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Greening Digital in Korea

Korea Case Study for Greening the ICT Sector

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Executive Summary

Digital technologies are making a significant impact on societies, economies, and the physical world, presenting both opportunities and challenges for the green agenda. Applications of these technologies in sectors such as energy, urban, transport, and agriculture are creating new possibilities for climate change mitigation strategies. However, the rapid expansion of digital technologies increases energy usage too, and is therefore also increasing greenhouse gas (GHG) emissions.

In seeking to address these challenges, the World Bank's Digital Development Global Practice (DD) will publish a flagship report on Digital Development Opportunities for Climate Change, which will assess opportunities for greening with information communication technology (ICT), as well as opportunities for greening the ICT sector itself. To inspire and inform this flagship report, DD studied Korea's experience in greening its ICT sector, with support from the Korean Green Growth Trust Fund.

The Republic of Korea was selected for the case study due to its experience in both the digital and green sectors, and its status as a globally recognized ICT powerhouse. The country was also an early adopter of a green policy agenda, and is integrating DNA (data, network, and AI) into these policies. The government announced a national policy vision of "Low Carbon, Green Growth" in 2008 and has taken concrete steps to build a solid foundation for the green transition, through legislation, standardization, information-based instruments, economic instruments, research and development (R&D), and green procurement. More recently, the country has been aligning its green ICT strategy with the broader national GHG reduction target.

Korea's experience can offer meaningful lessons to other countries looking to reduce the ICT sector's climate impact. It shows that public policies have an important impact on the ICT market. The policy tools that can spur decarbonization of the ICT sector include green government procurement, information-based instruments, economic instruments, and provision of guidelines on green business practices. Keys to success in applying such tools include strong and early political commitment; long-term planning and comprehensive policies; prioritization; research and development (R&D) and investment; and a governance structure that allows a whole-of-government approach. Additionally, Korea's experience shows that renewable energy will play an increasingly important role in reducing GHG emissions from the energy-intensive ICT industry.

Korea's experience also underscores the fact that more evidence and analysis are needed to measure and determine the effectiveness of policy and regulatory pathways for greening the ICT sector.

PART I: Context and Conceptual Framework

Introduction

Digital technologies are making a significant impact on societies, economies, and the physical world, presenting both opportunities and challenges for the green agenda. Countries around the world are bracing for the Fourth Industrial Revolution by investing in advanced information and communication technology (ICT) infrastructure and transforming industries with digital technologies. Addressing climate change is a top global priority, and digital technologies could play an important role—applications of these technologies in sectors such as energy, urban, transport, and agriculture are creating new possibilities for climate change mitigation strategies.

At the same time, digital technologies also present challenges for the green agenda. The rapid expansion of digital technologies increases energy usage, and is therefore also increasing greenhouse gas (GHG) emissions, despite the fact that this is partly offset by energy efficiency gains (International Energy Agency, Digitalization and Energy 2017). ICT's carbon footprint could account for as much as 14 percent of the world's carbon emissions by 2040 (Belkhir and Elmeligi 2018). The United Nations International Telecommunication Union (ITU) in 2020 predicted that ICT's GHG emissions will increase from 730 million metric tons of carbon dioxide equivalent(Mt CO_2-eq) in 2020 to a little more than 800 Mt CO2-eq in 2030. In order to follow the 1.5°C trajectory, per the ITU, GHG emissions from ICT should be reduced by half, and thus be limited to less than 400 Mt-CO2 equivalent in 2030. Although the differences in forecasts illustrate the difficulty of precisely projecting GHG emissions from the sector, the direct emissions of the ICT sector is still an issue of concern for many researchers and policy makers at the national and international level.

To reduce climate impact with digital technologies, developing countries need: (1) a clearer understanding of the ways in which digital technologies affect climate change (GHG emissions, mitigation, and adaptation); and (2) a more comprehensive plan for the ICT sector that incorporates each nation's climate change strategy.

To address these challenges, the World Bank's Digital Development Global Practice (DD) will publish a flagship report on Digital Development Opportunities for Climate Change, which will assess ICT greening opportunities in the urban, transport, agriculture, and energy sectors. ICT's carbon impact and the related options to reduce GHG emissions will be among the report's findings.

The Republic of Korea was selected for the case study due to its experience in both the digital and green sectors, and its status as a globally recognized ICT powerhouse (Ko, Sangwon et al 2014). Since the 2000s, Koreas has been called a digital leader by the ITU, the World Intellectual Property Organization (WIPO), and the World Economic Forum (WEF), among others.[1] It is a founding member of the Digital Nations, a network of the world's leading digital governments.

Korea was the world's 11th largest economy in 2020, with a gross domestic product (GDP) of US$1.630 trillion.[2] It is home to global electronics and ICT companies such as Samsung Electronics, LG, SK Telecom, SK Hynix, KT, Naver, and Kakao. Korea is also the world's leading memory chip producer, with the second largest share of revenue (19 percent) in the global semiconductor industry as of 2019 (Deloitte 2020). Since 2017, when the government started shaping the Fourth Industrial Revolution Strategies, Korea has sought to integrate DNA (data, network, and AI) to enhance industry competitiveness, the labor market, and the daily lives of its citizens.[3]

At the same time, Korea is one of the world's biggest GHG emitters. In 2018, the country emitted about 727.6 million metric tons of carbon dioxide equivalent (CO_2-eq).[4] In that same year, Korea ranked 17th in the world In terms of metric tons of CO_2 emissions per capita (12.2), well ahead of Japan (27th, with 8.7), Germany (28th, with 8.6), and China (38th, with 7.4).[5] Furthermore, other than during its 1998 economic

1 No. 2 in the ITU 2017 ICT Development Index; No. 2 in the UN E-Government Development Index 2020; No. 3 in the UN 2020 Global E-Government Development Index; No. 1 in human capital and research, per the WIPO 2020 Global Innovation Index; and No. 1 in ICT Adoption, per the WEF 2020 Global Competitiveness Index.
2 GDP data available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KR.
3 For example, the ICT industry is being restructured so that data are becoming the core competency of companies, which brings competitiveness to a platform or ecosystem-based business. In the labor market, automation is being introduced in various sectors and is enhancing the quality of human labor. At the same time, the rise of the sharing economy and platform-based services is disrupting the labor market with gig economy jobs and new types of employment. The advancement of digital technologies has also made citizens' daily lives more convenient (via maps that provide the fastest routes with real-time data, etc.) as well as safety (analyzing crime data to find patterns and estimate crime types, locations, and times of day they are occurring).
4 https://www.statista.com/statistics/1019810/south-korea-annual-greenhouse-gas-emissions-volume/.
5 World Bank Data. https://data.worldbank.org/indicator/EN.ATM.CO2E.PC.

crisis, the country has had the highest increase of GHG emissions among OECD member countries since 1990.[6]

Korea's energy supply still depends heavily on fossil fuel. These sources accounted for about 69 percent of Korea's electricity generation in 2019, and the share of nuclear power accounted for 25 percent. Coal-fired power, which is a baseload source, is the dominant fossil fuel used to generate electricity (40 percent); natural gas-fired power is the second-largest source (26 percent)[7]. The government has attempted to switch fuels, expand nuclear power, and increase the use of liquid natural gas (LNG) to integrate air management and energy policies. However, the Korean economy's energy intensity is still among the highest in the OECD.[8] Recognizing the urgent need for reducing the country's carbon footprint, the government announced a national policy vision of "Low Carbon, Green Growth" in 2008 and took concrete steps to build a solid ground for the green transition in the ensuing years by establishing the Presidential Commission on Green Growth (2008) and enacting the Framework Act on Low-Carbon Green Growth (2010). Addressing the ICT sector's carbon footprint was one of the priorities of the government's green transition, as illustrated by the announcement of the Green IT National Strategy (2009). Since the announcement of that strategy, the government has introduced various measures to green the ICT sector, including a green certification program (2010), standardization of green data center guidelines (2012), and a number of government-funded R&D projects for green data centers and communication network technologies.

In recent years, President Moon Jae-In's administration has demonstrated its commitment to addressing climate change through the announcement of its 2050 Carbon Neutral Strategy and the legislation of the Framework Act on Carbon Neutrality and Green Growth (or "Carbon Neutrality Act"). With its new Intended Nationally Determined Contribution (INDC), updated in 2020, Korea plans to achieve a 24.4 percent reduction in GHG emission by 2030, compared to the total national GHG emissions in 2017 (UNFCCC 2020a). In addition to setting an ambitious national GHG emissions target, Korea's 2020 NDC states that the 24.4 percent reduction target is an economy-wide absolute emissions reduction target instead of business-as-usual-based reduction target, and that mitigation measures will include banning construction of new coal-fired power plants (UNFCCC 2020a). Furthermore, in April 2021, President Moon announced that Korea will stop official financing for foreign coal power projects, effectively banning state-owned enterprises from participating in the construction and operation of coal-fired power plants abroad (Yonhap News Agency 2021). The government's carbon neutrality policy has strong public support, with 62.1 percent of adults backing the policy.[9] According to the Pew Research Center's survey (2021), 86 percent of Koreans view climate change as the top global threat, ahead of terrorism or the Democratic People's Republic of Korea. Koreans are more willing to make at least some changes to their lives to help reduce the effects of climate change (84 percent of respondents) than the people in the United States (74 percent), Japan (55 percent), France (83 percent), and Germany (79 percent).

With the ICT sector accountable for 11 percent of the country's GDP and 33 percent of total exports at the end of 2019, the greening of the ICT sector itself has become one of the key priorities in Korea's attempts to achieve carbon neutrality, as announced by the Ministry of Science and ICT's Carbon Neutral Tech Innovation Strategy (2021).

ICT Sector Definition

There is no single, universal definition of ICT. The World Bank (2003) defines ICT as consisting of hardware, software, networks, and media for the collection, storage, processing, transmission, and presentation of information (voice, data, text and images), which remains a flexible definition that can be adjusted depending on the context (World Bank 2009). According to the Organisation for Economic Co-operation and Development (OECD 2002), the ICT sector encompasses manufacturing and services industries whose products primarily fulfil or enable the function of information processing and communication by electronic means, including transmission and display. Per the statistical office of the European Union (EUROSTAT), the ICT sector covers both ICT manufacturing (manufacture of electronic components, computers, communications equipment, consumer electronics, etc.) and ICT

6 https://www.oecd.org/site/envind/korea.htm.
7 US Energy Information Administration (EIA). https://www.eia.gov/international/analysis/country/KOR.
8 https://www.oecd.org/site/envind/korea.htm.
9 According to a survey done by the Asian Citizen's Center for Environment and Health. For more details, see (article in Korean): http://eco-health.org/bbs/board.php?bo_table=sub02_03&wr_id=1076.

services (software publishing, telecommunications, data processing and hosting, etc.).[10] The term ICT is thus a broad term that relates to electronic computing equipment and related activities that convert, store, protect, process, transmit, and retrieve digital information.

The direct impact of the ICT sector on climate change (i.e., greenhouse gas emissions) is driven by the energy consumption during its life cycle: production, use and end-of-life. Similarly, indirect impacts, whereby ICT enables the reduction of GHG emissions in other sectors such as transport or urban, are also an active area of research (through the effects of mitigation, adaptation and monitoring of climate change).

