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Latest Technology Developments in Consumer Electronics and Their Impacts on Household Energy Use and the Design of Policies and Programmes in Developing Countries

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Abstract

Technology developments reflect changes in market demand and can further influence the energy use of domestic appliances. This report examines the major development trends in household appliances for entertainment purposes, also known as consumer electronics, and their impacts on the energy use of these appliances. It analyses the design and implementation of policies and programmes to influence consumers' purchase choices and everyday appliance use for energy efficiency and conservation. Ultimately, the paper further aligns policy and programme design and implementation with the circumstances in developing countries and emerging economies at different stages of appliance penetration and energy efficiency regulation.

1. Introduction

Consumer electronics are electronic products for entertainment purposes, including TV sets, radios, video players, personal computers (PCs), gadgets like iPads and tablets, and mobile phones. Compared with other household appliances, the technology for consumer electronics has developed much faster in the past three decades, especially in smart equipment, digitalization, and Internet access.

Consumers account for most Internet traffic. According to a CISCO report, in 2017 global IP traffic is 122 petabyte (PB) per month, of which 100 PB was used by consumers, while the rest was used by businesses. In the coming years, Internet video will see the fastest growth in data consumption (CISCO, 2019).

Rapid technological progress has brought about enormous changes to people's entertainment activities at home over the last three decades. TV sets have become thinner, with larger screens, better picture and audio quality. They are also becoming smart. People can select and change the packages and channels for their subscription and record their favourite programmes and watch them when they have time. They can also access the Internet to see films, videos and pictures on their TV, or even to listen to the radio on their TVs. Moreover, ever-faster web speed, decreasing prices of Internet access and the availability of mobile data and Wi-Fi enables people to access the sea of information, video and audio online at any time and from anywhere. The era of touch-screen mobile phones, tablets, and even laptops, makes consumer electronics ever more user-friendly. The rise of social media is making people move their social life online.

The Internet connects people worldwide, and its enormous influence is manifested in many aspects. It changed the business landscape in many sectors. Globally, IT companies such as Facebook, Netflix, Apple, Google and Microsoft rapidly overtook traditional manufacturing enterprises and became the most valuable enterprises on earth. E-commerce has not only created such giants as Amazon, eBay and Alibaba, but has also transformed many segments of the service sector, from travel and restaurant bookings to publishing, advertising, retail and financial payments. Global e-commerce reached USD 3 trillion in 2017 in volume and is expected to double by 2022 (Bansal et al., 2018). Smart use of online and social media tools was quoted as a main reason for Barack Obama winning the US presidential elections in 2008 (Michaelsen, 2015).

The increasing ownership and use of consumer electronics causes dramatic social changes and brings about energy and environmental impacts. Globally, on average, people with Internet access spend several hours every day surfing the Internet for information, news, and entertainment, visiting and updating their social accounts, checking their emails, watching videos, listening to music and playing games.

People can put their personal opinions and views on the Internet and tend to search and associate with others of similar opinions. There is a lack of incentives and requirements for people to clean up the mass of information they put online. People's online activities leave a large amount of information waste online, which is stored in servers and clouds. Storing the information and making it accessible all the time consumes electricity and causes energy waste.

Despite efficiency improvements from technology progress, information and data storage on the Internet and Internet use is causing increases in elec-

tricity consumption, not only in consumers' homes but in the global Internet infrastructure, as well as the data centres that help store and process the data. Globally, the information and communication technology (ICT) sector contributes to around 5 per cent of global electricity consumption. The further spreading of Internet use in developing countries means global energy use and related carbon emissions will continue growing in the absence of effective policy interventions.

Another significant impact of booming consumer electronics ownership and use is the increases in electronic waste (see Table 1). Due to rapid technological progress and continuous price decrease, many mobile phones, computers, DVD players and TV sets are dumped before the end of their useful life. For example, many people replace their mobile phones within two years. Globally, in 2016, 46.6 million metric tonnes of electronic waste was generated (Baldé et al., 2017). E-waste contains many hazardous elements, including mercury, copper, other heavy metals, rare earth, plastics and glass. How to recycle and treat e-waste is a global challenge.

Governments have many policy options to maximize the benefits from ICT technology progress and curtail the negative impacts, including tapping the potential of using ICT technology to reduce energy waste and resource waste, tackling the issues of Internet security, and setting minimum energy performance standards for consumer electronics, Internet infrastructure and data centres. They can also require producers to offer disposal solutions and obligations so that that e-waste treatment can be addressed from the source. Moreover, they can deal with the problem from the end-user side, raise public awareness about the energy use and environmental impacts of the Internet, encourage the reduction of junk data and information storage and sharing in the cloud, and promote the repair, maintenance and longer use of consumer electronics.

Table 1. Global ICT penetration, 2018

	Mobile phone subscriptions	Individuals using the Internet	Fixed telephone subscriptions	Active mobile-broadband subscriptions	Fixed-broadband subscriptions
Per 100 inhabitants	107	51.2	12.4	69.3	12.4

Source: ITU World Telecommunications/ICT Indicators database

2. Progress in consumer electronics in the information age

Since the 1990s, personal computers (PCs) – including desktops and laptops – are becoming faster and more powerful in data storage, processing, retrieval and transmission. Meanwhile simple versions for Internet access, which can be used for browsing the Internet, are spreading quickly. The most important drivers behind the recent changes in consumer electronics include display technologies, information technologies and communication technologies. Reading devices like the Amazon Kindle are also consumer electronics and can have Internet access.

