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MEASURING IMPACT, DRIVING CHANGE

White Paper

Internet Emissions & its Increasing Footprint

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Abstract.

This white paper examines the energy consumption and carbon emissions associated with internet usage and related activities. The rapid growth of digital technologies has led to an increased environmental impact, making it crucial to understand and mitigate these effects. This paper provides insights into energy usage and carbon emissions from internet activities through an analysis of current trends, research findings, and mitigation strategies.

Introduction

1.1 Background

The widespread use of the Internet and digital technologies has revolutionized various aspects of our lives. Internet technology has gradually spread and permeated into numerous economic and sociological domains in the current global technological and industrial revolution, which has become a major driving factor in fostering global economic growth. Currently used wireless communication technologies often use energy produced by carbon-based energy sources. Information and communications technology (ICT) systems now account for 5% of worldwide carbon emissions, which is rising daily; as a result, cutting Information and Communications Technology's carbon footprint will be a crucial concern. The architecture of wireless networks for the next generation must have solutions based on energy efficiency. However, the energy consumption and resulting carbon emissions associated with internet infrastructure and activities have become a growing concern. It is essential to assess and address the environmental impact of the Internet to achieve sustainability goals.

1.2 Purpose and Scope

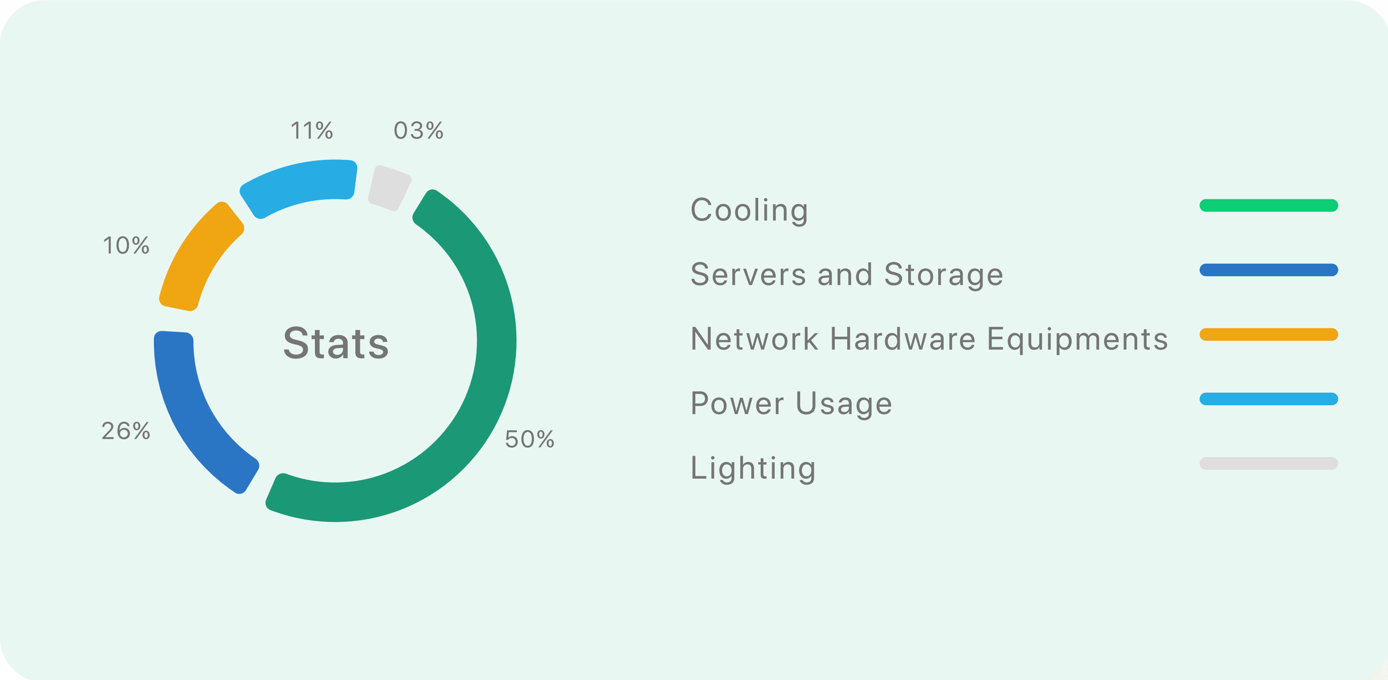
This white paper aims to overview the energy usage and carbon emissions caused by internet-related activities. It explores the energy consumption of data centers, network infrastructure, end-user devices, and associated carbon emissions. The paper also discusses emerging trends, research studies, and mitigation strategies to reduce the environmental footprint of the Internet.