To estimate the ICT sector's energy consumption and GHG emissions, the World Bank's DD conducted a literature review analyzing recent estimates of the sector's direct impacts, to inform the flagship report Digital Development Opportunities for Climate Change. This identifies the three most energy consuming activities in the sector:

1. Data management infrastructure (data centers). A data center is a physical facility that any public or private organization can use to house online applications and data. Data centers host all the required digital equipment to store, share and process data and applications, such as servers, routers, switches, etc. A typical average data center is about 10,000 square meters; the world's largest data center is about 600,000 square meters (Allen 2018).[11]

2. Data transmission infrastructure (telecommunication networks). Telecommunication networks consist of many physical transmitters and receivers that send digital communications between end-users, including wireless networks (especially mobile communication networks and satellite networks) and fixed networks. At the end of 2019, mobile networks consisted of equipment placed on 4.8 million towers and rooftops around the world (Osmotherly 2019). These networks are still growing - about 250,000 new towers were erected in 2020 (Global Newswire 2021).

3. End-user devices that may rely on one or both infrastructures above. End-user devices include computers and peripherals (e.g., servers, individual computers, game consoles, laptops, and office imaging equipment); digital data recorder-storage-player devices (e.g., DVDs, hard disk drives, USB memory sticks, and MP3 devices); modems (e.g., high and low speed network interfaces); phones and multimedia devices (e.g., normal and cordless phones, mobile feature phones, smartphones, and tablets). Televisions and peripherals (e.g., STBs, antennas, and satellite dishes) and Internet of Things (IoT) devices may also be included. The boundary between ICT equipment and consumer electronics (CE) is difficult to define. For example, triple play set-top boxes (allowing internet access and telephony, as well as access to digital TV services) are at the convergence of ICT and CE and are therefore difficult to categorize.

This approach is consistent with the ICT sector definition set out by the ITU to assess the environmental impact of the ICT sector (ITU 2018).

Scope of the Case Study

This case study analyzes the policies, regulations and other measures implemented by Korea to support its ICT sector's green transition. It also identifies existing research that has been carried out in this area and draws lessons from Korea's experience. Specifically, the study analyzes the government measures to green data management infrastructure, data transmission infrastructure, and ICT devices. As one of the world's most connected countries and an early mover on the green-ICT agenda, Korea's experience and policies in greening the ICT sector can present meaningful lessons to other countries looking to adopt measures to reduce the sector's climate impact.

In terms of greening ICT devices, the study primarily focuses on the government's efforts to support the development of innovative and energy-efficient ICT devices, information-based instruments to induce green purchases by consumers, and green government procurement. Measures to reduce Scope 1 direct emissions[12] by decarbonizing the ICT manufacturing industry's processes and measures to reduce the

10 EUROSTAT, ICT Sector, statistical presentation available at: https://ec.europa.eu/eurostat/cache/metadata/en/isoc_se_esms.htm
11 Equivalent to the area of nearly 85 soccer fields.
12 "Scope 1" emissions are direct emissions from owned or controlled sources;
"Scope 2" emissions are indirect emissions from the generation of purchased energy; and
"Scope 3" emissions are all indirect emissions (not included in Scope 2) that occur in the value chain of the firm (including both upstream and downstream emissions).

environmental harm of sourcing materials for ICT devices and e-waste are beyond the scope of this case study.

This study is based on thorough desk research and literature review, a series of interviews, and materials provided by relevant ministries from April to October 2021.

PART II: Korea ICT Sector's GHG Emission Estimates

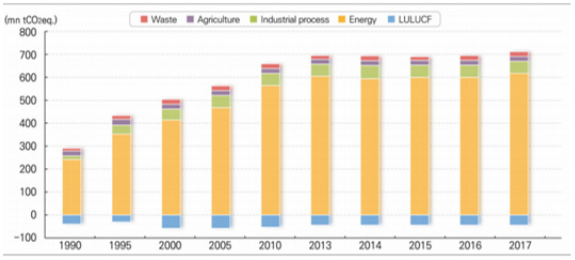
Estimates for GHG Emissions in the ICT Sector

The Greenhouse Gas Inventory and Research Center (GIR) under the Ministry of Environment (ME) publishes the National Inventory Report (NIR), with input from various sectors including waste (ME), agriculture (Ministry of Agriculture, Food and Rural Affairs; MAFRA), industrial processes (Ministry of Trade, Industry and Energy; MOTIE), transport (Ministry of Land, Infrastructure and Transport; MOLIT), fisheries (Ministry of Oceans and Fisheries; MOF), and land use and forestry (MOLIT and MAFRA).

In 2018, Korea's total GHG emissions were 727.6 million metric tons of carbon dioxide equivalent (Mt-CO2eq), up 2.5 percent from the previous year (709.7 Mt-CO2eq), and up 142.7 percent from the 1990 level (292.2 Mt-CO2eq). During the 1990s, year-on-year emissions from 1990 to 1997 grew sharply, with an average annual increase of 8.1 percent (with the exception of 1998, when GHG emissions decreased by 14.1 from the previous year in the aftermath of the 1997 Asian financial crisis). Beginning in the 2000s, GHG emissions growth slowed significantly, with steady growth since 2013 without much fluctuation (Figure 1).[13]

In 2017, Korea was estimated to be the 11th largest GHG emitter in the world. The country's emissions amounted to 5.7 percent of the emissions of China and 10.9 percent of those of the United States, the top two emitters globally. By CO_2 emissions per capita, Korea ranked 17th in the world in 2018 at 12.2 metric ton(t), well ahead of Japan (27th, 8.7 t), Germany (28th, 8.6 t), and China (38th, 7.4 t).[14]

Figure 1. Korea's national GHG emissions trends



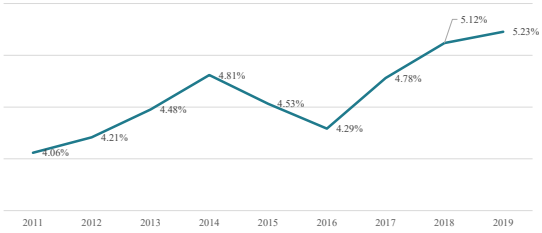
Source: Ministry of Environment

ICT sector GHG emissions are not reported separately in the GIR's NIR. However, the GHG emissions data from ME on the ICT companies[15] subject to the Emissions Trading Scheme (K-ETS) and GHG and Energy Target Management system (TMS) can be a potential data point for understanding the GHG emissions from the sector, although GHG emissions from the ICT devices' use phase are not accounted for.[16]

According to the GHG emissions data from the ICT companies subject to K-ETS and TMS, ICT companies' GHG emissions accounted for 5.23 percent of Korea's emissions in 2019,[17] while the sector's output accounted for 11.2 percent of GDP and 33 percent of total exports in the same year.[18] The Korean ICT sector's absolute contribution to the overall GHG emission is higher than the global estimates of the ICT sector's contribution to total global GHG emissions, which are estimated to range from 1.4-3.6 percent in 2020 (Malmodin and Lundén 2018) (Belkhir and Emigli 2018).

13 According to the Korean government, the slowdown of emissions is due to a series of policy measures to cut emissions that came into effect with the enforcement of the Framework Act on Low Carbon Green Growth (enacted on January 13, 2010).
14 https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?most_recent_value_desc=true.
15 ICT companies here include companies in the semiconductor, electronics, telecommunications, and display industries as classified by the Korea Standard Industry Code.
16 GHG emissions data from the companies subject to K-ETS and energy and GHG TMS available here (in Korean): https://ngms.gir.go.kr/link.do?menuNo=30130101&link=/websquare/websquare.html%3Fw2xPath%3D/cm/bbs/OGCMBBS021V.xml%26menu%3D30130101.
17 National GHG emissions include Scope 1 emissions; ICT sector GHG emissions include Scope 1 and 2 emissions. National GHG emissions data for 2019 are an estimate by the Ministry of Environment.
18 ICT sector contribution to GDP is available at: https://www.itstat.go.kr/itstat/kor/stat/StatList.html (in Korean).
The ICT sector's contribution to total exports is available at: https://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=2782.

Figure 2: ICT sector GHG emissions relative to the National GHG emissions (2011-2019)

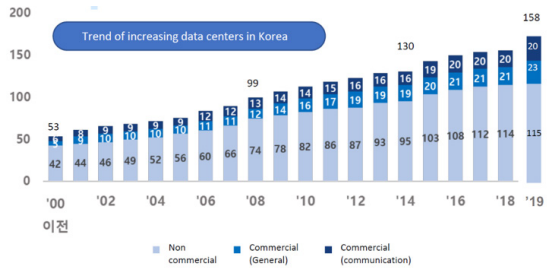


Source: WBG analysis based on the data from the Ministry of Environment.

Data Centers

With the rapid development of Korea's ICT sector, the number and power consumption of data centers have similarly increased. The number of data centers in Korea has increased steadily since 2000, reaching 158 sites in 2019 (see Figure 3). According to the Korea Data Center Council (KDCC), 24 additional private data centers will be built by 2024 (Kim 2021).

Figure 3. Data center growth trend in Korea



Source: KDCC 2020

There is limited data on data center power consumption trends in Korea. However, according to the government fact-finding survey conducted in 2020 as part of the Cloud Computing Industry Promotion Project, the annual power consumption of Korea's 58 biggest private data centers in 2019 was estimated to be 601.8 megawatts (MW) (5,272 gigawatt-hours, or gWh).[19] This accounts for 0.9 percent of annual electricity production (585,301 gWh) and 3.6 percent of service industry electricity consumption (145,816 gWh) in the same year. When converted to GHG equivalent, these data centers emitted 2.5 million tons of GHG in 2019, accounting for 0.35 percent of total national GHG emissions.[20]

MSIT estimates that data centers will consume a maximum of 1711.8 MW of power by 2024, resulting in 6.9 million tons of GHG emissions, a 126 percent increase from 2020.

The GHG emissions of a data center occur through energy consumption in two main areas: ICT hardware and cooling system. The energy consumption of hardware is directly correlated with its data processing capacity, data servers (processors consuming the largest share), data storage devices, and other network components.

The electricity consumed in data centers is converted into heat and thus cooling systems are designed for removing this generated heat. Power usage/utilization effectiveness (PUE) is the indicator commonly used to describe how efficiently a data center uses energy. PUE is the ratio of the total amount of electrical energy used by a data center to the electrical energy used purely by its IT equipment (servers, network, and storage devices). The closer the PUE value is to 1, the greater the energy efficiency of the data center.

PUE for Korean data centers (accounting both industry and public data centers) is 2.54 as of 2016 (MSIT 2018), approximately 1.6 times higher than the global average (see Table 1). Industry data centers have higher energy efficiency with lower PUE than government-owned data centers.[21] According to KDCC, the average PUE range of recently built industry data centers is 1.3 to 1.5. Naver, Korea's largest search engine company, has an average of 1.09 PUE for its data centers as of 2021.