2.1 Progress in consumer electronics technologies

The differences in functions between phones, computers and televisions are vanishing – people used to send photos and documents through their computers; nowadays they can watch their photos and videos on their TVs and computers and browse the Internet on their phones, smart TVs and tablets.

The amount of data circulating the Internet has been growing by almost a thousand times every decade since the early 1990s (see Table 2). The ICT sector's electricity use for hosting, transferring and processing data already accounts for more than 2 per cent of global electricity use (IEA, 2017). As most phones and computers have an average use life of around three years, the massive quantity of electronic waste produced every year also means increasing environmental impacts. Therefore, reducing the time, resources, and electricity consumption due to people's use of consumer electronics for entertainment purposes is of great importance to the achievement of the sustainable development goals for sustainable and clean energy, environmental protection and climate change mitigation.

Behind this lifestyle change is the rapid progress and breakthroughs in ICT technologies, in terms of thinner and bigger devices, touch screens, rapid increases in the operating speed and storage capacity of consumer electronics, high speed and universal access to the Internet via mobile data, Wi-Fi, inter-device Internet access sharing, cable fibre, as well as ever-decreasing prices for both consumer electronics and Internet access.

Table 2. Evolution of global Internet traffic

Year	Global Internet Traffic
1992	100 GB per day
1997	100 GB per hour
2002	100 GB per second
2007	2,000 GB per second
2017	46,600 GB per second
2022	150,700 GB per second

Source: Cisco, 2019.

Smartphones are phones that have touch screens and can access the Internet. The rise of the smartphone in consumer electronics started in 2007 when Apple released its first generation of iPhone and sold 1.39 million units during the year (Statista, 2019). The vast popularity of the smartphones attracted other producers into the market, and smartphone sales quickly picked up. In 2009, worldwide sales of smartphones reached 173 million (Statista, 2019a). Since then, the annual sales of smartphones have grown exponentially. In 2018, there were around 1.56 billion smartphones sold worldwide; that means approximately 20 per cent of the world population got a new smartphone that year (Statista, 2019a).

Today's smartphones can meet people's entertainment needs: calling other people, taking pictures and

Table 3. Changing trends of consumer electronics ownership among households in the UK

Type of device	2008	2018	Type of device	2008	2018
Digital TV	84%	95%	DAB radio	27%	64%
Smartphone	17%	78%	Smart TV (2012)	5%	42%
DVD player	83%	64%	Desktop PC	69%	28%
Laptop (2009)	44%	63%	MP3 player	44%	27%
Tablet (2011)	2%	58%	Smart speaker	no data	13%
Digital video recorder (DVR)	20%	56%	VR headset	no data	5%
Game console	46%	44%			

Source: OfCom, 2018b

videos, reading news and books, searching for information, sharing content, downloading and watching videos, listening to music. A smartphone can function as a pocket camera and recording machine. They have many other functions and replace a long list of different things, including timers and alarms, landline phones and telephone boxes, photo albums, calendars, phonebooks, timepieces, calculators, torches, compasses, maps, GPS devices, notepads, mirrors and music players. They can also function as a newspaper, a small TV, a handheld games console and a small laptop. Moreover, mobile phones can be used to make payments, replacing the functions of credit cards and wallets.

ICT technology progress also ushered in the era of e-commerce. People's online time is not only for entertainment, but also for shopping, education, information and social connections. With net banking and mobile pay, people can pay bills and order almost everything online. Businesses are also going online for advertising, marketing, sales, and services.

HDTVs, PCs, mobile phones and tablets can be used for both work and entertainment. For example, in many workplaces, HDTVs are used for video conferences and as projectors. The PC is more a tool for work, while HDTVs, mobile phones and tablets are mainly for individual uses and entertainment.

The last decade witnessed a big change in household consumer electronics toward smart and digital electronics. A report by OfCom in 2018 offered a clear illustration of the increased penetration of consumer products among households in the UK (OfCom, 2018b), see Table 3. Smartphone ownership growth saw the biggest increase, followed by tablets, smart TVs and DAB radio. At the same time, the ownerships of some traditional consumer electronics – like DVD players, game consoles, desktop PCs and MP3 players – declined in the decade from 2008 to 2018.

One example is the development of the built-in digital cameras of smart mobile phones. As smartphones are small and carried around most of the time, the built-in digital camera and ubiquitous Internet access enables consumers to take photos, record videos and share them with others. The first mobile phone with a built-in digital camera was sold in 2000 in Japan and Korea. Since then, the digital camera has undergone tremendous development.

Globally, digital camera sales by main producers peaked in 2010, at 121.4 million. They fell 84 per cent to 12.4 million in 2018 (CIPA, 2019)[1].