Energy Consumption of Internet Infrastructure

2.1 Data Centers and Servers

Data centers house the hardware and equipment required to support online services. A data center may house mainframes, databases, web servers, or any combination of the three. Data centers consume a substantial and growing share of global electricity. With the proliferation of cloud services, online applications, and streaming platforms, the demand for data centers has increased significantly. Data centers consume high electricity due to their continuous operation, which requires servers to work 24/7. Additionally, the cooling systems which are required to maintain optimal temperatures also contribute to electricity consumption. As cooling is critical to data center work maintenance, traditional cooling methods, such as air conditioning, can be energyintensive. Cooling consumes about 50% of the total energy data centres consume (Dayarathna et al., 2016). Data centers in colder climates can take advantage of natural cooling, whereas those in warmer regions require more energy for cooling. Using solar, wind, or hydropower can help reduce the environmental impact of data centers (Zhang et al., 2014). Breakdown of energy consumption in data centers is shown in Figure 1.

Figure 1.1 Energy Consumption Breakdown in Data Centers



Many companies now rely on cloud services to meet their data center requirements. In other words, they have outsourced the hardware to a third party that enables their internet presence. All data centers, whether internal or rented out to a specialized cloud service provider, require energy to function.

Data centers consumed 240-340 TWh of electricity globally in 2022, roughly 1-1.3% of the world's total electricity demand (ITU, 2023).

Table 1 represents the percent change in internet infrastructure.

Global Trends in the year 2015 & 2022			
	2015	2022	Change
Internet Users	3 billion	5.3 billion	↑ 78%
Internet Traffic	0.6 ZB	4.4 ZB	↑ 600%
Data Center Workloads	180 million	800 million	↑ 340%
Data Center Energy Use	200 TWh	240-340 TWh	↑ 340%
Data Transmission Network Energy Use	200 TWh	260-360 TWh	↑ 18-64%

(Internet users (ITU, 2023);
Internet traffic (IEA analysis-Cisco, 2015);
Telegeography (2023);
Data center workloads-Cisco, 2018);
Data center energy use (IEA analysis-Malmodin & Lundén, 2018); ITU, 2020);
Masanet et al. (2020);
Malmodin (2020);
Hintemann & Hinterholzer (2022);
Data transmission network energy use (Malmodin & Lundén, 2018); Malmodin, 2020)

2.2 Network Infrastructure

Network infrastructure, including routers, switches, and transmission lines, enables the communication between end-user devices and data centers. Energy consumption in network infrastructure varies based on network size, topology, and technology.

Power and cooling must be provided for network equipment. This includes supplying DC power to the racks that house the equipment and an uninterruptible power supply that provides power continuity to the network equipment (Hinton et al., 2011). However, there has been a significant increase in energy consumption within network infrastructure due to the rising demand for data-intensive applications, rising internet usage, and the proliferation of connected devices (Sabyasachi & Muppala, 2022). One study estimated that network equipment accounted for 10-20% of total data center energy consumption (Baliga et al., 2007).

Wireless networks consume much more power per user than fiber-based networks. As wireless network allows greater mobility and simplicity of access to the Internet, high-speed wireless connectivity is becoming increasingly popular. However, its growing popularity may become unsustainable unless the wireless network’s energy efficiency is improved. Due to the demands on core routers, the power consumption of the Internet's infrastructure will rise exponentially to unsustainable levels unless continual technological advancements are made. As internet users increase exponentially, the network infrastructure needs to be developed, which demands more energy. A substantial quantity of Internet traffic is generated by a diverse set of web-based services and resources made available to end users via the Internet.

2.3 End-User Devices

End-user devices are getting increasingly energy-efficient. One factor is technological advancement in individual system components, particularly processors, hard drives, and power supply. Another factor is the growth of energy-efficient mobile end-user devices like notebooks and tablets outpaces that of stationary personal computers. Mobile end-user devices have outsold traditional computers. The mobile device market has dominated the global market share and is still growing, as represented in Figure 2 (Cegan, L., & Filip, P, 2017). The advancement in efficiency has resulted in decreased energy consumption. But the problem is that global data center energy consumption has increased significantly, and significant increases in data center energy consumption are expected in the future due to the use of end-user devices. Even when not in use, some end-user devices use energy. Energy consumed by end-user devices when turned on and on standby mode is shown in Table 2.