Wireless/Wired Networks

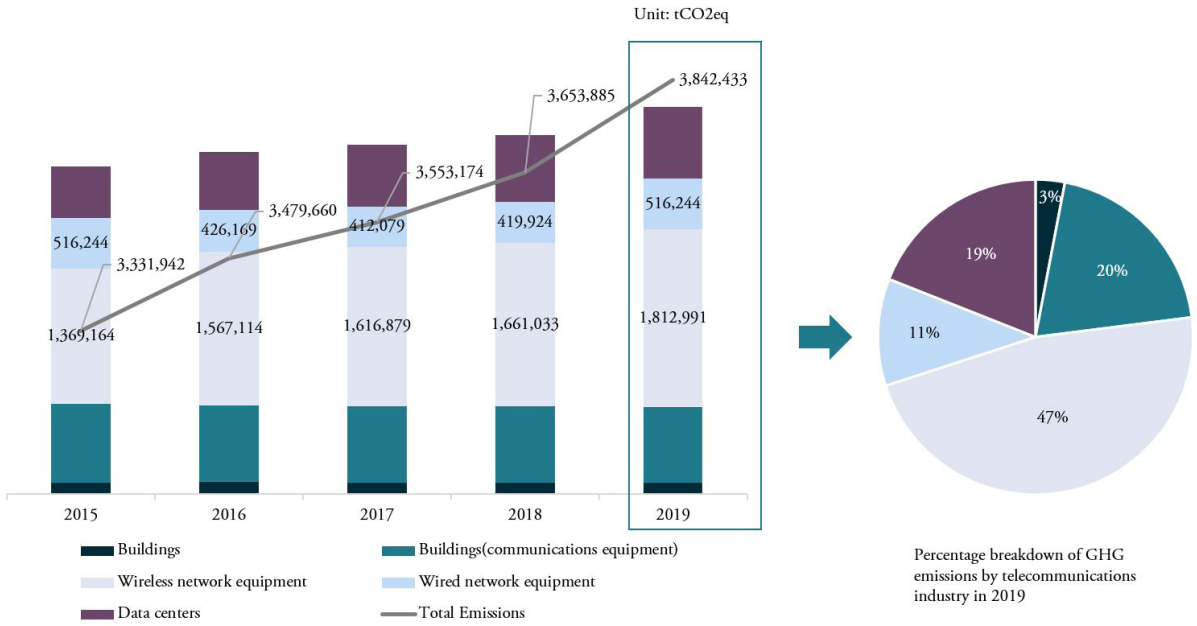
According to the telecommunications industry, GHG emissions data from telecommunications companies[22] subject to the Energy and GHG Target Management System (TMS) and Emissions Trading Scheme (K-ETS), wired/wireless network equipment accounts for 58 percent of the industry's total emissions (see Figure 4). With the launch of 5G networks in 2019, GHG emissions from wireless network equipment increased 9 percent from 2018. The telecommunications industry's GHG emissions accounted for approximately 0.5 percent of total national emissions in 2019.[23]

19 Estimates provided by MSIT.
20 Emission coefficient: 0.46625 tCO2eq/mWh.
21 According to an interview with the researcher who undertook the Korea data center PUE survey, the smaller scale of government/public data centers compared to industry data centers can be partly attributable to their higher PUE. The economies of scale offered by hyperscale data centers can increase energy efficiency. According to a study by the Lawrence Berkeley National Laboratory, it is estimated that if 80% of servers in small data centers in the United States were moved over to hyperscale facilities, this would result in a 25% drop in energy use. Additionally, the government data centers are generally equipped with older equipment as many of them were introduced earlier than industry data centers.
22 Companies must be classified as wired telecommunications (code 61210), wireless and satellite telecommunications (code 61220), telecommunications resellers (code 61291), other telecommunications (code 61299) industries by the Korean Standard Industrial Classification (KISC) and that meet the GHG emissions and energy consumption threshold set by the Ministry of Environment to be subject to K-ETS and TMS.
23 The national GHG emissions data for 2019 are an estimate by the Ministry of Environment as of September 2021.

Table 1. Global comparison of data center PUE

Country(ies), Geographical Zones	Average PUE	Year	Data Source
Korea	2.54 (Total) 1.73 (Industry) 3.89 (Government/ Public)	2016	MSIT, Korea Information Technology Service Industry Association
Global	1.58	2018	Uptime Institute *PUE for industry data centers only
Nordic countries (Denmark, Finland, Norway, Sweden)	1.71	2017	Environment Agency Austria and Borderstep Institute *PUE for industry data centers only
UK and Republic of Ireland (England, Scotland, Wales, Northern Ireland, Republic of Ireland)	1.83		
Northern/Central Europe (Austria, Belgium, France, Germany, Hungary, Luxembourg, The Netherlands, Portugal, Poland, Switzerland)	1.72		
Southern Europe/Mediterranean (Gibraltar, Greece, Italy, Malta, Spain, Turkey, Monaco, Romania, Bulgaria)	2		

Figure 4. Telecommunications industry GHG emissions trends and breakdown by emissions source



Source: MOTIE

PART III: The Evolution of Korea's Green ICT Policy

Introduction

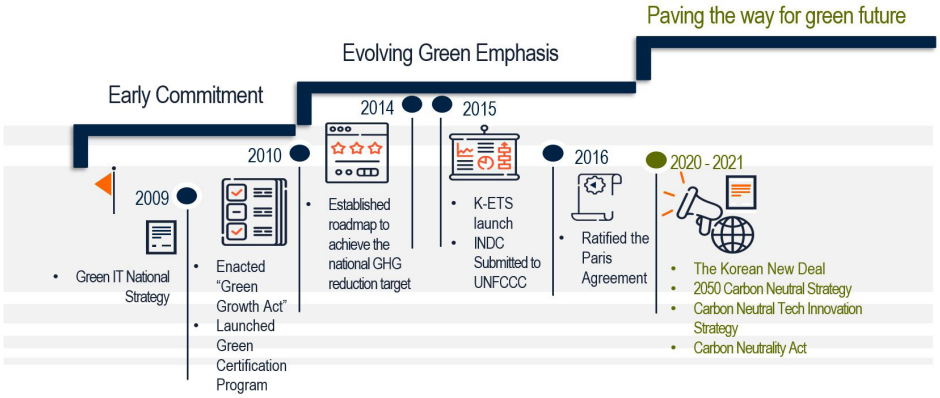
Korea's push to lay the foundation for green growth dates to the early 1990s. In 1990, the country enacted the Framework Act on Environmental Policy and embraced sustainable development as a guiding principle in its environmental law and policy. Korea adopted its Five-Year National Plan for Energy Conservation Technology Development (1992–1996), which was followed by a Ten-Year Basic Plan for New and Renewable Energy Research, Design, and Development (RD&D) (2003–2012) that focused on diversifying the nation's energy mix, establishing clean energy technology development targets, and identifying priorities for green energy research and development (R&D) (Burton 2010).

In August 2008, the government announced a new national policy of "Low Carbon, Green Growth." The initiative was intended to pursue three primary objectives: (1) promotion of "eco-friendly new growth engines" for the national economy, (2) enhancement of Korea's quality of life, and (3) contribution to international efforts to fight climate change. Korea's green growth model is characterized by its high degree of bureaucratic centralization and strong leadership that elevated green growth as a national priority (Global Green Growth Institute 2015).

The government took steps to lay the groundwork for the green transition in the following years. In February 2009, the government established the Presidential Commission on Green Growth (PCGG) and enacted the Framework Act on Low-Carbon Green Growth ("Green Growth Act") in 2010. Under the Green Growth Act, green growth is defined as "growth achieved by saving and using energy and resources efficiently to reduce climate change and damage to the environment, securing new growth engines through research and development of green technology, creating new job opportunities, and achieving harmony between the economy and environment."

In 2010, the government established the Greenhouse Gas Inventory and Research Center (GIR) in the Ministry of Environment (ME) to manage national GHG statistics efficiently. Since then, it has implemented a national-scale emissions trading system (K-ETS); and has submitted Intended Nationally Determined Contributions (INDC) and Nationally Determined Contributions (NDC), and its Long-term low greenhouse gas Emission Development Strategy (LEDS), namely, "2050 Carbon Neutral Strategy of the Republic of Korea Towards a Sustainable and Green Society," to the UNFCCC Secretariat, according to the Paris Agreement on climate change. As of August 2021, Korea is one of the nine countries to have introduced an ETS on a national scale.[24]

Figure 5. Korea's key green policy milestones



24 World Bank, "Carbon Pricing Dashboard," accessed August 26, 2021.

Table 2. Korea's green policy in recent decades

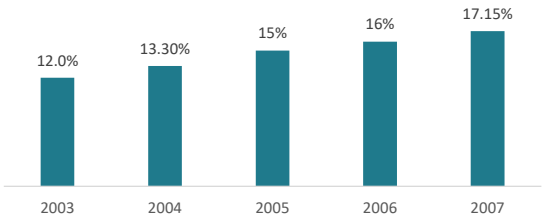
Year	Gov't Initiative	Major Projects/Goals	Budget (₩)
2006-2009	Seoul Initiative on Green Growth	• Sustainable Infrastructure forum • Green GDP, tax incentives discussion • Green growth training for developing countries (Bhutan, Vietnam) • Climate change and green growth projects	400 million/yr
2008-2013	The Green Growth National Strategy	**Goals** • Promote eco-friendly new growth engines • Enhance people's quality of life • Contribute to international efforts to fight climate change **Major Project** • The Four Major Rivers Restoration Project	50 trillion for 4 yrs
2013-2017	The Creative Economy	• More focused on ICT innovation and nurturing business/ investment/startup • Its "ICT planning" selected some green technologies as part of 120 national strategic technologies and 30 focus technologies: solar energy technology, eco-friendly cars, smart grid, carbon capture and sequestration/storage (CCS), pollutant processing technology[25]	21.5 trillion for the first 3 yrs
2020-2025	Korean New Deal	• Digital New Deal (12 projects) • Green New Deal (16 projects) • Human New Deal (11 projects)	160 trillion, 2020-2025

The Journey of Korea's Green ICT Strategy

Green IT National Strategy (2009)

After the "Low Carbon, Green Growth" vision announcement, a number of government ministries announced green ICT industrial policies in the following months: "Green IT Industry Strategy" (January 2009) by the Ministry of Knowledge Economy (MKE), "New Green ICT Korea" (January 2009) by the Ministry of the Interior and Safety (MOIS), and "Green Broadcasting and Communications Strategy" (April 2009) by the Korea Communications Commission (KCC). In the "Green IT Industry Strategy," MKE outlined as main drivers: 1) increased energy consumption in the IT industry; 2) environmental damage from e-waste, especially with increased use and disposal of devices and equipment; 3) the growth potential of the green ICT industry; and 4) increased awareness and demand for greening with ICT and of the ICT industry itself.

Figure 6. Percentage of ICT industry's energy consumption in total industrial consumption, 2003-2007



Source: MKE 2009

After a series of green ICT policy announcements by different ministries, the PCGG, nine ministries, and six government agencies jointly announced the Green IT National Strategy (May 2009), which emphasized the whole-of-government approach facilitated by cross-ministerial collaboration.[26]

The two strategic pillars of the Green IT National Strategy are: 1) greening of the IT industry itself through the green transformation of the entire cycle of IT products and services; and 2) greening by IT to maximize energy efficiency and accelerate the transition to a low-carbon society. In the greening of the IT industry itself, the government prioritized three key tasks (see Table 3).