Apple and Samsung are leading companies in smartphone technology progress. The evolution of iPhones is a good indicator of smartphone technology progresses. Since it released iPhone 1 in June 2007, Apple has launched a new generation of iPhone each year. The iPhone 1 had a storage capacity of 4 GB, a camera of 2.0 megapixels (MP), and a memory of 128 MB. The iPhone XS released in 2018 is equipped with 64 GB storage, 12 MB + 12 MP dual camera, up to 512 GB internal memory and storage capacity. In 11 years, smartphones had experienced many technol-

[1] CIPA (Camera & Image Product Association) is an international industry association. Its members include such main camera producers as Olympus, Casio, Canon, Kodak, Sony and Nikon.

ogy breakthroughs, including touch screens, faster and more powerful data processing, and many new functions.

By the end of 2018, 1.5 billion iPhones had been sold, making Apple one of the most valuable companies in the world and iPhones one of the most used smartphones in the world (Statista, 2019).

2.2 Progress in communication technologies

Another group of technologies behind consumer electronics' wide application is progress in telecommunications technology. Since 1G in the 1980s, telecommunication technologies have passed 2G, 3G, and 4G. 5G is being rolled out. The progress enabled faster and more convenient data exchange. A comparison of the different generation of communication technologies is provided in Table 4.

Moore's Law is the observation that the number of transistors on integrated circuits doubles approximately every two years. It describes the exponential technological progress and computational power in terms of operations that can be performed per second by computers. The power and speed of computers have been increasing exponentially; the doubling time of computational capacity and memory for personal computers was 1.5 years between 1975 to 2009 (Roser & Ritchie, 2019).

Another indicator is the constant decrease in the price of consumer electronics and other ICT products. From 1997 to 2017, the price index of TV sets declined by 96 per cent in the US, that of software declined by 67 per cent. The price of new cars remained roughly the same over the same period (Roser & Ritchie, 2019).

ICT technology progress and the quick decrease in prices, as well as ICT companies offering free cloud storage for consumers in exchange of their attention, mean that people are only a few clicks away from the ocean of free and downloadable documents, books, audio and videos. As a result, most people accumulate a large number of documents on their computers; share documents, pictures, videos and audios through emails and social accounts; and rarely take time to delete or clean up the huge amount of information they harnessed. As a result, the data in mobile phones, gadgets, personal computers, servers and data centres keep growing. The exponential expansion of knowledge and information provides many options and new sources of information.

Table 4. The main differences between 1G to 5G telecommunication technologies

Generation	1G	2G	3G	4G	5G
Approximate deployment date	1980s	1990s	2000s	2010s	2020s
Primary service	Analogue phone calls	Digital phone calls and messaging	Phone calls, messaging, data	All IP services (including voice, messaging)	Dynamic information access, wearable devices with AI capabilities
Key differentiator	Mobility	Secure, mass adoption	Better Internet experience	Faster broadband Internet and low, lower latency	SSimultaneous access to different wireless technologies – complete wireless communication
Weakness (addressed by subsequent generation)	Poor spectral efficiency, major security issues	Limited data rates – difficult to support demand for Internet/email	Real performance failed to match the hype, failure of WAP for Internet access	Due to speeds, bandwidth, and latency constraints, capacity unable to accommodate "Internet of things"	High-band spectrum may lead to some reliability issue
Theoretical download speed	2kbit/s	384kbit/s	56Mbit/s	1Gbit/s	10Gbit/s
Latency	N/A	629ms	212ms	60-98ms	<1ms

Source: ITU, 2018; Sood and Garg, 2014.

3. Rocketing Internet use via consumer electronics and the trends in developing countries

The price of smart mobile phones are steadily declining due to lower costs of production and manufacturing, while the capabilities of mobile phones increase. Other factors contributing to the dramatic increase of people's time online includes continuously cheaper and faster and widely available Internet access, through Wi-Fi and LANs, and mobile data packages. Often such access is based on subscription, making the marginal cost of Internet use close to zero.

3.1 What people do with their time online

Consumer electronics are changing people's lifestyles. Users spend nearly 70 per cent of their media time on smartphones on average (Statista, 2019b). People spend hours every day on their phones to check and update their social media account, read news, search for information, play games and watch videos. Among the global Internet traffic, in 2018, 51% of the global Internet traffic is from smartphones, TVs, tablets, and PCs (Cisco, 2020), meaning that more than half of global energy use by the ICT sector can also be attributed to the use of consumer electronics.

Watching movies/videos online is the most popular mobile Internet activity. In 2018, 52.2 per cent of all website traffic worldwide was generated through mobile phones. The second most popular Internet activity among mobile users was checking emails while using social media came third (Statista, 2019b). The same survey found that daily social media usage in 2018 amounted to 136 minutes per day, up from 135 the previous year (Statista, 2019b). The global penetration rate of social media is 37 per cent and the most popular social media platforms include Facebook, WeChat, Twitter, Instagram, Tumblr and Sina Weibo. Around 70 per cent of social media time is spent on smartphones (Statista, 2019b).

Data about the time people spend on the Internet are based on household and individual surveys. Different sources may provide different data. For example, Kanter IMRB, based on random sampling and face-to-face interviews of more than 80,000 rural and urban households, estimated that on average Internet users in India spend 77 to 78 minutes per day online (Bhattacharjee & Pansari, 2019). This is less than the World Web Index's estimate, which is that in India Internet users on average spend 2 hours 32 minutes on social media (see Table 5) (Global WebIndex, 2019).