Figure 2 Market share of Desktops and Mobile devices between 2013-2017

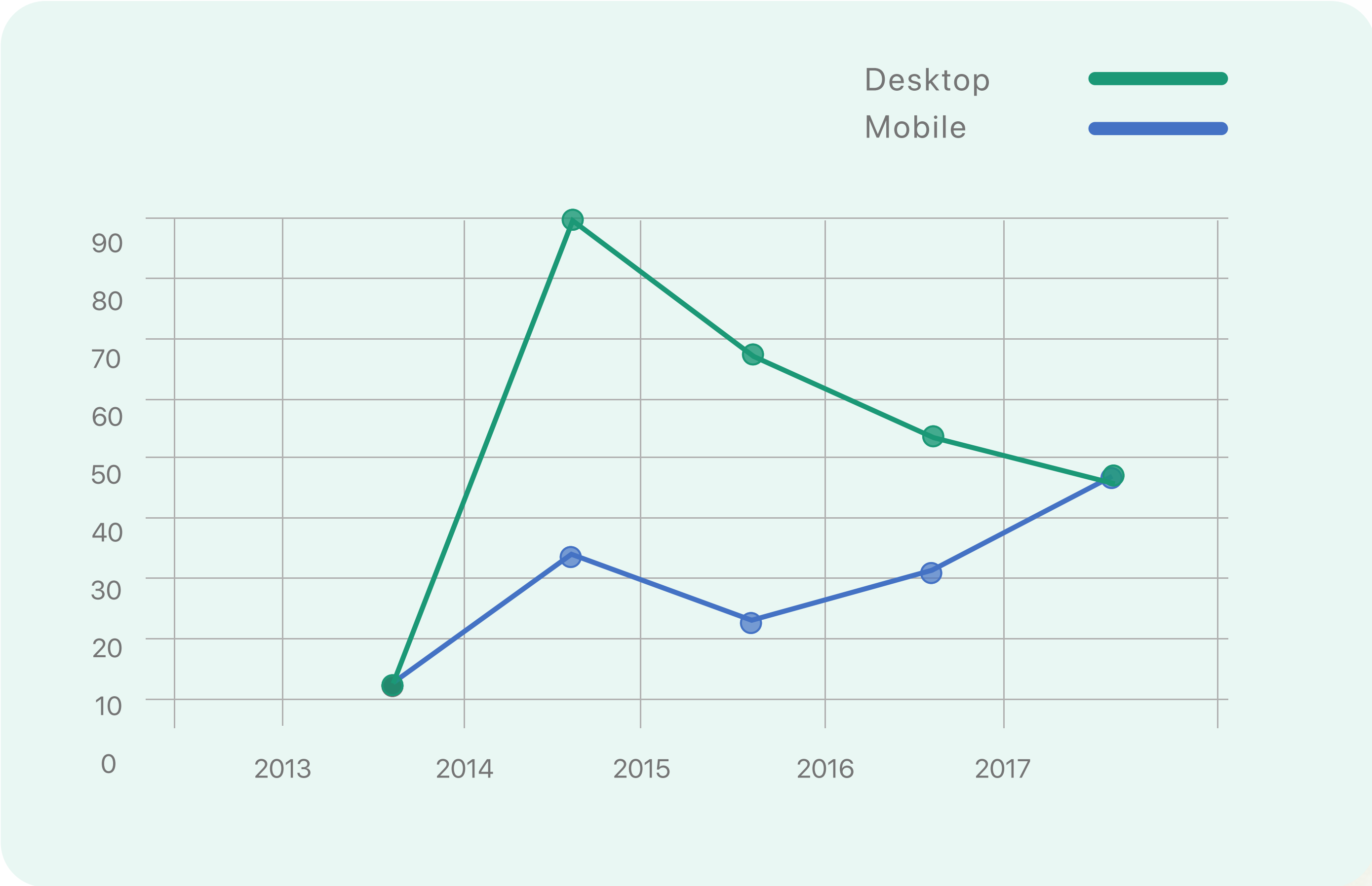


Table 2. Energy used by end-user device per hour (W) (Borzycki, K., 2012)

	On	Standby
Computer	140	70
21'' Monitaor	40	2
Game Console	100	5
Laptop	200	5
Television Set	120	5

Carbon Emissions from Internet Usage

3.1 Electricity Generation and Carbon Intensity

The carbon intensity of electricity generation influences the carbon emissions associated with internet usage. Countries with a higher reliance on fossil fuels for electricity production tend to have higher carbon emissions from internet activities. Due to increased energy demand in 2018, worldwide energy-related CO_2 eq.