25 https://www.hellodd.com/news/articleView.html?idxno=48693
26 Green IT National Strategy document (in Korean) available at: https://kcc.go.kr/user.do?mode=view&page=A05030000&dc=K05030000&boardId=1113&cp=336&boardSeq=25578

Table 3. Greening of IT key tasks in the Green National IT Strategy

Greening of ICT Key Tasks	Description	Carbon Footprint (2008)	Target
World's best in green IT product development and exports	The government prioritized developing three key green IT products (PCs, TV displays, servers) with high market potential. The government also committed to introducing green procurement mandate.	14.9 Mt-CO2eq annually *PCs (4.68 Mt-CO2eq), TV displays (3.35 Mt-CO2eq), servers (1.34 Mt-CO2eq)	Reduce annual energy consumption by 20% (2 Mt-CO2eq) by 2020
Greening IT services	The government targeted raising IT service energy efficiency by 40% by greening data centers, adopting cloud computing, greening broadcasting/communications network infrastructure.	Data center energy consumption is doubling every five years	40% increase in energy efficiency in IT service industry by 2020
Giga-internet network deployment to support the green transition	The government targeted building a high-speed, high-capacity network, up to 10 times faster than the existing infrastructure, to support the green transition of society. As the demand for public Internet of Things (IoT) sensors for climate data monitoring and collection rapidly increased in previous years, the government planned to utilize network base stations and repeaters to install public IoT sensors for climate data monitoring and collection.	Increased need for high-capacity, high-speed network to support remote working, real-time climate/environment/disaster monitoring.	High-speed broadband convergence network deployment and core technology development by 2013 to support remote working/healthcare/education

Korea's Green ICT Strategy Today Toward a Carbon Neutral Future

Notwithstanding the 2009 announcement of the Green IT National Strategy, the government has yet to present a cross-ministerial strategy solely focused on the greening of the ICT sector. However, the government's plan for greening ICT is manifested through the Carbon Neutral Tech Innovation Strategy (focused on R&D for greening ICT) and the Korean New Deal (through smart and green industrial projects). Plus, greening "with" ICT is a key means through which the government plans to reduce the carbon footprint of all industries, including the ICT sector.

2050 Carbon Neutral Strategy (December 2020)

In December 2020, the government announced the 2050 Carbon Neutral Strategy, the country's long-term Low GHG Emission Development Strategies (LEDS), which shared the nation's vision and plan to achieve carbon neutrality by 2050 (The Government of Republic of Korea 2020a). In 2020, Korea also submitted its updated Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat. The updated target is to reduce 24.4 percent of total national GHG emissions in 2017, 709.1 MtCO2eq, by 2030.

The primary objective of Korea's 2050 Carbon Neutral Strategy is to achieve the three goals of carbon neutrality, economic growth, and improved quality of life. The policies are focused on decarbonizing the industries while building a low-carbon industry ecosystem. The government emphasizes its plan to leverage digital technologies to power and bolster its various carbon-neutral programs and projects, as outlined in the 2050 vision (see Box 1).[27]

Box 1. Korea's 2050 vision

The Republic of Korea is moving towards the goal of carbon neutrality by 2050. The Korean New Deal will serve as a stepping stone to reach carbon neutrality by 2050. Korea will harness green innovations and advanced digital technologies to create synergies between the Green New Deal and the Digital New Deal, the two pillars of the Korean New Deal. Korea will also take decisive action, especially in supporting and investing in the development of innovative climate technologies to achieve carbon neutrality by 2050. Tackling climate change requires global efforts and collective engagement. Korea will lead by example to help the international community jointly make efforts to reach carbon neutrality by 2050.

27 2050 Vision is introduced in the 2050 Carbon Neutral Strategy

For the robust implementation of the Carbon Neutral Strategy, the government announced the "2050 Carbon Neutral Strategy Action Plan," which emphasizes the whole-of-government approach in carrying out the country's climate policies and projects. The plan lays out key policy directions along with 10 key tasks (see Table 4).

Table 4. Key tasks for the 2050 Carbon Neutral Strategy and ministries in charge

Policy Directions	10 Key Tasks	Ministry in Charge
Low-carbon economic structure	Expanding the use of clean power	Ministry of Trade, Industry and Energy (MOTIE)
	Low-carbon transition of energy-intensive, high-carbon industries	MOTIE, Ministry of SMEs and Startups (MSS)
	Future mobility	MOTIE
	Urban/land	Ministry of Land, Infrastructure and Transport (MOLIT) Ministry of Environment (ME) Ministry of Agriculture, Food and Rural Affairs (MAFRA) Ministry of Oceans and Fisheries (MOF) Korea Forest Service
Low-carbon industrial ecosystem	New industries	MOTIE
	Innovation ecosystem	MSS, ME
	Circular economy	ME
Just transition towards carbon-neutral society	Incorporation into a greener industrial system	MOTIE, MSS
	Centering local communities	ME
	Increasing national awareness	ME Ministry of Education (MOE)
Strengthening the institutional foundation for carbon-neutral society	Carbon emissions trading	ME
	Green financing	Financial Services Commission ME
	R&D	Ministry of Science and ICT (MSIT)
	International collaboration	Ministry of Foreign Affairs

The Korean New Deal (July 2020)

As an additional measure to accelerate implementation of the updated NDC, Korea has been promoting the Korean New Deal 1.0 since July 2020. The Korean New Deal 1.0 consists of three pillars: the Digital New Deal, the Green New Deal and Stronger Safety Net, and an additional drive for a Local New Deal. The Green New Deal 1.0 is underpinned by three key pillars: green transition in cities/spatial planning/living infrastructure, diffusion of low-carbon and distributed energy, and establishment of innovative green industry ecosystems. The government launched 10 key projects, including three digital projects, three green projects, and four digital and green convergence projects (see Table 5).

Establishing low-carbon and green industrial complexes is one of four green and digital convergence projects of the Korean New Deal. As such, cities and municipal governments are building public-private partnerships to develop large-scale green data centers (see Table 6).

After one year of the Korean New Deal 1.0, the government announced an upgrade—to Korean New Deal 2.0—to reflect internal and external changes to the initial strategy. Internally, there had been increasing concerns related to the pandemic, such as COVID-19 disproportionately affecting lower income groups. Additionally, surging demand for labor in new industries, such as software, prompted critics to urge a transition to a low-carbon economy. Meanwhile, the government believed it needed to respond to external trends, such as movements to achieve carbon neutrality and to accelerate digital transformation (e.g., transition to 6G).

Table 5. Green and digital projects in the Korean New Deal 1.0

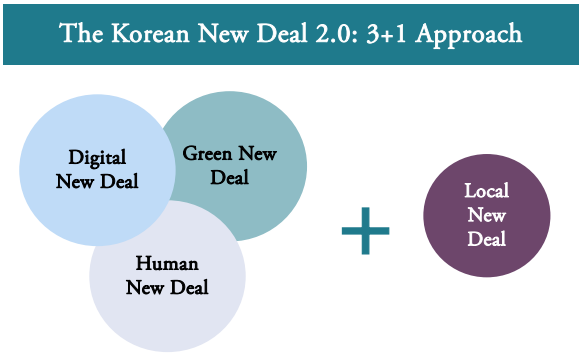
Green and Digital Projects	Project Overview	Targets by 2025
Green and Smart Schools	The installation of energy-saving facilities supports environmentally friendly classrooms, while the use of technology-based educational materials provides a learning environment that incorporates a blend of both online and offline methods.	• Invest ₩15.3 trillion (approx. US$13.5 billion), including ₩3.4 trillion (approx. US$3 billion) from the treasury • Create 124,000 new jobs
Digital Twin	Digital twins (digital replicas of objects that can be used for the analysis and prediction of the future through simulation) will be made for roads, underground spaces, harbors, and dams to lay the foundation for new industries such as drones and self-driving vehicles, and to allow for the safe management of land and facilities.	• Invest ₩1.8 trillion (approx. US$1.6 billion), including ₩1.5 trillion (approx. US$1.3 billion) from the treasury • Create 16,000 new jobs
Digitization of Social Overhead Capital(SOC)	Key infrastructure (water, expressways, early-warning system for disasters) that ensure safe and convenient lifestyles will be digitalized, and systems will be prepared to efficiently prevent and respond to disasters.	• Invest ₩14.8 trillion (approx. US$13 billion), including ₩10 trillion (approx. US$8.8 billion) from the treasury • Create 143,000 new jobs
Smart and Green Industrial Complexes	Industrial complexes will be made smart and eco-friendly (high productivity, high energy efficiency and low pollution) based on digital technology.	• Invest ₩4 trillion (approx. US$3.5 billion), including ₩3.2 trillion (approx. US$2.8 billion) from the treasury • Create 33,000 new jobs

Table 6. Regional green data center construction projects as part of the Korean New Deal 1.0

Project Name	Description	Project Period, Budget (₩)
K-Cloud Park (Gangwon-do)	The eco-friendly hydrothermal energy convergence cluster project is promoted as part of the Korean New Deal. One of the main goals of the project is to build six green data centers using cold water from Soyanggang Dam on an area of 784,912₩ in Chuncheon, the capital city of Gangwon-do.	Invest 302.7 billion by 2025
Saemangeum Data Center Industrial Park (Jeollabuk-do)	Saemangeum area of Gunsan city signed an agreement with SK Broadband—the internet infrastructure division of SK Telecom—to build 16 large-scale, renewable energy-powered data centers. The company's goal is to make the data centers run off 100% renewable energy by 2029.	Invest 2 trillion by 2029
Suncheon-NHN Cloud Data Center (Jeollanam-do)	In March 2021, the city of Suncheon signed a ₩300 billion investment agreement with NHN Enterprise to build public cloud data centers and a smart IT industrial complex in the city. The city plans to transfer public data to the cloud by 2025.	Invest 300 billion in a 20-year period

To respond to ongoing challenges strategically and systemically, the Korean New Deal 2.0 takes a 3+1 approach, with the three main pillars of Digital New Deal, Green New Deal, and Human New Deal (an upgrade of jobs and social security programs), and Local New Deal (see Figure 7). The government increased its investment to ₩220 trillion by 2025, from the previously planned ₩160 trillion.

Figure 7. The Korea New Deal 2.0 Frame



For the Green New Deal 2.0, a new category of carbon neutrality has been added, under which investment will be made in projects to achieve the 2030 NDC, such as building an emissions measurement system and creating a carbon reduction program for industries, and the scope of previous Green New Deal projects have been expanded to effectively support the transition to a low-carbon economy (see Appendix A). Ultimately, the Korean New Deal 2.0 is expected to create synergy between the Digital and the Green New Deal to help the country achieve carbon neutrality by 2050.

Box 2. The Green New Deal ODA (Official Development Assistance) Strategy

According to the OECD Development Assistance Committee(DAC), Korea provided 19.6% of its aid as Green ODA during 2015-2019, lower than the OECD DAC country average of 28.1% in the same period.

In July 2021, Korea's Committee for International Development and Cooperation (CIDC) announced the Green New Deal official ODA strategy as part of its foreign aid strategy. The Green New Deal ODA strategy's main objective is for Korea to lead global climate response with the following three priorities:

1.Increase the share of green ODA above that of the OECD DAC average by 2025 and support partner countries' green transition through building a Green New Deal ecosystem and flagship projects tailored to partner countries' needs;

2.Lead global discussions and initiatives on green ODA through increased contributions to green-related international organizations including the Green Climate Fund and the Global Green Growth Institute. Expand partnerships with UN agencies and multilateral development banks; and

3.Build mutually beneficial partnerships with partner countries and the private sector by focusing support in the sectors with high alignment between the partner countries' development needs and Korea's strengths such as green energy and green mobility.