According to the Global WebIndex survey conducted in the 2nd and 3rd quarters of 2018, the average duration of both time online and time on social media,

Table 5. Social media time spent by Internet users among main regions

Region	Europe	North America	South America	Africa and the Middle East	Asia and the Pacific	Global average
Average daily time spending on social media (in hour: minutes)	1:53	2:06	3:29	3:19	2:16	2:22

Source: Global WebIndex, 2019

Table 6. Average daily time spending on social media by Internet users

Year	2012	2013	2014	2015	2016	2017	2018
Duration (hour:min)	1:30	01:35	01:41	01:49	02:06	02:15	02:22

Source: Global WebIndex, 2019

Table 7. Duration of daily time spent on social media by Internet users of different age groups

Age groups (years)	16-24	25-34	35-44	45-54	66-64
Duration (hour:min.)	03:01	02:37	02:04	01:39	01:13

Source: Global WebIndex, 2019

for users aged between 16 and 64 years old, is much higher in developing countries than in the developed world.

The series of Internet user surveys conducted by the Global Webindex on Internet users indicate that the time an average Internet user spends on social media has been continually increasing during the past few years, from 1 hour 30 minutes per day in 2012 to 2 hours 22 minutes in 2018, an increase of 36 per cent (See Table 6).

Apart from surfing the Internet for information, news, entertainment and social connections, people also use their Internet for work and education. Online payment and e-commerce mean people can order food, buy and sell various things, or attend courses online.

In 2018, 52.2 per cent of all website traffic worldwide was generated through mobile phones; in 2009, the share was only 0.7 per cent (Statista, 2019c). Britons are now so addicted to their phones that they check them every 12 minutes. The report, "A decade of Digital Dependency", says that 40 per cent of adults look at their phone within five minutes of waking up, rising to 65 per cent of those aged under 35 (OfCom, 2018a).

15 years of annual surveys on Internet use in the United States indicated that in 2016 the average duration of Internet use among Americans of 12 years old and above reached a new high of 23.6 hours per week, or 3 hours 42 minutes per day online (see Table 7) (Center for the Digital Future, 2017).

Even after excluding the online time at work, the average American spends 2 hours 31 minutes a day online at home. This was more than double the 9.4 hours reported in 2000, when Internet use was already widespread in the US. Moreover, 82 per cent of users go online on a mobile phone (see Table 8).

Table 8. Internet use among Americans of 12 years old or above, 2016

Indicator	Quantity
Percentage of American Internet users	92%
Average hours per week online	23.6
Average hours per week online at home	17.6
Internet users who go online on a mobile phone	82%
Hours online at work (weekly)	14.3
Hours actively using the Internet at work (weekly)	10.1

Source: Center for the Digital Future, 2017

3.2 Future trends

The sea of information and applications online is increasing every day, and will continue. As indicated in Table 9, Cisco projected that Internet users would increase from 3.4 billion to 4.6 billion during the five years from 2017, and the number of devices and connections, and broadband speed, will experience even faster growth. Moreover, people will spend a higher proportion of their online time watching videos.

Table 9. Future trends of global Internet growth

	2017	2022
Internet users	3.4 billion	4.6 billion
Devices and connections	18 billion	28.5 billion
Broadband speed	39.0 Mbps	75.4 Mbps
Video viewing	75% of traffic	82% of traffic

Source: Cisco, 2018

Table 10. Global IP traffic by devices, 2017-2022

	2017	2022
Smartphones	18%	44%
TVs	32%	24%
PCs	41%	19%
M2M (Machine to machine)	3%	6%
Tablets	5%	6%
Non-smartphones	0.1%	0.1%
Other	0.01%	0.02%

Source: CISCO, 2018

As indicated in Table 10, in 2017 people mainly accessed the Internet via PCs, TVs, smartphones, and tablets. By 2022, the smartphone will become the most important Internet access device, followed by TVs and PCs. At the same time, with the spreading of the Internet of Things, the share of M2M (machine-to-machine) data traffic will double, reaching 6 per cent of total Internet traffic.

4. The energy and environmental impacts of consumer electronics use and policy recommendations for developing countries

Apart from entertainment, consumer electronics can be used for many other functions, including learning, communication, home offices and business. There is no doubt about the huge benefits they bring, yet they can also cause negative impacts and even dangers. It is necessary to use government policies to help people benefit from the penetration and usage of consumer electronics and control the negative impacts.

4.1 The positive and negative social impacts of consumer electronics

The social impacts of consumer electronics include helping people to access knowledge and information and enable people to collaborate across the globe. For instance, it enables remote learning and meetings and the rapid sharing of ideas, enhances the success rate of new products, shortens time-to-market, ensures compliance and minimizes costs. Therefore, access to consumer electronics and the Internet can help narrow social gaps and reduce poverty.

First, it is necessary to control screen time among young people and children. The processing capacity of the conscious mind is estimated at 120 bytes per second. This sets the speed limit for the information flow that one can pay conscious attention to at any time. People can at most do two things at the same time; information overload and constant distraction cause stress and frustration (Levitin, 2014).