emissions increased by 1.7% to a record high of 33.1 Gigatonne. While emissions from all fossil fuels grew, roughly two-thirds of the rise was attributed to the electricity sector. Coal use in electricity generation alone exceeded 10 Gigatonne CO_2 eq. emissions, primarily in Asia. China, India, and the United States accounted for 85% of the net rise in emissions, while Germany, Japan, Mexico, France, and the United Kingdom saw decreases. Even as the world economy expanded, CO_2 emissions remained stable between 2014 and 2016. This decoupling was primarily caused by significant advances in energy efficiency and low-carbon technology deployment, which decreased coal consumption. However, the dynamics shifted in 2017 and 2018. Higher economic growth was not met by higher energy production, and lower-carbon alternatives did not scale quickly enough to meet rising demand (IEA analysis, 2022). Renewable energy generation surged by over 7% in 2018, infusing an additional 450 TWh into global electrical networks. Increased nuclear output generated another 90 TWh of low-carbon generation.

However, this increase was insufficient to keep up with the significant expansion in power demand, which necessitated an additional generation of nearly 1000 TWh. The increased generation from fossil-fuel-fired power plants accounted for over two-thirds of the rise in total emissions. Electrification does not always imply reduced emissions if there is no concomitant decarbonization of the power industry.

Regarding the absolute change of Carbon intensity per KW from 2000 to 2022, Hong Kong ranks '58th'. Globally, the reliability of coal is still high among the top 3 of the five global economies, namely the United States, India and China.

In Hong Kong, two electricity-generating companies are working to decrease CO_2 eq. emissions. HK Electric ensures that company's annual average emissions do not exceed 0.6 kg of CO_2 eq. per kWh by 2023. And in 2022, CO_2 emission was ~0.68 kg/kWh.

There is an approximately 32% decrease in absolute carbon emissions compared to 2005 (HK Electric Sustainability Report, 2022).

Similarly, the CLP Group achieved its decarbonization goals in 2010 and 2020 by bringing the carbon intensity of its generation portfolio below 0.8 kg CO_2/kWh and 0.6 kg CO_2/kWh, respectively, since its first Climate Vision 2050 in 2007.

The intensity of GHG emissions from electricity sold by the company in 2022 is 0.55 kg CO_2 e/kWh, which was 0.57 kg CO_2 e/kWh in 2021 (CLP sustainability report, 2022).

3.2 Greenhouse Gas Footprint of Internet Activities

The world's ICT infrastructure consumes over 1500 TWh of electricity, accounting for around 10% of worldwide usage, while ICT contributes to 2% of global carbon emissions (Reddy et al., 2017). End-user computing devices, such as desktop PCs and notebook computers, are responsible for 0.37 Gt CO_2 of GHG emissions. Different internet activities have varying levels of carbon emissions. Online video streaming, cloud computing, digital advertising, and data transmission contribute to the carbon footprint of the internet (Figure 3).

Carbon emission from various end-user devices is shown in Figure 4.

Figure 3 Carbon Emissions by Internet Activity (EHS Myanmar & ELC Advocates, 2022)