*Green ODA markers: environment, climate mitigation, climate adaptation, biodiversity, desertification as tracked by OECD-DAC

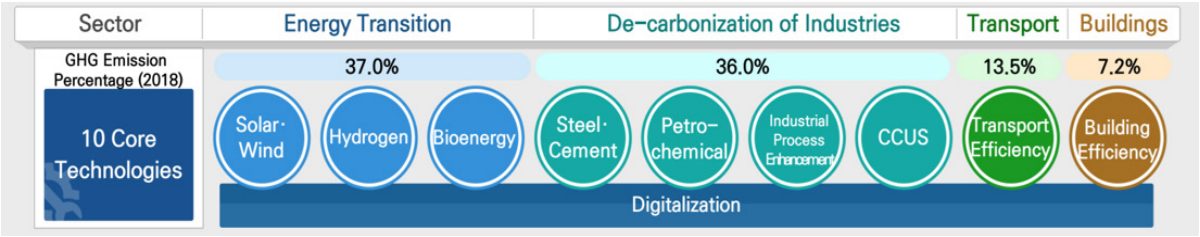
The Ministry of Science and ICT (MSIT) Carbon Neutral Technology Innovation Strategy (April 2021)

Achieving "greening by ICT" with the use of ICT technologies to reduce GHG emissions and accelerate sustainable development is a crucial component of the 2050 Carbon Neutral Strategy and the Korean New Deal. The policies to support "greening of ICT," by reducing the climate footprint in the entire ICT product and service life cycle in the ICT sector, is also in development and is expected to be announced by early 2022.[28]

In April 2021, MSIT disclosed high-level policy directions for greening the ICT sector in its announcement of the Carbon Neutral Technology Innovation Strategy (MSIT 2021a). Innovation in energy efficiency in the ICT sector through digitalization is one of the top 10 goals of the strategy (see Figure 8). With MSIT as the ministry in charge, the technology experts group consisted of members from the private sector, academia, research institutes, relevant ministries, and government institutions jointly formulating R&D strategy and key tasks for developing the 10 core technologies for carbon neutrality.[29] The identification of the 10 technologies is based on the sectoral targets stated in LEDS, sector analysis, contribution level of GHG emissions reduction, relevance to major sectors, and the policy environment. The government has committed to provide a targeted support system for the commercialization of carbon neutral technologies through the expansion of regulatory sandboxes, public procurement, venture investment, subsidies, tax cuts, and research capacity development.

Specifically, through digitization, MSIT plans to green the ICT sector by developing innovative technologies to green data centers, communication networks, and ICT devices. The long-term R&D roadmap and focus technologies under the greening ICT agenda are described in detail in Part IV of the case study.

Figure 8. Ten core technologies for carbon neutrality [30]



Source: MSIT 2021

PART IV: Key Actions and Measures for Greening the ICT Sector

Introduction

There have been numerous policy tools and instruments deployed to implement the government's greening of the ICT sector. Some were introduced in the early 2010s (i.e., green certification, green data center guidelines, K-ETS, etc.) following the announcement of the Green IT National Strategy (May 2009) and the enactment of the Green Growth Act (February 2010) that provided legal basis for implementing the government's national strategy for green growth, whereas others were unveiled more recently. Although the government is a lead facilitator for several tools, such as laws and economic instruments, the private sector is also contributing to the national efforts to green ICT by adopting voluntary measures. This section categorizes measures for greening the ICT sector into the following seven domains, informed in part by the OECD's Environmental Performance Reviews policy categorization.

28 According to an interview with MSIT.
29 Relevant ministries and government institution include MSIT (ministry in charge), Ministry of Finance, Ministry of Trade, Industry, and Energy, Ministry of Environment, Ministry of Land, Infrastructure and Transport, Ministry of Oceans and Fisheries, Ministry of SMEs and Startups, and Kores Forest Service.
30 Carbon Capture, Utilization, and Storage(CCUS) CCUS is a collective term used to describe various methods of trapping CO2 from industrial processes, and either storing it permanently or utilizing it

Legislation

The Framework Act on Low Carbon Green Growth (February 2010)

Despite a number of environmental protection laws,[31] Korea's national policy strongly focused on economic growth and industrialization until the mid-1990s. The Framework Act on Low Carbon Green Growth (or "the Green Growth Act") is an umbrella law introduced in 2010 to combine fragmented laws and provide the legislative framework for systematic implementation of green growth national strategy and action plans.

The Green Growth Act set mid- and long-term emissions reduction targets, cap-and-trade, carbon tax, carbon labeling, carbon disclosure, and the expansion of new and renewable energy (UNESCAP 2012). Main provisions of the act include the following:

- It defines the main principles of a green economy, including green growth via environmental technologies and industries, and the balance between environment and economy.
- It established the Committee on Green Growth to deliberate on the country's major policies and plans related to low carbon green growth.
- It declares that the government will foster new green industries and formulate means to transform traditional industries into green ones, setting targets and adapting infrastructure to an environmentally friendly structure; and that green investment companies shall be established and may be supported by the government.
- It calls for the facilitation of research, development, and commercialization of green technology.
- It prescribes mandatory annual GHG emissions reporting to the government, and the establishment of an Integrated information management system for GHGs.
- It instructs the government to prepare and enforce a basic plan for energy every five years for a planning period of 20 years.

The Green Growth Act will be replaced by the Framework Act on Carbon Neutrality and Green Growth legislated in September 2021, as the country's highest legal base for addressing climate change (see the subsection on the Framework Act on Carbon Neutrality and Green Growth).

The Act on the Allocation and Trading of Greenhouse Gas Emissions Rights (November 2012)

The Act on Allocation and Trading of Greenhouse Gas Emissions Allowances ("Emissions Trading Act") and its Enforcement Decree, passed in 2012, stipulate government actions, institutions, and timelines for the Korea Emissions Trading Scheme (K-ETS). K-ETS covers six sectors including the industry sector in which ICT companies belong.

The Framework Act on Carbon Neutrality and Green Growth (September 2021)

In September 2021, Korea became the 14th country in the world to legislate a carbon neutrality act after the National Assembly passed the Framework Act on Carbon Neutrality and Green Growth (or "Carbon Neutrality Act") in August 2021. The Carbon Neutrality Act integrates carbon neutrality and green growth and will replace the Green Growth Act as the country's highest legal base for tackling climate change. The act stipulates legal procedures and policy instruments to achieve the country's 2050 carbon neutrality vision. Specifically, the act introduces measures to achieve four primary policy goals, including GHG emissions reduction, climate adaptation, just transition toward a carbon-neutral society, and green growth.[32]

The act requires the government to actively utilize ICT technologies and services to reduce GHG emissions and save energy. The act also promotes the development of technologies to green the ICT sector and devices. Other major provisions of the Carbon Neutrality Act include the following:

- The Carbon Neutrality Act clearly states 2050 carbon neutrality as Korea's national vision and legally sets forth procedures required to achieve that vision. The procedures are mainly about the details for establishing a national strategy, a mid- to long-term greenhouse gas emissions reduction target, and a framework plan, as well as on reviewing implementation.

31 Environmental Pollution Prevention Act (1963), Environmental Preservation Act (1977) and Framework Act on Environmental Policy (1990)
32 Carbon Neutrality Act text is available at (in Korean): https://www.lawmaking.go.kr/lmSts/nsmLmSts/out/2112217/detailRP.

- The act sets a mid-term target to achieve the 2050 carbon neutrality vision, requiring the government to cut greenhouse gas emissions in 2030 by 35 percent or more from 2018 levels, increasing the target by 9 percentage points. The government is also required to set sector and industry-specific annual reduction targets.
- Participatory governance is legislated in the act to encourage the participation of youth, workers, and local residents. Previously, participation was limited to experts and businesses. With the enactment of the act, the Presidential Committee on 2050 Carbon Neutrality established in May 2021 will gain legal status as a commission.
- Various policy options are included in the act, including the adoption of climate impact assessments for major national plans and development projects.
- The act introduces climate-responsive budgeting to reflect emissions reduction targets in drafting national budgets. The Climate Response Fund will be established as well to support industries in transforming their structure and industrial processes.
- The act includes detailed policy measures for just transition. The measures aim to protect the regions and groups vulnerable to impacts in the context of transition. Designation of special districts and establishment of support centers are part of such measures designed to protect specific regions and groups who could be affected by the transition, for instance workers in coal and internal combustion engine vehicle industries.

The Carbon Neutrality Act comes into effect in March 2022. However, the Climate Response Fund will be implemented on January 1, 2022 and the climate impact assessments will be begin September 2022.

Standards

Standards for Green Data Center Construction and Self-Evaluation Guidelines

In 2012, the Korea Communications Commission (KCC) published the national standard for green data center construction guidelines and self-evaluation methodology for calculating data center energy efficiency.[33] The standardized green data center construction guidelines provide technical, operational, and architectural recommendations for energy-efficient and green data centers. The guidelines were previously developed through the green data center standardization project Korea and the EU initiated in 2010 and adopted as an international standard (ITU-T L.1300) by the International Telecommunication Union (ITU) in September 2011.

In April 2021, the government announced its plan to develop detailed evaluation indicators for resource use efficiency in data centers by 2025.[34]

Information and Product Based Instruments

As of December 2020, there were 17 environmental and green technology-related certifications that companies could acquire. Of the 17 certifications, six are mandatory and 11 are optional certification programs meant for providing environmental information to consumers and inducing firms to develop and produce green products (GTC 2020). Among the optional certification programs, the Green Certification program, Eco-Label program, and Carbon Footprint of Products (CFP) labeling certification are most relevant for ICT products and services.

33 https://www.rra.go.kr/ko/notice/newsList_view.do?nb_seq=508&cpage=15&nb_type=2&searchCon=&searchTxt=&sortOrder=.
34 https://www.korea.kr/news/pressReleaseView.do?newsId=156449429.

Green Certification

Article 32 of the Green Growth Act stipulates that "the Government may grant certification of conformity for green technology, green projects, and green products or accreditation of specialized green enterprises, impose an obligation to purchase on public institutions, or provide technical guidance in order to facilitate the development of green technology and green industries."[35] Following enactment of Green Growth Act, the Green Certification program launched in April 2010.

With MOTIE as ministry in charge and the Korea Institute for Advanced Technology (KIAT)[36] as a dedicated organization, the program is jointly operated by nine ministries (MOTIE, Ministry of Economy and Finance (MOEF), Ministry of Culture, Sports and Tourism (MCST), MAFRA, MSIT, MSS, MOF, ME, MOLIT) and 11 evaluation institutions.

Certification Types and Eligibility

There are four types of certifications including: 1) green technology, 2) green technology product, 3) green project, and 4) specialized green enterprise.

- Green technology: Technologies minimizing GHG emissions and pollution, such as those related to renewable energy, green mobility, smart cities, clean manufacturing, sustainable farming, and energy efficiency improvement.
    - Eligible green ICT technologies: LED, semiconductor (system and memory), next generation display, green software & solutions, green computing (hardware, software, infrastructure, AI, big data computing technologies), internet of things (IoT), communications networks.
- Green technology product: A commercialized product that utilizes certified green technologies.
- Green project: Large-scale projects with substantial economic and technological ripple effects in relation to green growth and carbon reduction, such as renewable energy deployment projects.
- Specialized green enterprise: Companies with 20 percent or more of sales from certified green technologies in the previous year's total sales.

