed the growing problem of e-waste, often warning of a "tsunami of e-waste rolling out over the world."[151] A number of global agencies have emphasized the importance of confronting the global e-waste challenge effectively and in a timely manner, including the International Telecommunications Union[152] (ITU), International Labour Organisation (ILO), UN Environment Programme (UNEP), and others.

In order to promote recycling, reduce the disposal of e-waste, and combat illegal dumping, the ITU in partnership with the International Solid Waste Association (ISWA) and the UN University established the Global E-waste Statistics Partnership[153], which gathers relevant data and organizes workshops on statistics collection that are necessary for the realization of SDGs. The ITU also adopted a set of "guidelines for developing a sustainable e-waste management system"[154] where it drafted out "policy and legal frameworks, collection mechanisms, financial mechanisms and engagement with all relevant stakeholders."

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal[155] (1992) outlaws the export of e-waste from developed to developing countries. Moreover, the parties to the Basel Convention adopted the Ban on Exporting Hazardous Waste to Developing Countries in 1995, which prohibits the export of hazardous wastes from the members of the EU, Organisation for Economic Co-operation and Development (OECD), and Liechtenstein to all other countries. The Ban entered into force on 5 December 2019 and 188 countries have ratified it[156], including Germany. The U.S. signed the Basel Convention in 1990 and the U.S. Senate provided its advice and consent to ratification, however, it remained not ratified because the U.S. does not have sufficient domestic statutory authority[157] to implement all of its provisions. Despite the USA not having ratified the Basel Convention, the U.S. Environmental Protection Agency continues to be engaged in Basel activities, including the Partnership for Action on Computing Equipment (PACE) Exit[158] which develops guidance on key policy issues and supports capacity-building to developing countries on used electronics and e-waste issues.

On the EU level, the European Commission has issued its Circular economy action plan[159] as a part of the European Green Deal. It aims to revise the EU Ecodesign Directive[160] and propose additional legislative measures as appropriate. It also intends to make products – electronics and ICT equipment included – placed on the EU market more sustainable. The European Commission is expected to approve the outcomes of this initiative by the end of 2021. With regards to e-waste, the EU's WEEE Directive[161] aims to contribute to sustainable production and consumption by preventing the creation of e-waste and contribute to the efficient use of resources and the retrieval of secondary raw materials through re-use, recycling and other forms of recovery.

Within the EU framework, Germany has adopted its Resource Efficiency Program[162] (ProgRess) in February 2012 and has updated it every four years. It includes specific measures to enable sustainable use and protection of natural resources by increasing raw material and resource efficiency. In the latest update, ProgRess III[163], the German government is putting special emphasis on the interactions between digitization and resource efficiency.

Additionally, German Digital Policy for the Environment puts forward several new possibilities for design and management, such as:

- Introducing digital product passport containing the environmental data on the life cycle of products and services
- Digital platforms should support the transition towards sustainable consumption e. g. by prioritizing environmentally friendly products in search engines and ensuring goods are no longer destroyed unnecessarily.
- Use of pattern recognition, improved monitoring and public data promote a better understanding of ecosystems.

In the future, Germany plans[164] an extensive policy and regulatory push in the area of circular economy, environment and digital technologies. These new initiatives will, for example:

- Accelerate standards on and standardization of the integration of resource and environmental aspects in industrial development, automation and IT.
- Formulate recommendations for action for regulatory, economic, and fiscal instruments to strengthen the environmental potential of digitalization for the transport sector.
- Set an example for environmentally sound mobility in developing countries and emerging economies, especially in urban areas of Asia and Latin America to reduce greenhouse gas emissions.

The U.S. so far lacks a comprehensive and cross border policy framework on the circular economy similar to the EU. There are, according to sources[165], some 950 policies either announced, in the legislative process, or in force in the U.S., mostly on state and regional levels[166]. In the first national scan of how circular economy solutions are being pursued in the USA[167] in 2018, CircularCoLab has identified 202 initiatives for circular economy, and noted that "there are already 115 state and municipal extended product responsibility laws in 13 different product categories."

Regarding the so-called "right to repair", the discussion is also taking place at the Federal Trade Commission (FTC) and is framed as antitrust practices of the manufacturers. In the recent Report of FTC to US Congress on Repair Restrictions[168], the FTC describes existing rules on state level and model regulation for the federal level, giving comparisons to current regulations in the EU.

With regards to the sustainable use of resources, the Executive Order 13693[169] from 2015 on Planning for Federal Sustainability in the Next Decade outlines goals for U.S. federal agencies with respect to sustainable resource management, reducing GHG emissions, and environmentally sustainable electronic product stewardship. Based on this EO, the U.S. Environmental Protection Agency issued the National Strategy of Electronics Stewardship[170], which aims at:

1. Building incentives for design of environmentally preferable electronics and enhancing science, research, and technology development
2. Increasing safe and effective management and handling of used electronics
3. Reducing harm from US exports of electronics waste (e-waste) and improving handling of used electronics in developing countries.

6. Conclusion

The link between the use of digital technologies and addressing environmental issues, especially climate change, is becoming more prominent. While digital technologies are not yet widely adopted, their potential to accelerate the much-needed efforts to help solve the climate crisis is becoming increasingly recognized.

Looking forward, the interconnection between digital technologies and their contribution to the environment is gaining momentum in international policy discussions. The same is true for the bilateral talks between the United States and Germany - while the discussions are in the early stages at the moment, the alignment of values and efforts across the Atlantic is apparent. With the Biden administration on one side and the new German government planning to be the greenest one yet, both partners are well-positioned to work bilaterally and multilaterally to accelerate reaching a net-zero future.

The developments ahead will relate to aligning policies on the reduction in GHG emissions, coordinating on climate and trade agendas, and mobilizing finance for sustainable development, increasingly involving digital technologies in attaining common goals. Both the United States and Germany can strengthen the implementation of their shared values in this alignment, such as respect for human rights both in the environmental policy setting and in digital technologies, rights of future generations, and in support of developing countries.

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