People only have 24 hours a day. Apart from sleeping, their daily work, meals, commuting and doing chores, an ordinary person only has a few hours of free time. High screen time can cause health and mental problems among people, especially among children and young people. The time spent online eats into the valuable time people need to relax, enjoy the company of their family and friends, or do sports. Based on a systematic review of reviews, Stiglic and Viner (2019) found that higher levels of screen time are associated with a variety of health harms for children and young people, with evidence strongest for adiposity, unhealthy diet, depressive symptoms and quality of life. Zhao et al. (2018) studied a sample of over 20,000 preschool children in Shanghai and found the existence of excessive screen time during early childhood exists in Shanghai preschool children. Their study indicates that excessive screen exposure was associated with poor psychosocial well-being in preschool children via a number of mediators, mostly by reducing parent-child interaction.

Ofcom's survey indicated that the Britons are so addicted to their smartphones that they check it them every 12 minutes; young people between 15 and 24 years old check their phones every 8.6 minutes, more frequently than any other age group (OfCom, 2018). OfCom's report illustrated the far-reaching influences of the era of digitalization and consumer electronics usage on people's lives (Hymas, 2018).

Governments and education authorities are already taking actions to reduce screen time among children and young people. The examples of existing policies and measures include controlling screen time among children and young people at kindergartens and schools, limiting the airing hours of childrens' TV channels, restricting the hours each day when online platforms can provide young players access to online games, and raising public awareness about the health and psychological impacts.

The Internet offers a wealth of opportunities, but it also brings dangers. The most common Internet security issues users may face include hackers,

viruses, spyware, phishing, spamming, and identity theft. There are various software options and techniques, as well as services provided by different companies, to address the security threats.

The government needs to make people aware of the security threats they can face online through awareness-raising and hold major online platforms accountable for the economic losses and harmful contents that they host. The government can improve Internet security through legislation and the enactment of various requirements and rules.

Another issue is about the contents people put online. Since CERN made the World Wide Web ("www" for short) technology available on a royalty-free basis to the public domain, the web has been flourishing. According to Internet Live Stats (2019), in 2019 there were around 1.7 billion websites on the web, of which only 200 million are active. In other words, 88 per cent of the websites are not active.

In the age of digitalization and social media, people save a lot of contents online and share documents, photos, audio and videos. With technological progress, the size of data and information shared and stored online has been growing exponentially. Social media and portal site companies get their revenues from selling advertisement space on their websites. To attract users, they often offer free email boxes, online space, and even cloud saving space to individual consumers free of charge. The sufficiency of free online space offers consumers no incentive to delete useless emails in their email boxes, their posts and the documents they shared. At the same time, popular platforms like YouTube and Facebook do not delete videos and pictures uploaded by their users. The information is stored in the servers in data centres. Around 54 per cent of emails sent every day are unsolicited spam mails, such as advertisements, scams, hoax virus warnings and hoax charity appeals (Statista, 2020).

A large share of the huge amount of information put online and shared on social media platforms every day is fake news and false information. The Council of Europe (2017) divided the issue of online information disorder into three types: disinformation, misinformation, and mal-information. Disinformation is false information deliberately created to harm a person, social group, organization or country. Misinformation is information that is false but not created with the intention of causing harm. Mal-information is genuine information shared to cause harm. Kumar & Shah (2018) divided false information into two broad categories based on knowledge: opinion-based fake information (e.g. fake reviews) and fact-based information (e.g. false news and hoaxes).

Experts are evenly split on whether false and misleading narratives online will decline in the coming decade. Some believe the situation will improve because of technological fixes and societal solutions. Others think the dark side of human nature will dominate, and the situation will become worse (Pew Research Center, 2017).

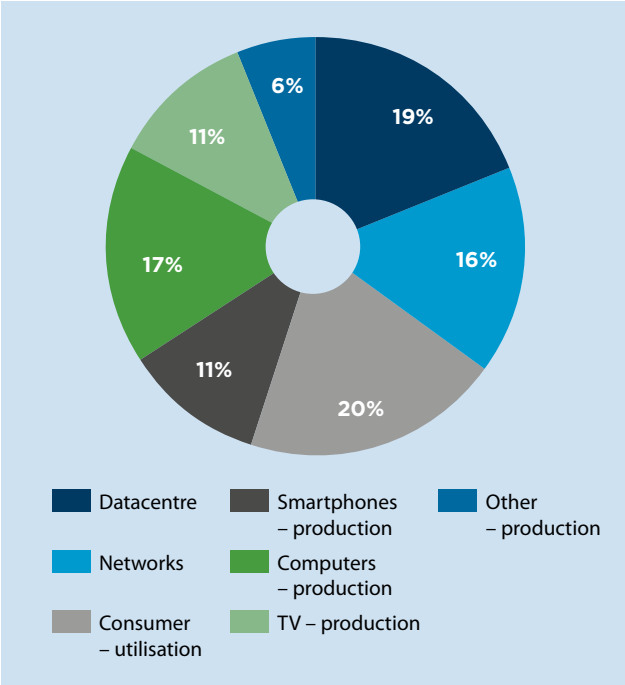
There are already laws and international collaborations to tackle online criminal activities and hold online platforms and social media companies responsible for the content they publish. The EU published the General Data Protection Regulation (GDPR) in 2016 to protect online data privacy.