Incentives

- Green certified companies get preferential consideration in public procurement (1.5 points added in the qualification screening process by the Public Procurement Service, 1 point advantage in the Multiple Award Schedule (MAS), 1 to 2 points advantage in getting excellent product classification).
- The certified companies are selected as a target for preferential purchase of technology products by MSS, and preferential treatment for technology guarantee funds and credit guarantees.
- Korea Technology Finance Corporation expands the guarantee limit (₩3 billion → ₩7 billion) through the Green Hi-Tech Preferential Guarantee for preferential support to green certified companies and reduces the guarantee fee by 0.5 percent. In addition, guarantees of up to ₩300 million are provided for green-related R&D expenses and technology introduction costs.
- The Korea Credit Guarantee Fund preferentially supports green technology and green industries and gives preference to guarantee conditions.

Environment Product Declaration (EPD) and Carbon Footprint of Products (CFP) Labeling Certification

The CFP labeling certification program[37] is a voluntary certification system that seeks to promote consumer-led purchases of low carbon goods and green business processes. It is one of the seven impact categories of the Environment Product Declaration (EPD) certification program.[38] The amount of GHG emitted during the life cycle of a product (including a service) is converted into the amount of CO2 emissions and marked on products. Among the CFP certified products, products with lower-than-average carbon emissions compared to products of the same type can be certified as Low Carbon Products.

35 https://www.law.go.kr/LSW/lsInfoP.do?lsiSeq=98467&viewCls=engLsInfoR&urlMode=engLsInfoR#0000.
36 KIAT is a quasi-NGO under MOTIE.
37 EPD certification is categorized into seven different impact categories and labels: carbon footprint, ozone depletion, eutrophication, resource footprint, photochemical smog, acidification, and water footprint.
38 EPD certification is categorized into seven different impact categories and labels: carbon footprint, ozone depletion, eutrophication, resource footprint, photochemical smog, acidification, and water footprint.

ME manages the program with the Korea Environmental Industry and Technology Institute (KEITI) in charge of the development and revision of the Guidelines for Carbon Footprint of Products, certification of carbon footprint label, and follow-up management. The Korea Environment Preservation Association (KEPA) provides education programs to train certification inspectors for carbon footprint labeling.

Target Products

All products and goods, with the exception of agricultural products, fishery and livestock products, forest products, pharmaceutical products and medical equipment, can be considered for certification.

Incentives

- CFP labeling status is reflected in the selection of the total bidding system by the Public Procurement Service.
- Up to 2 points can be added to G-SEED when using carbon footprint labeled materials.[39]
- Green Card credit card holders who purchase CFP labeled products get ECO MONEY points.[40]
- Certification service fee reduction by 50 percent to small and medium enterprises (SMEs).
- Carbon emission calculation support is provided to SMEs.
- Certified products are promoted through newsletters, advertisements, and exhibitions.

Figure 9. Certification mark for CFP labeling

Figure 10. Certification mark for Low Carbon Products

Eco-Label Certification Program

The Eco-Label certification program[41] aims to provide accurate environmental information to consumers and to encourage firms to produce environment-friendly products in line with consumers' preferences. The certification requirements include both environmental aspects and the quality of the products (KEI 2016). The environmental requirements pertain to the environmental effects of products (i.e., how much do the products reduce the use of hazardous materials, promote human health, save energy and water, etc.) throughout their life cycles. To be certified, the products must also satisfy the quality requirements of the Korean Standards (KS). KEITI is in charge of the management of the program.

Target Products

Products in 165 categories, including office supplies and machines, and electric and electronic products, are subject to certification.

Incentives

- Additional points are given during the tendering process of the Public Procurement Service.
- Priority purchase status is given for local government procurement and construction specifications.
- Diverse policies and advertisement programs promote certified products.
- Mandatory procurement of certified products by public institutes and organizations.

Figure 11. Certification mark for Eco-Label

39 G-SEED is Korea's green building certification system, which has certified more than 8,000 buildings from its 2002 inception to 2016. G-SEED undertakes assessments across seven categories, including land use and transportation, energy and environmental pollution, materials and resources, water management, ecology, and indoor environment. Incentives for certification include 5 percent to 15 percent acquisition tax reduction, 3 percent to 15 percent property tax reduction, and ease of building standards.

40 Eco-Money is a consumer reward program for incentivizing green consumption with the use of the Green Card. The Green Card was first introduced in 2011 to promote environmentally friendly consumption, providing "Eco-Money Points" every time the cardholder partook in an eco-friendly activity such as purchasing low-carbon, environmental products, or using public transportation.

41 http://el.keiti.re.kr/enservice/enindex.do.

Regulation on Standby Power Reduction Program[42]

With MOTIE as ministry in charge, the program aims to induce the minimization of standby power and the adoption of an energy saving mode during standby periods that do not require the operation of a product. The producers (or importers) that do not meet the energy efficiency requirements of the program must attach a warning label on their products. The producers (or importers) can voluntarily attach an energy efficiency label on products meeting requirements mandated by the program. ICT devices such as computers, monitors, and residential gateway devices are subject to regulation.

Figure 12. Voluntary label for products that meet the standby power reduction standards standards

Figure 13. Mandatory warning label for products that do not meet the standby power reduction standards

Economic Instruments

The Energy and GHG Target Management System (TMS) and Emissions Trading Scheme (K-ETS)

An emissions trading scheme is a market-based scheme designed to cost-effectively meet a nation's GHG reduction targets by allocating a number of emissions permits to eligible entities. The participating entities can trade any surplus or deficit in their emissions allowances with other participants in the market.

The Korea Emissions Trading Scheme (K-ETS) launched in January 2015 as East Asia's first nationwide mandatory ETS. Entering into the third phase of the program (2021-2025), the K-ETS covers 685 of the country's largest emitters, accounting for 73.5 percent of national GHG emissions (ICAP 2019a). During Phase II (2018-2020), 3 percent of total allowance was allocated for auctioning. For comparison, 57 percent of allowances were auctioned in Phase III (2013–2020) of the EU Emissions Trading System (EU ETS) (ICAP, 2019b) (see Table 7).

Table 7. K-ETS threshold, emission cap and allocation by phase

Phases	Threshold	Emission Cap	Allocation
Phase I (2015-17)	Companies with over 125,000 tCO2e or more total annual emissions or companies with one or more business sites with over 25,000 tCO2e or more annual emissions are subject to caps under the K-ETS. Companies with emissions below the threshold may voluntarily participate in the K-ETS.	1,686.3 MtCO2e, including a reserve of 88 MtCO2e for early action and new entrants. 84.5% of the reserve was used within the phase.	100% free allocation
Phase II (2018-20)		1,777 MtCO2e, including 134 million for new entrants and other purposes.	3% allocated for auctioning
Phase III (2021-25)		3,048.3 MtCO2e. This corresponds to an average annual cap of 610 MtCO2e, including reserves. Annual caps are higher in Phase III due to the expansion in scope, but reflect a 4.7% decrease in emissions compared to the 2017-2019 baseline.	At least 10% allocated for auctioning

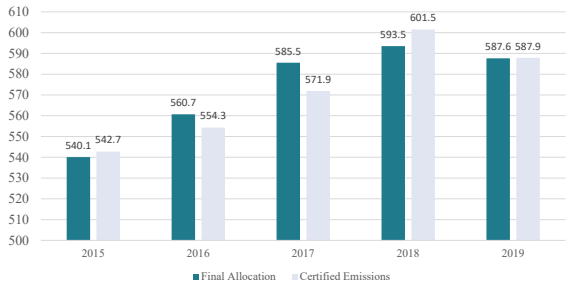
Source: ICAP 2019a

K-ETS covers six sectors including the industry sector in which ICT companies belong. During Phase III, the industry sector is divided into 50 subsectors, including semiconductor manufacturing, electronics components manufacturing (includes display manufacturing), telecommunications, data processing, hosting and related industries (Ministry of Environment 2020a).

42 The overview of the Regulation on Standby Power Reduction Program is available at (in Korean): https://eep.energy.or.kr/business_introduction/standby_summary.aspx.

In 2019, total emissions dropped by 2.3 percent from the previous year for the first time since the scheme's launch (see Figure 14).

Figure 14. Final allocation and certified emissions by year, in million-ton CO_2e (source: GIR 2020, ME 2021)



Source: GIR 2020, ME 2021

The K-ETS was preceded by a mandatory GHG and Energy Target Management System (TMS) that launched in 2012. The TMS facilitated the collection of verified emissions data, and it still applies to smaller entities not covered by K-ETS. TMS combines command-and-control components with strong voluntary network-like mechanisms (Niederhafner 2014).

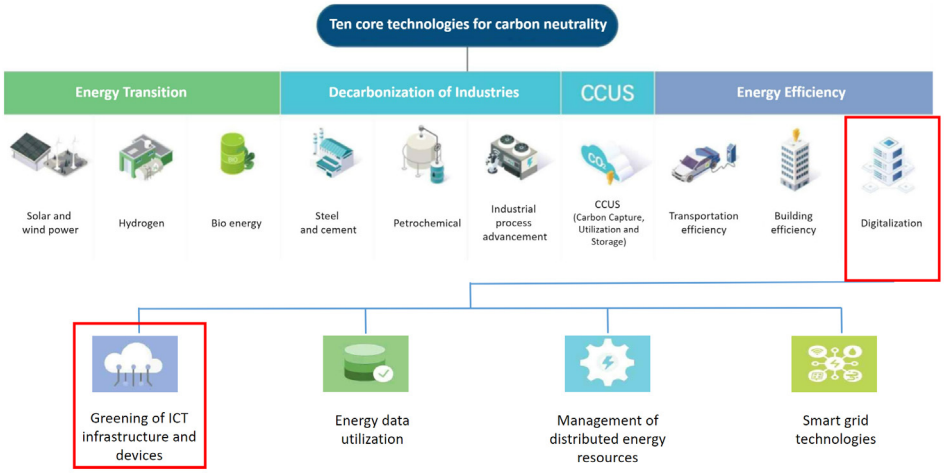
ME is the ministry in charge of TMS and K-ETS to manage GHG emissions by companies exceeding a threshold set by the government.[43] Although ME is responsible for controlling and operating K-ETS and TMS, other relevant ministries such as MOTIE, MAFRA, and MOLIT co-manage the TMS and K-ETS. As of 2020, MOTIE manages GHG emissions by 32 ICT companies (in semiconductor, electronics, telecommunications, and display industries, as classified by the Korea Exchange) under TMS. There are 11 institutions, including the Korea Standards Association, that certify emissions reporting by these companies.[44]

Stimulating Innovation

MSIT has been funding R&D projects to increase energy efficiency of data centers and communications networks in recent years. MSIT's green data center R&D projects focus on improving the operational efficiency of data centers, especially in cooling and power provision systems (see Appendix D). From 2018 to 2021, MSIT funded 10 R&D projects to increase energy efficiency and reduce the carbon footprint of communications networks, investing ₩9.4 billion (see Appendix E).

In September 2021, six months after the announcement of the Carbon Neutral Technology Innovation Strategy, MSIT and the Korea Institute of Energy Research published the "Carbon Neutral Technology Innovation Strategy—10 Core Technology Development Directions" report (MSIT 2021c). The report describes a long-term roadmap and goals for developing and commercializing 10 key carbon-neutral technologies that will be instrumental in achieving carbon neutrality by 2050. The 10 technologies will support energy transition, accelerate decarbonization of industries, and increase energy efficiency. Greening ICT is a key component of digitization (see Figure 15).