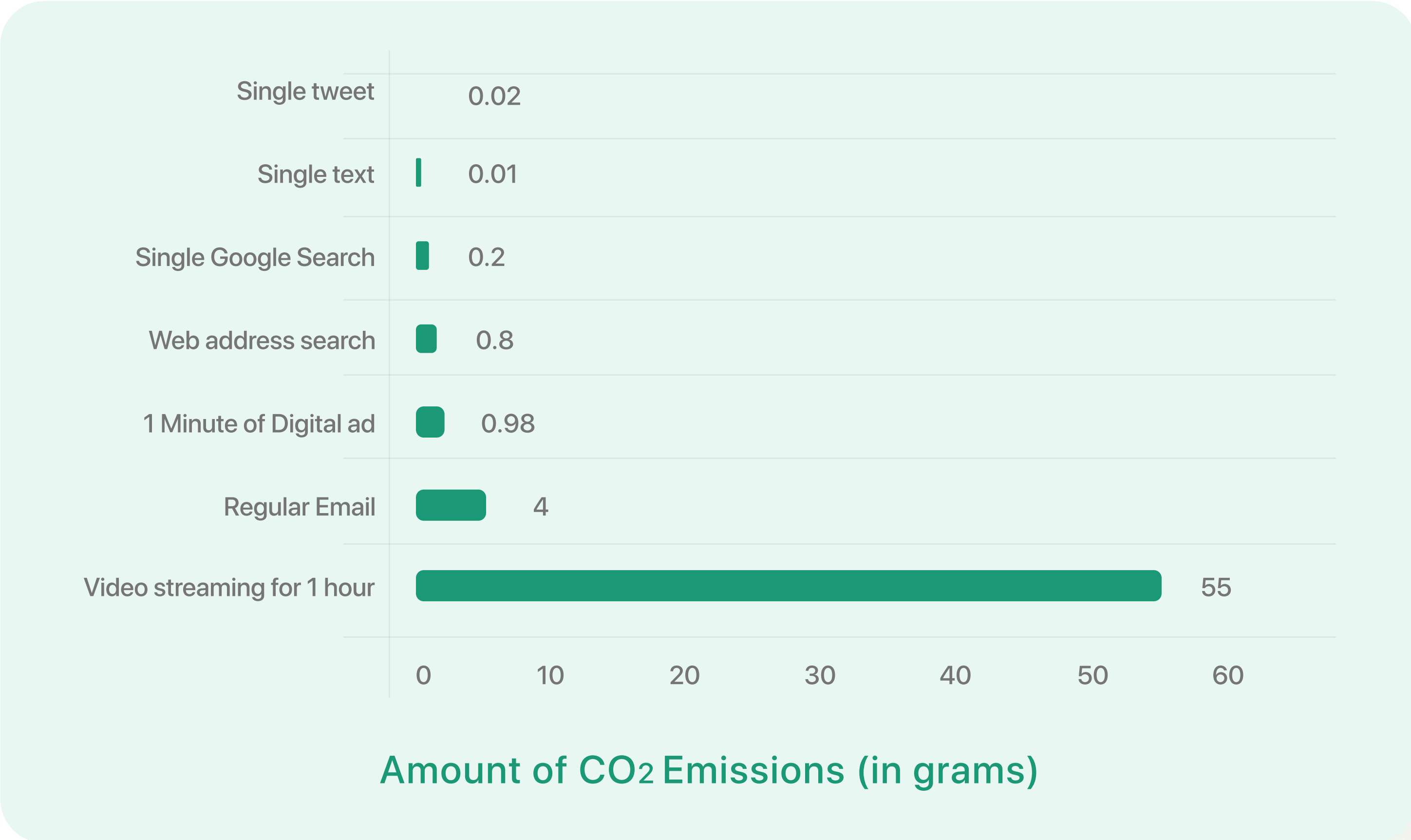
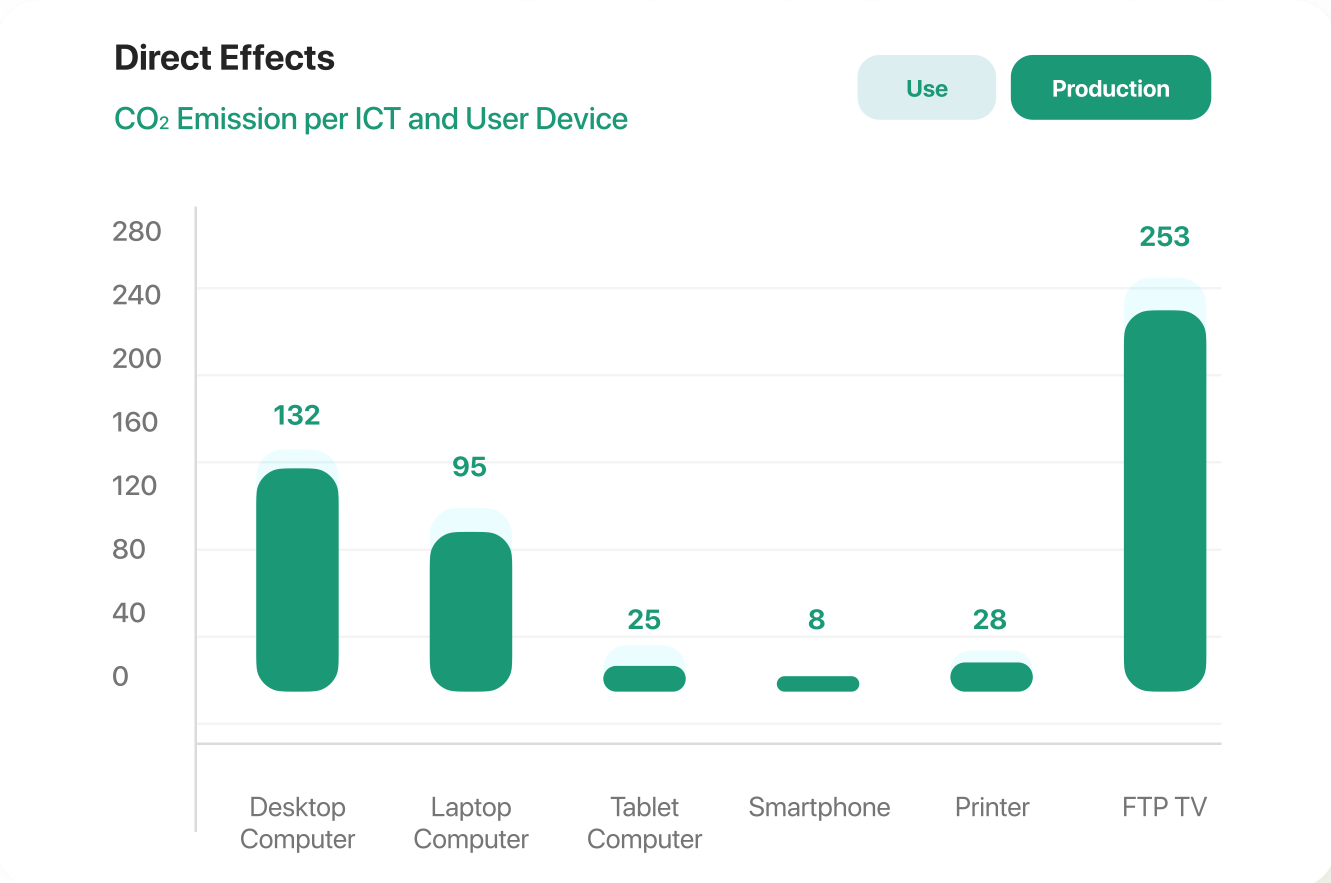