Governments from different countries need to cooperate in the governance of the Internet: to clean up the online space by deleting dormant and out-of-date information, requesting information creators and platform owners to delete misinformation and false information, and setting duration limits on the information people put online. In this way, they can reduce harmful, false and repetitive information online, hence reducing the data stored at data centres and the energy and resource use to keep such information readily accessible (Council of Europe, 2017).

4.2 The energy and carbon footprint of consumer electronics usage

Increasing ownership and use of consumer electronics lead to higher household energy consumption. Usually, the Internet involves two-way data traffic – requests to the server for the webpage, document, audio and video, and the sending of the file, webpage, or document to the Internet user. The whole process involves electricity use at the consumer's electronic

Figure 1. Digital energy consumption, 2017



Source: The Shift Project, 2019

product, the cables and connections, and the data centres where the data is stored.

Electricity usage from ICT can be divided into four principal categories (Andrae & Edler, 2015):

- consumer devices, including personal computers, mobile phones, TVs and home entertainment systems;
- network infrastructure;
- data centre computation and storage;
- production of the above categories.

Figure 1. shows the energy consumption by the global digital sector in 2017. It can be seen that compared with the energy consumption by consumers only accounted for 20% of the total, another 35% was for data centres and networks, while the production of various digital products contributed 45% of the total energy footprint of the digital sector.

Despite constant technology progress and improvement in energy efficiency, the rapid growth of consumer electronics and online data traffic more than offset the gains from energy efficiency improvement. As a result, it is projected that the electricity use of ICT will continue to grow. In 2017, ICT consumed around 2000 TWh of power, or roughly 10 per cent of global electricity demand. By 2030, the ICT share in global electricity consumption is predicted to be between 8 and 21 per cent, depending on whether the ICT sector continues on its current development path, pursues a highly sustainable development path, or follows a worst-case path (Andrae & Edler, 2015).

As indicated in Table 11, data traffic has increased one billion times in the past three decades. Data centres, are energy-intensive not only to provide power for the servers but also to keep the temperature relatively low so that the computers and services can function properly.

Data centres worldwide consumed around 194 terawatt-hours (TWh) of electricity in 2014 and contributed about 1 per cent of total global demand (IEA, 2017). Data networks, which form the backbone of the digital world, consumed around 185 TWh globally in 2015, or another 1 per cent of total demand, while mobile networks accounted for around two-thirds of the total (IEA, 2017). Due to improvements in Internet data-transfer efficiency, energy use for those tasks has declined rapidly, halving every two or so years, although it remains significant (Aslan et al., 2017). A meta-analysis of the energy use associated with data transfer across the Internet – from the point at which the data leaves the data centre to where it reaches the user – estimated this energy use at 0.027 kWh/GB (Aslan et al., 2017).

Gaming is responsible for more than one-third of all digital media consumption in the US. For televisions or displays in general, increases in screen size, res-

Table 11. The Exponential Growth of Internet Data Traffic

Year	1987	1997	2007	2017
Traffic to & from data centres	2TB	60 PB	50 EB	1.1 ZB
Note:	TB, terabyte, 10^{12} bytes	PB, petabyte, 10^{15} bytes	EB, Exabyte, 10^{18} bytes	ZB, zettabyte, 10^{21} bytes

Source: IEA, 2017

olution and picture quality counteract the effect of energy savings (Lane et al., 2019).

In such situations, the government need to establish minimum energy performance standards for all consumer electronics, telecommunication infrastructure and data centres. Due to rapid technological progress and a large variety of consumer electronics products, only a small proportion of products are covered by energy efficiency standards and labels. For example, the EU's energy labelling requirements cover televisions, but other consumer electronics – like personal computers, tablets and mobile phones – are not on the list of the European Product Database for Energy Labelling (EPREL). Standby power use is another aspect that affects the energy use of a product.

Minimum energy performance standards and labelling, energy auditing and management for data centres and telecommunications infrastructure, as well as top-runner programmes to encourage technology innovation, are important to reduce the energy footprint from consumer electronics use.

4.3 Energy saving based on smart technologies

Home automation allows homeowners to control their appliances through smartphone apps, creating many new ways to save energy and adjust the time of energy consumption. People can use smartphones to schedule when appliances turn on and off and reduce the energy waste from forgetting to turn appliances off when they are not in use. They can choose to turn on dishwashers, washing machines and clothes dryers during off-peak hour, when renewable energy is sufficient and electricity is cheap. Smartphones make it possible for people to work from home, and video conferences can save time and energy use for transport.

Governments in many countries are building smart cities, providing government services online, and tapping into the potential of smart technologies and consumer electronics to support energy-saving and green development.