Figure 15. Ten core technologies for carbon neutrality



Source: MSIT 2021c.

43 Companies subject to TMS: companies with an average annual total of more than 50,000 tons of GHG emissions, companies with one or more business sites of 15,000 tons or more.
44 Written response from MSIT.

Within the broader goal of greening ICT, the government prioritizes greening data centers, communication networks, and ICT devices (see Table 8). The long-term R&D roadmap in Table 9 shows milestones by phase, from development to commercialization of these technologies.

Table 8. Greening ICT key projects and tasks

MSIT's Greening ICT Policy Priorities	Rationale for Prioritization	Key Projects and Tasks
Greening data centers	• To improve energy efficiency of ICT devices, mobile communication base stations, and data centers for digital transformation. • To secure data platforms, optimal networking technology, and eco-friendly and high-efficiency ICT-based technologies to serve the common infrastructure for carbon neutral technologies. • To strengthen competitiveness and lead the sustainable market by building capacity in ICT materials, parts, and equipment.	• Cooling and heating: Real-time analysis of data center operating environment using IoT sensor optimization of temperature control based on AI to reduce energy use by 40%. • IT equipment: Development of technology that automatically adjusts servers according to data throughput and energy-efficient server/network equipment.
Greening communications networks		• Wireless communication: Dynamic adjustment of power amplifier and antenna usage in base stations (2023 approx.). Apply gallium nitride (GaN) element with higher output than convention silicon. • Wired communication: Develop dynamic power adjustment technology to minimize power consumption of high-speed internet communication equipment.
Greening ICT devices		• Energy harvesting technology and intelligent/ autonomous IoT.

Table 9. R&D roadmap for greening ICT

Digitization Technology Development Roadmap										
Digitization Technology	Current Technology Development level	Short Term				Medium Term			Long Term	Goal
		2022	2023	2024	2025	2026	2028	2030	2050	
Greening ICT Infrastructure and Devices	At 80.1% of developed countries	Development of energy harvesting and high efficiency autonomous device technology				System demonstration and commercialization				(by 2030) Development of mW or W-level beta voltaic cell or multi-source energy conversion device
		Development of self-learning, autonomous Artificial intelligence of things(AIoT) technology								
		Development of high-efficiency power amplifier and repeater manufacturing technology				Demonstration and commercialization of energy efficiency in distributed power-linked base stations				(by 2030) establishment of 0.1 umGaN foundry and demonstration of high-efficiency power amplifier integrated circuit
		Development of SQRA-supported energy networking analysis, design, and deployment technnology				Advancement of energy networking technology and demonstration/commercialization				(by 2030) Application of Green Data Center Certification in more than 50 data centers
		Development of intelligent/autonomous PUE management system for data centers							Demonstrati-on	(by 2045) Achieve autonomous PUE management (Data Center Infrastructure Management Maturity: level 5, PUE: 2.3 for public, 1.5 for private)
		Development of measurement index for data center facility/equipment efficiency and PUE accuracy improvement standard				Application of advanced green data center certification				

Source: MSIT 2021c

An expert subcommittee led by the Electronics and Telecommunications Research Institute (a government-funded research institute) will lead R&D for digitization and technologies for greening ICT infrastructure and devices. The subcommittee has members from the academia (Ewha Woman's University), research institutes (Korea Institute of Energy Research, Korea Electrotechnology Research Institute, Korea Institute of Science and Technology, KEPCO Research Institute), and industry (Korea Data Center Council).

Green Procurement

In 2011, following the enactment of the Green Growth Act, the government revised and expanded the Act on the Encouragement of Purchase of Environment-Friendly Products, which mandated government procurement of green products including electronic products and ICT devices. The newly introduced Act on the Promotion of Purchase of Green Products requires public organizations to submit the record of green purchases to ME to be verified. According to the act, public organizations are required to purchase green products among available options when: 1) direct purchasing, 2) purchasing through subcontractors, or 3) purchasing construction materials through construction companies. The Green Growth Act defines green products as products that received Eco-label certification, Low-Carbon Product certification, and Good Recycled certification (Ministry of Environment 2020b).[45]

Voluntary Approaches

Korea Data Center Council (KDCC) Green Data Center Certification Program

KDCC has been managing a private green data certification program since 2012 to increase energy efficiency in data centers. The program was first initiated as a response to the data center power efficiency policy promoted by the Ministry of Knowledge Economy (currently MOTIE and MSIT) in 2011, through the Act on the Development of Cloud Computing and the Protection of its Users and the Framework Act on National Informatization. As of 2021, around 20 data centers are certified out of approximately 160 in Korea.

The two criteria for evaluation include 1) infrastructure efficiency (80+5 points) and 2) green operation practices (20 points). Infrastructure efficiency is measured based on international standard ISO/IEC 30134-2 (PUE). The applicants are evaluated by application documents and site visits. Best practices for energy efficiency of certified data centers are promoted through certification awarding ceremonies and media reports.

Certification types include 1) new certification, 2) renewed certification, 3) preliminary certification, and 4) design certification. Energy efficiency is evaluated from the design stage to the building and operation stage, and the centers graded according to the scores received.

When the program launched in 2012, the need for green data centers was yet to be established in Korea. PUE for most data centers at that time ranged from 2 to 3. Major private data centers in Korea recently have achieved much lower PUE levels (e.g., Naver - PUE 1.1 and LG CNS - PUE 1.3.[46] KDCC's certification program may have played a significant role in achieving these improvements in energy efficiency. [47]

As of 2021, only about 12 percent of data centers have been certified by KDCC as green data centers. KDCC believes lack of substantial incentives to justify the costs and time required for acquiring and maintaining the certificate could be contributing to the low participation rate. Data center-related policies and issues span many different ministries (MSIT (technology), MOIS (operations), MOTIE (facilities), and MOLIT (construction)). There needs to be cross-ministerial coordination and consensus to develop support measures, which can be difficult to attain (Choi 2021). According to MSIT, however, relevant ministries and organizations are under close discussions, aiming to lay out the incentives in 2022.[48] Several options, including tax benefits, are being discussed as potential incentives for certified data centers.

Industry initiatives from the telecommunications sector

SK Telecom is one of the 29 global mobile network operators (MNOs) that has agreed to the Science-Based Target (SBT) set by ITU, GeSI, and GSMA in line with the Paris Agreement (UNFCCC 2020b). MNOs adopting the SBT are required to reduce emissions by at least 45 percent by 2030.

SK Telecom is reducing its energy consumption by, for instance, lowering the consumption of cooling energy (through the elimination of heat given off by equipment), integrating network equipment such as base stations and repeaters, and replacing old cooling equipment (SK Telecom 2020). In November 2020, the company joined

45 Good Recycled Certification is given to high-quality products manufactured from recycled materials. MOTIE is the ministry in charge of the program.
46 Comments based on the interview with the World Bank Digital Development team.
47 A view expressed by Professor Yunmook Nah, dean of the Software College at Dankook University and chairman of the Green Data Certification Committee at KDCC
48 Based on the written response from MSIT.

Box 3. Green data center best practices in Korea

LG CNS Busan Global Cloud Data Center

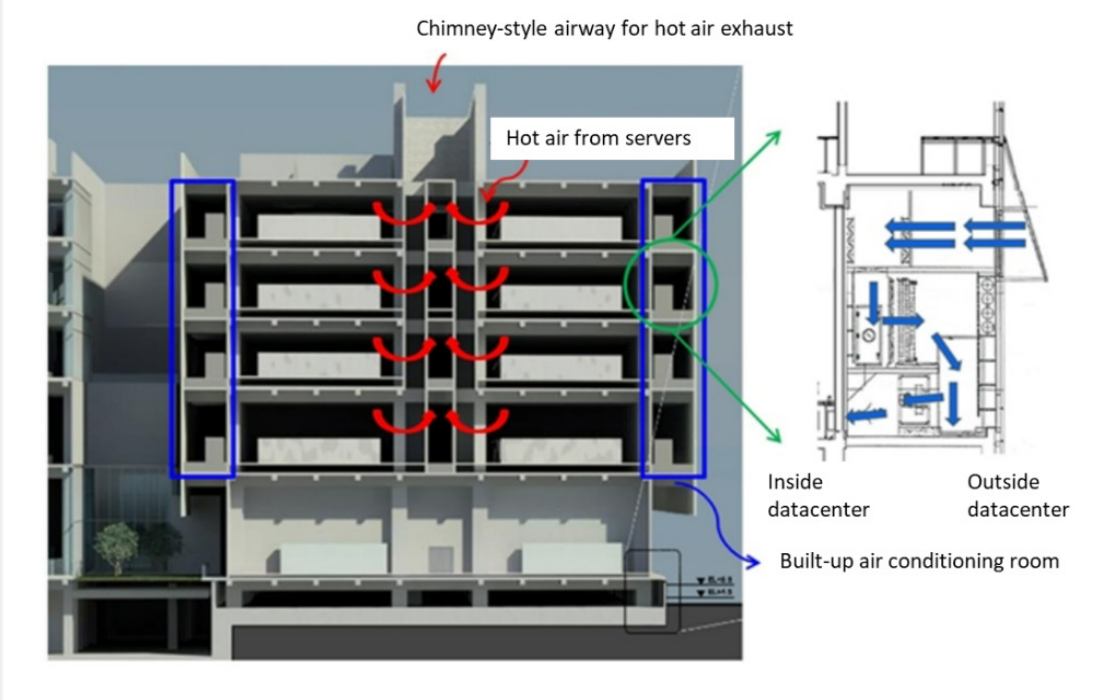


Figure 16. Design of the chimney-style airway(Source: Design Log)

LG CNS is a subsidiary of LG Corporation that provides information technology services including consulting, System Integration, Network Integration, Business Process Outsourcing, and Information Technology Outsourcing. The company opened Korea's first dedicated data center in 1992 and operates eight data centers in Korea and globally today. Especially, the company's Busan Global Cloud Data Center has been recognized for its high energy efficiency with the annual average PUE of 1.39 anwd the lowest PUE at 1.15 during the winter season when cooling devices are not in operation. The Busan Global Cloud Data Center earned the highest rating of A+++ by the KDCC's green datacenter certification program, consecutively between 2014 and 2016. The Busan Global Cloud Data Center uses a unique chimney-style hot-air exhaust and a hybrid cooling system called the Built-Up Outside Air-cooling System to improve energy efficiency.

Naver Data Center GAK

NAVER Corp. is a global ICT company that provides Korea's number one search portal NAVER and the global messaging platform LINE. Naver operates data centers in Korea and globally under the brand GAK with an average 1.1 PUE. The Center won "platinum" certification from LEED[50] New Construction (NC) 2009, for the first time among data centers in the world. The Center uses a range of methods, including the reuse of waste heat, photovoltaic and solar thermal power generation, and a natural cooling system using outside air to increase energy efficiency.

Figure 17. Naver Data Center GAK Chuncheon

the RE 100 Initiative and pledged to procure 100 percent of its electricity use from renewable energy sources by 2050. [49]

Telecommunication companies are also developing technologies to reduce carbon footprint in their operations. LG U+, for example, developed the next-generation eco-friendly rectifier to increase energy efficiency in its 5G base stations. The eco-friendly 5G rectifier is 25 percent smaller in size than the existing one and uses high-frequency switch circuits and high-precision control technology. With an increased rectification efficiency rate of 94 percent (previously 90 percent), expected energy savings are 80 watt-hours (W/h) per unit and a total of 700 kW annually. The company installed eco-friendly rectifiers in 80,000 5G base stations to save 5,600 kW of electricity per year. As of March 2020, a total of 31,816 units have been installed in the company's LTE and 5G base stations (LG U+ 2019).