Figure 4: Carbon emission from various end-user devices



Reduction of Environmental Impact from Production by

-Reduction of the number of devices (e.g., through lifetime extension, fewer devices per person).

-Increase in energy and material efficiency in production.

Data traffic in the ICT sector surged fourfold between 2005 and 2015, while carbon footprint climbed sixfold. Smartphone use produces the highest carbon footprint compared to any other end-user device. Many Internet of Things products, such as household appliances, security systems, and smart speakers, are available with an always-on Internet connection (Jens & Dag, 2018).

The IPCC (Intergovernmental Panel on Climate Change) estimates that CO_2 emissions must be reduced by 45% by 2030, However emissions have been increasing year after year. According to a data study, a 1% increase in internet users raises electricity consumption by 0.026% (Mohammad, S. & Khorshed, 2016).

3.3 Transmission-Related Carbon Emissions

Data transmission across networks involves routing, switching, and network equipment, which consume energy and contribute to carbon emissions.

Including embodied emissions, the data centers and data transmission networks that support digitalization accounted for about 330 Mt CO_2 equivalent in 2020, which is 0.9% of energy-related GHG emissions (or 0.6% of total GHG emissions).

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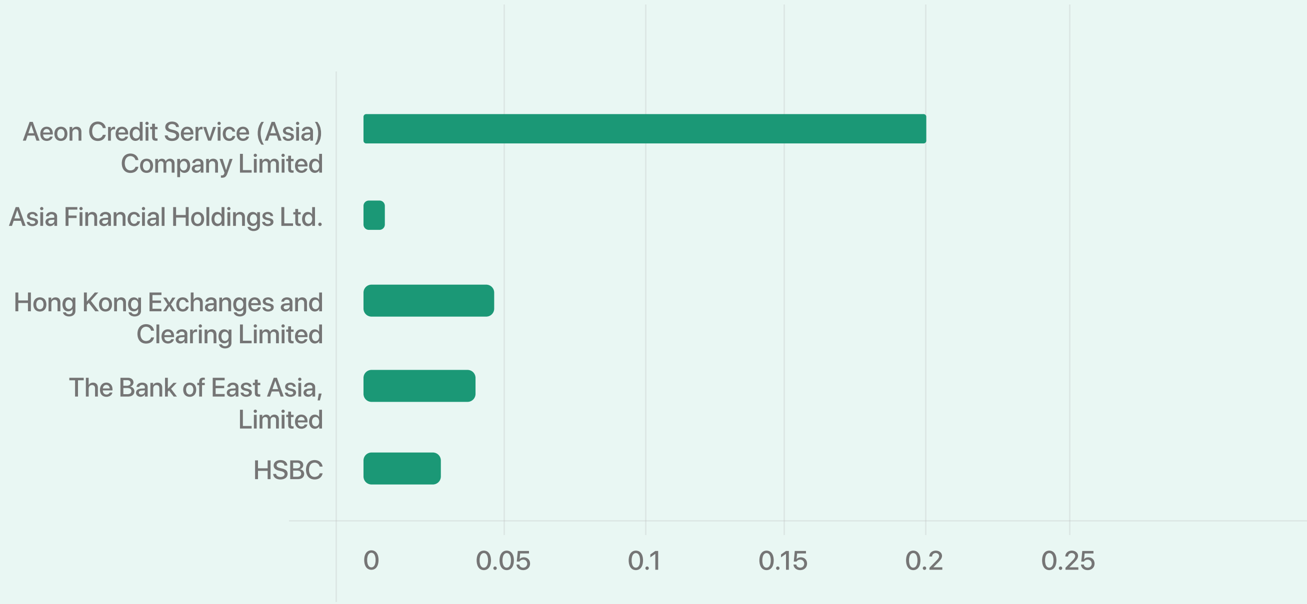
Figure 5