4.4 The challenge of growing electronic waste – status, trends, and policy recommendations

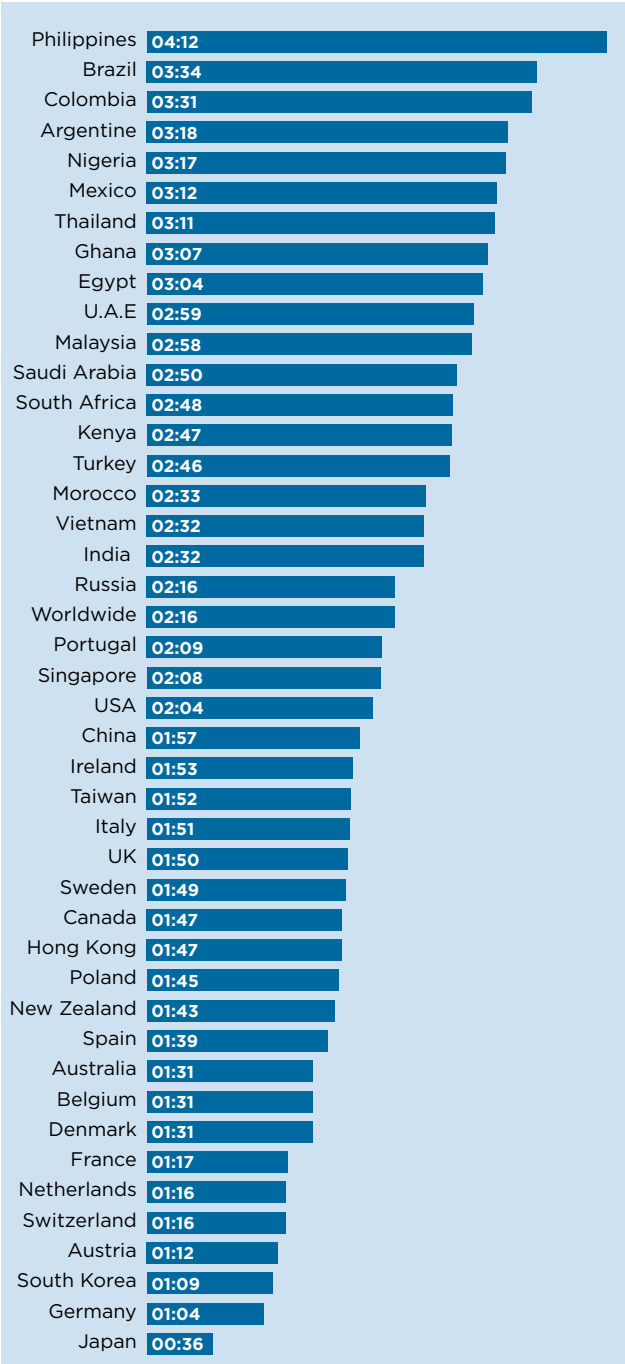
E-waste is the shortened form of the term electronic waste and is the waste material generated from electronic products. It refers to electrical or electronic materials that are unwanted, discarded, obsolete or broken. Some of the sources of this category of waste include radio and television sets, computers, monitors, all types of phones, fax machines and copiers, personal digital assistants and electronics from industrial sources (Onyeje, 2009).

After consumer electronics are damaged, out of order, or replaced with new ones with better performance and new functions, they either end up in corners of collecting dust or being recycled, landfilled or incinerated. Developed countries generally have systems for e-waste collection. With their strict environmental regulations and high labour costs, they often donate or sell their e-waste as used products or export them as waste to developing countries for processing. For over two and a half decades, more than half of global trash export has been sent to China for processing and recycling. This changed when several Chinese ministries enacted a ban on trash import, by including waste paper, plastics, as well as electrical and electronic waste in the catalogue of products subject to import ban from 1 January 2018 (MEE et al., 2017). The ban is due to environmental and health concerns and efforts to increase domestic waste sorting and recycling. This regulation changes the global flow of e-waste trade, and developed countries are trying to find a new market for their waste.

E-waste is recycled because they contain a long list of usable materials and components, such as plastics, iron and steel, glass, copper, silver and gold. When they are disassembled, the materials can be recycled for different uses. Compared with producing new materials, it is often cheaper to obtain materials from recycling. That's why enterprises in developing countries find it an attractive business to import and process e-waste. However, the e-waste also contains some toxic and polluting elements such as mercury, lead, cadmium, beryllium, or brominated flame retardants. Recycling and disposal of e-waste, espe-

cially in the absence of proper equipment and personal protection, may involve significant risks to the health of the workers and communities. Therefore, it is important to take measures to avoid unsafe exposure in recycling operations and leakage of materials such as mercury and heavy metals into the waste system and land. Electronic items that are considered to be hazardous include: televisions and computer monitors that contain cathode ray tubes, LCD desktop monitors, LCD televisions, plasma televisions and portable DVD players with LCD screens.

Figure 2. Internet users' daily time spent on social media in different countries



Source: Global WebIndex, 2019

An estimated 60-90 per cent of e-waste is illegally traded or dumped, according to UNEP's "Waste Crimes, Waste Risks: Gaps and Challenges in the Waste Sector", published in 2015. The global volume of e-waste created each year is growing at an average speed of 3-4 per cent per year (Kumar et al., 2017). Currently, the majority of e-waste is produced by developed countries, and developed countries are addressing the issue through systematic collection, but the rate of e-waste growth in some developing countries is alarming. For example, e-waste in India has been growing at 25 per cent per year in recent years (Garlapati, 2016). On top of that, developing countries face the additional challenge of e-waste export from developed countries (Park et al., 2017). E-waste contains a wide range of materials; they can generally be classified into substances found in large quantities, substances found in small quantities, and elements found in trace amounts.

Existing international initiatives on e-waste stretch from policy development, statistical work and training to designing out hazardous elements from products (UN Environment Management Group, 2018). Developing countries need to establish environmental and health rules and regulations on e-waste disposal and processing to promote clean processing and address leakages and pollution in the e-waste treatment process. Meanwhile, it is also important to require consumer electronics manufacturers to consider product recycling and disposal in the product design stage and provide technical support to the disposal and recycling of their products at the end of their useful life.

4.5 The situation in developing countries and policy recommendations

The situation in developing countries includes a rapid increase in ownership and use of consumer electronics, less strict regulations and standards on energy efficiency, incomplete e-waste sorting and recycling systems, and poor coverage and enforce-

ment of environmental and health rules regarding e-waste disposal.

Figure 2 is the result of a survey on people's daily time spent on social media in different countries. It is noteworthy that, generally, people in developing countries spend a longer time on social media than people in developed countries. One possible explanation could be that people in developing countries generally have longer working hours, fewer options of outdoor activities, low-cost of using the Internet on smartphones, as well as the wide availability of Internet connections. When people cannot find time to meet their friends, and when family members are not living together, or when people lack a sense of security in cities after dark, they are more likely to resort to social media for keeping in touch with friends and families. Another factor is that young people tend to spend more time on social media and online than older people. The lower average age and higher proportions younger people could be another reason for the higher social media use in developing countries.

4.5.1 Ownership and use of consumer electronics

In developing countries, ownerships of consumer electronics is growing fast, especially among young people and expanding middle classes. Consumer electronics' rapid technology progress leads to constant price declines, making it more affordable to own and use consumer electronics.

The government can play an important role through consumer information and awareness-raising, as well as establishing rules and regulations to promote the benefits of the Internet while restricting the harm it can cause. For example, they can learn from the experiences of developed countries, clean up the Internet, and raise awareness about the energy footprint and potential risks of people's online activities.

4.5.2 Energy use and energy performance of consumer electronics

Around the world, only a small number of countries have energy efficiency standards and labelling systems for consumer electronics. Rapid technological progress, a great variety of products, and constant market entry of new products make any energy efficiency standard quickly out of date.

More importantly, consumer electronics products and information technology can also help save energy. For example, video conferences and joint work online can help avoid business trips; smart sensors and programming capacity can help avoid energy waste.

In recognition of the huge energy use by data centres, developed countries have established rules and standards on the energy performance of data centres. However, most developing countries do not have them yet.

To promote energy efficiency, governments need to take a long list of actions, including awareness-raising through standards and labelling, educating and training professionals and technicians, public procurement, and providing economic incentives for enterprises and the general public to opt for energy-efficient products.

4.5.3 Dumping sites of e-waste

Lower-income levels mean that a higher proportion of consumer electronics are on the lower price end in developing countries. They are also the destinations of used consumer electronics and e-waste from developing countries due to their less strict environmental rules, and lower labour cost for e-waste processing. However, as evidence shows, primitive processing of e-waste can cause serious environmental and health problems to the workers and local communities, due to the leakage of heavy metals and the landfilling and incineration of components that are of low commercial value. Governments need to establish rules and promote good practices for e-waste recycling and processing.

5. Conclusions

In the last three decades, tremendous technological progress has led to major changes to the ownership and use of consumer electronics in all countries and regions. Today, more than half of the world's population are regular Internet users. This makes the Internet a powerful tool in shaping people's knowledge and views. Going back 20 years, few people could have imagined having a multipurpose device so small in your pocket. The smartphone is the Swiss army knife of the 21st century.

While enjoying the benefits of technological progress, a few side effects from consumer electronics utilization need to be tackled. This includes improving Internet security and fighting against criminal activities online, through spreading malware and spyware, scams, false information and misinformation. Another issue is the health impact of information overload and Internet addiction. Many people spend hours every day surfing the Internet, watching videos, playing games and communicating with others on social media platforms. Online time is the longest among young people. This can cause distractions, stress and reduction in time with family, face-to-face meeting with friends, and work and education.

Another issue is the energy use from people's online time. This includes not only household energy use, but the energy use by the cables, routers, switches and data centres. Internet use is expected to further increase, both among the people and the Internet of Things. In such situations, countries, especially developing ones, need to speed up their effort to promote the energy efficiency of consumer electronics, Internet infrastructure, and data centres.

Finally, most consumer electronics are designed for a short life of only a few years. Rapid technological progresses, the constant introduction of newer products with better and faster functions, and continuous cost reduction in consumer electronics and Internet access means many consumer electronics are dumped even before the end of their useful life. Globally, total e-waste reached 46 million tonnes in 2017. A large share of the e-waste from developed countries is shipped to developing countries for processing and recycling. E-waste contains many recyclable and valuable components, making its processing a profitable business for some countries and regions. However, e-waste also contain some hazardous components and parts that are low value. The leakage of heavy metals and incineration and landfill of e-waste can cause serious environmental and health problems to workers and local communities. Countries need to collaborate to tackle these environmental and social problems from the information age through awareness-raising, legislation, policies and regulations.

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