Ping response time for various banking websites (in seconds)

4. Trends and Projections

4.1 Growing Internet Adoption and Digital Services

The internet's global penetration continues to expand, leading to increased energy consumption and carbon emissions. The proliferation of digital services, e-commerce, and the Internet of Things (IoT) further amplifies the environmental impact of the internet. Research conducted by the International Telecommunication Union reported that by 2020, data centers and data networks will have produced 300 million tons of CO_2 eq. or 0.6% of all greenhouse gas emissions. (ITU,2020).

4.2 Future Energy Demand and Carbon Emissions

With the internet's continued growth, future energy demand and carbon emissions are expected to rise. A study projects a significant increase in global energy consumption due to the Internet, with estimates reaching 20% of global electricity usage by 2030 (Andrae and Edler, 2015). Projected energy demand is shown in Figure 6.

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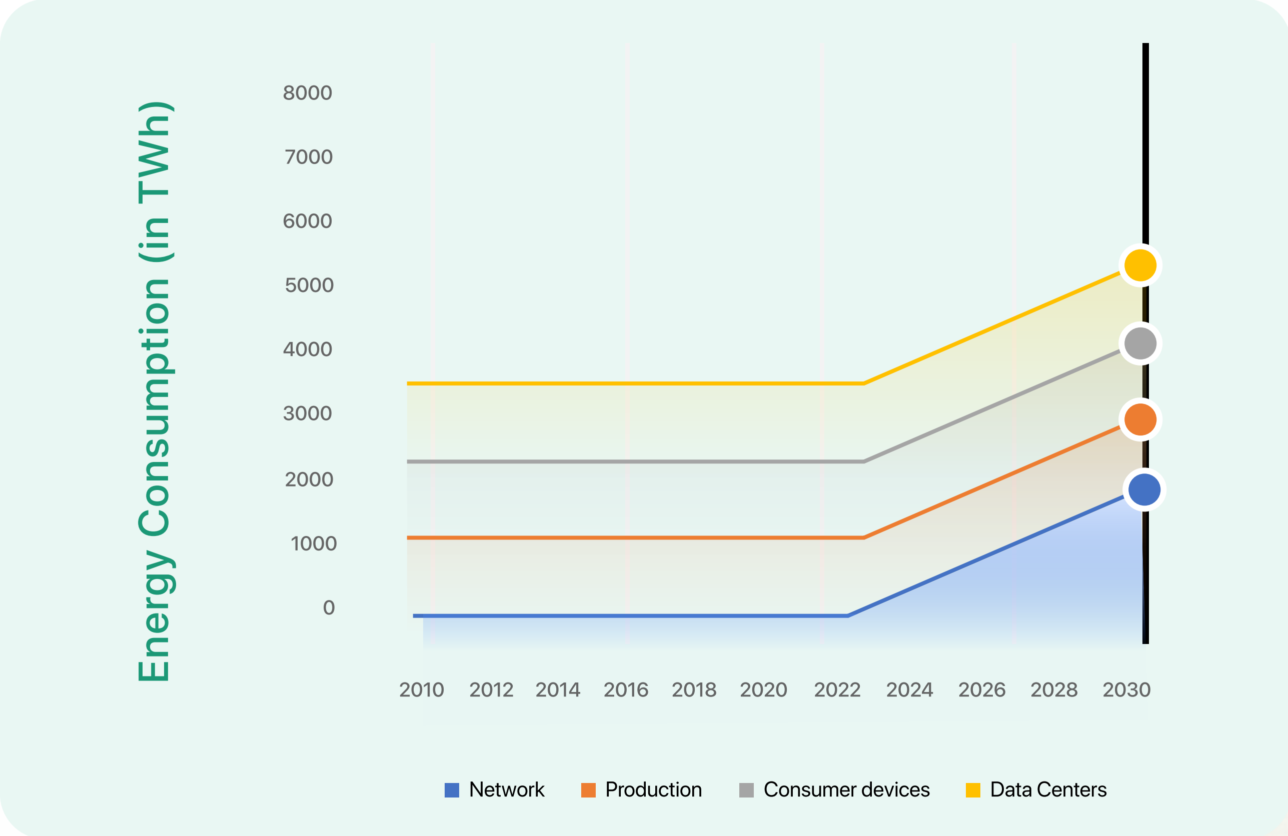
Figure 6: Projected Energy Demand of the Internet



It is predicted that operational electricity used by gadgets will increase globally from 335 TWh in 2020 (about 1.2% of the world's electricity demand) to 450 TWh in 2030 (ITU, 2020).
Emerging technologies, such as the Internet of Things, artificial intelligence, and blockchain, offer numerous benefits but pose challenges in energy consumption. Understanding and optimizing the energy usage of these technologies are crucial for mitigating their environmental impact. According to one projection, Bitcoin will consume approximately 110 TWh of electricity in 2021, over half the total energy expected by all global data centers (Kamiya, G., 2019). One report said IoT devices would virtually triple between 2020 and 2025 (Pirson, T. et al., 2021). All industries are anticipated to utilize machine learning more frequently. Creating machine learning and its use requires energy (Strubell, E. et al., 2019).

5. Policy and Industry Initiatives

Governments, organizations, and industry stakeholders can play a significant role in reducing the Internet's carbon footprint. Implementing energy efficiency regulations, incentivizing renewable energy adoption, and promoting sustainable practices through certifications and standards are essential. Governments and industry organizations can establish regulations and standards to promote energy efficiency in data centers and servers. Compliance with these standards can drive sustainable practices.

The International Sustainability Standards Board (ISSB) voted overwhelmingly to adopt the most recent GHG Protocol Corporate Standard and demand company reporting on Scope 3 greenhouse gas emissions. To assist businesses in implementing the Scope 3 standards, the ISSB will create relief options as part of these specifications. Indirect emissions from an organization's upstream and downstream operations are included in scope 3 emissions. The ISSB plans to use existing materials, such as the Integrated Reporting Framework and the International Accounting Standards Board's guidance, to support this policy.
European Sustainability Reporting Standards (ESRS) mandates that companies within its scope must disclose specific sustainability information, regardless of their assessment of its significance. This includes disclosing information about governance, strategy, management of impacts, risks and opportunities, and metrics and targets related to climate change. ESRS requires all reporting companies to disclose all material information on sustainability-related impacts, risks, and opportunities. They must also account for GHG emissions, including indirect Scope 3 emissions, in metric tons of CO_2 eq.

Conclusion

3. Regulatory Frameworks: Governments and regulatory agencies must set and enforce strict environmental standards for the technology industry. This can stimulate green technology innovation and hold firms accountable for their carbon footprints.

4. Collaborations: Industry collaboration is essential for creating sustainable practices. Tech businesses, internet service providers, and environmental organizations should collaborate to develop new solutions that balance the internet's benefits with its environmental costs.

5. Research and Development: Continued research and development activities are required to generate more energy-efficient hardware and software solutions. This includes investigating technologies such as edge computing and quantum computing, which can potentially minimize energy use.

In summary, the white paper emphasizes the urgent need for consumers, organizations, governments, and technology providers to work together to minimize the energy consumption and carbon emissions related to internet use. We can harness the revolutionary power of the internet while reducing its impact on the environment by taking a proactive approach.

Conclusion

Finally, this white paper emphasizes the crucial significance of recognizing and mitigating the environmental consequences of our increasingly digitalized society. The rapid growth of the internet and digital technology has provided several benefits to society but has also introduced a serious environmental concern.
According to our findings, the energy consumption and carbon emissions associated with internet use are significant and expanding. Data centres, network infrastructure, and electronic device manufacturing are all critical contributions to this problem. As the internet continues to permeate every aspect of our lives, we must take proactive actions to solve these issues.
This white paper provides several significant takeaways:
1. Energy Efficiency and Renewable Energy: For powering data centers and network infrastructure, investing in energy-efficient technologies and moving to renewable energy sources is critical. This has the potential to reduce the carbon footprint connected with internet usage significantly.
2. Consumer Awareness and Responsibility: Consumers may help reduce their internet use's environmental impact. Conscious data storage, streaming quality, and device usage can significantly reduce energy consumption and carbon emissions.

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Thank You !

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