KT announced its intent to become a carbon-free company and has established a goal of reducing GHG emissions by 35 percent in 2030 compared to 2007 emissions. The company has been managing scope 1 and 2 emissions since 2007 and scope 3 emissions since 2013. The company manages scope 1 and 2 emissions according to the guidelines set by the Ministry of Environment (ME) and manages scope 3 emissions through an independently developed methodology. Scope 1 to 3 emissions are verified by a verification agency designated by ME. The company has installed GHG monitoring system in 322 office buildings across the country for monthly emissions evaluation (Cha 2021).

In 2019, the company reduced 46,000 tons of CO2-eq through various energy-saving and eco-friendly practices. In 2011, KT built a solar power plant in Gangneung and has continued to invest in its renewable energy facilities since then. The company's solar power energy generation increased more than 14-fold from 2016 to 2019 (KT Corp. 2020).

Other Incentives and Regulations

There are a number of programs in place to incentivize the use of renewable energy and energy efficient business practices in the ICT sector (see Table 10).

Table 10. Regulations and incentives to increase energy efficiency in the ICT sector

Ministry in Charge	Program	Overview and Incentives
MOTIE	K-RE100	Both industrial and general consumers of electricity can participate in the K-RE100 system through registration at the state-run Korea Energy Agency. The renewable energy can be procured through various methods, including the green premium system, the third-party power purchase agreement (PPA), the purchase of renewable energy certificates (REC), or self-generation. Companies' participation in the K-RE100 system will count toward their overall GHG reduction targets. The Ministry of Environment is in the process of revising relevant guidelines on detailed energy sources and methods of reducing emissions. Moreover, the government will prepare various support measures to promote renewable energy use.
MOTIE, Ministry of Land, Infrastructure and Transport (MOLIT)	Zero-energy building certification (ZEBC)	ZEBC officially launched in 2017 to promote the implementation of renewable energy systems and building energy management systems to reduce building-energy consumption and improve building-energy independency rates. Buildings are rated as level 1 to 5 based on the energy independent rate achieved.
MOLIT, ME	Green Standard for Energy and Environmental Design (G-SEED)	G-SEED is Korea's green building certification system, which has certified over 8,000 buildings from its inception in 2002 to 2016. G-SEED undertakes assessments across seven categories, including land use and transportation, energy and environmental pollution, materials and resources, water management, ecology, and indoor environment. Incentives for certification include 5-15% acquisition tax reduction, 3-15% property tax reduction and ease of building standards.

49 RE100 is the global initiative led by international non-profit the Climate Group in partnership with CDP to accelerate the transition to zero carbon electricity grids.
50 LEED: Leadership in Energy and Environmental Design, Environmentally friendly building certification developed by the U.S. Green Building Council

PART V: Key Takeaways of Korea's Policy Approach

Korea's ICT sector decarbonization strategy and policies can be understood as part of the country's broader and systematic efforts to achieve carbon neutrality. As one of the world's most connected countries and early movers, Korea's experience can present meaningful lessons to other countries looking to adopt measures to reduce the ICT sector's climate impact. Below is a list of key takeaways from Korea's decade-long policymaking in greening its ICT sector.

1. **Early commitment**

   Korea was among the first countries to embrace green growth as a national development strategy and announce its commitment to green the ICT sector as early as the 2000s. In the years following the announcement of the "Low Carbon, Green Growth" vision (2008), the government pursued a green growth strategy characterized by a strong top-down leadership that elevated green growth as a national priority (Global Green Growth Institute, 2015). The government's commitment to green the ICT sector was first officially promulgated in the Green IT National Strategy (2009), followed by the enactment of the Green Growth Act (2010), which provided a strong legal framework to introduce measures such as K-ETS and a green certification program.

2. **Long-term planning and comprehensive policies**

   The move for greening of ICT in Korea has been incorporated into and backed by a long-term vision and strong political commitment (e.g., 2050 Carbon Neutral Strategy), large-scale infrastructure projects (e.g., the Korean New Deal), R&D for innovative technologies (e.g., Carbon Neutral Tech Innovation Strategy), and a robust legal framework to support the implementation of green initiatives (e.g., Green Growth Act, Carbon Neutrality Act).

   These initiatives, collectively, provide a coherent national strategy on green ICT that has been sustained over a long period. The strategy continues to evolve with new measures to green the ICT sector (e.g., incentivizing the use of renewable energy in data centers, and designing incentives for green data center certification) but these are all based in this overall framework.

3. **Prioritization**

   The government is pursuing greening of ICT with strategic prioritization aligned with the country's core industrial competitiveness while also aiming to create and lead global green ICT market. With the Carbon Neutral Technology Innovation Strategy (2021), MSIT has clearly defined three priorities in greening ICT, with a focus on greening data centers, communication networks, and ICT devices. The prioritization is not solely based on environmental impact, but also on the country's strategic goal to lead the global green ICT market by building capacity in green ICT materials, parts, and equipment manufacturing.

4. **R&D and investment to drive implementation**

   The government is collaborating with public research institutes, academia, and industry to develop innovative carbon-neutral technologies that will improve the energy efficiency of data centers, networks, and ICT products over the next 30 years. Additionally, Korea's government R&D expenditure as a percentage of GDP (1.09 percent) is the highest in the world as of 2021.[51] The national R&D budget for 2022 is set at ₩29.8 trillion, representing an 8.8 percent increase from the previous year's budget.

5. **A governance structure that allows a whole-of-government approach will be required**

   In combating climate change, a government-wide strategy and approach accompanied by a governance structure enabling effective policymaking and cross-ministerial coordination would be critical for a country's successful green transition. In Korea's case, the Presidential Committee on 2050 Carbon Neutrality will be the central governing body for the carbon neutrality policy agenda, as stipulated in the Carbon Neutrality Act. However, it is not yet clear how green ICT policy coordination will be achieved, because different ministries—including MOTIE (in charge of energy and GHG

51 https://www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=112&pageIndex=1&bbsSeqNo=94&nttSeqNo=3180682&searchOpt=ALL&searchTxt=%EC%98%88%EC%82%B0.

TMS, energy policies, green certification, and data center facilities), MSIT (green ICT R&D), MOIS (government/public data centers), MOLIT (ICT building regulation and data center construction regulation), and MOE (K-ETS)—have split responsibilities and mandates in this matter. A number of potential incentives for greening data centers—including discounted electricity rates for highly energy efficient data centers, regulatory reform to allow waste heat utilization by data centers, and exempting highly efficient data centers from GHG emission limit—require coordination across multiple ministries. For effective policymaking, a governance structure that supports a whole-of-government approach in greening ICT will be required.

Conclusion

Public policies have an important impact on the ICT market. Korea's case illustrates a range of different policy tools available for the government to induce decarbonization of the ICT sector, including green government procurement, information-based instruments, economic instruments, and the provision of guidelines on green business practices. Some of the lessons from Korea's experience may not be readily applicable or feasible for developing countries. However, there are some steps developing countries can take early to establish greener business practices. These would include providing a strong legislative framework for the green transition, facilitating cross-ministerial coordination for effective policymaking, setting long-term targets, and encouraging the industry to adopt global best practices in greening business processes and products in the ICT sector.

Additionally, renewable energy will play an increasingly important role in reducing GHG emissions from the energy-intensive ICT industry. Many countries, including Korea, have a nascent renewable energy industry that cannot yet fulfill the ICT sector's high energy demands. However, governments can help facilitate the renewable market and incentivize the use of renewable energy in the ICT sector by reforming energy policies. In Korea's case, the launch of the K-RE100 system— which allows industry and consumers to procure renewable energy through third party power purchase agreements (PPAs), the purchase of renewable energy certificates (REC), or self-regulation—is expected to accelerate the transition.

Because policy and regulatory pathways for greening ICT are still in development globally, additional time and research are needed to assess the outputs of these strategies and their effectiveness in identifying best practices for developing countries. Indeed, even in Korea's case, while many of the policies observed have been in effect for a few years, more evidence and analysis are needed to measure and determine their effectiveness. However, there is still no universally accepted method to calculate the carbon footprint of Korea's ICT sector (or the global ICT sector) for policy assessment purposes.[52] Recently, the need for environmental data and standards for the ICT sector was also echoed by the Greens–European Free Alliance in their open letter to the European Commission.[53] Going forward, the international community should establish an agreed-upon, standardized methodology to measure the effectiveness of green policies and calculate GHG emissions by the ICT sector.

52 In 2018, the International Telecommunications Union published a Recommendation (ITU-T L.1450) on "Methodologies for the assessment of the environmental impact of the information and communication technology sector." However, the Recommendation ITU-T L.1450 only provided guidelines and best practices to follow to assess the carbon footprint of the ICT sector.
53 https://www.greens-efa.eu/en/article/document/need-of-environmental-data-and-standards-for-the-ict-sector.

Appendix A: Comparison of Government Investment Plans for Korean New Deal 1.0 and 2.0

Table A.1 Comparison of Government Investment Plans for Korean New Deal 1.0 and 2.0

		2020–2025 Budget(₩, Trillions)	
	Focus Areas	**New Deal 1.0**	**New Deal 2.0**
Digital New Deal	1. Stronger integration of DNA[54] throughout the economy	31.9	33.5
	2. Advancing "untact" (or contactless) infrastructure (INTEGRATED)	2.9	3.2
	3. Fostering hyperconnected new industries (e.g., metaverse) (NEW)	-	2.6
	4. Digitalization of Social Overhead Capital (SOC)	10.0	9.7
	Sub-total	**44.8**	**49.0**
Green New Deal	1. Establishment of carbon neutrality drive (NEW)	-	4.8
	2. Green transition of infrastructures	12.1	16.0
	3. Low-carbon and decentralized energy	24.3	30.0
	4. Innovation in the green industry	6.3	10.2
	Sub-total	**42.7**	**61.0**
Human New Deal	1. Investment in human resources	4.0	9.3
	2. Employment and social safety net	22.6	27.0
	3. Youth policies[55] (NEW)	-	8.0
	4. Reducing income/social divides and promoting inclusive policies[56] (NEW)	-	5.7
	Sub-total	42.6	50.0
Total		**114.1**	**160.0**
Local New Deal		42.6	62.0

54 DNA refers to data, network and artificial intelligence (AI), the three innovative industries selected by the Presidential Committee on the Fourth Industrial Revolution.
55 This new component aims to ease young adults through the impacts of the pandemic by additional support in areas from education and employment to housing and asset building.
56 This new component intends to bridge gaps by upgrading education and childcare support for low-income households and prepare them for a rapid transformation of the economy, and by upgrading the country's caregiving systems in areas from child and senior care to disability assistance and single-parent support.

Appendix B: ICT Sector Taxonomy as Classified by the Ministry of Science and ICT (MSIT)[57]

According to the Harmonized Classification system of Information and Communication Technology Industry introduced by the Ministry of Science and ICT of Korea (MSIT) in 2017, the ICT sector consists of three levels: equipment, service, and software and digital content.[58] MSIT introduced it in order to create a unified ICT classification system for all ICT statistics in Korea. The classification system is compatible with the existing industry classification systems of the OECD and the UN.

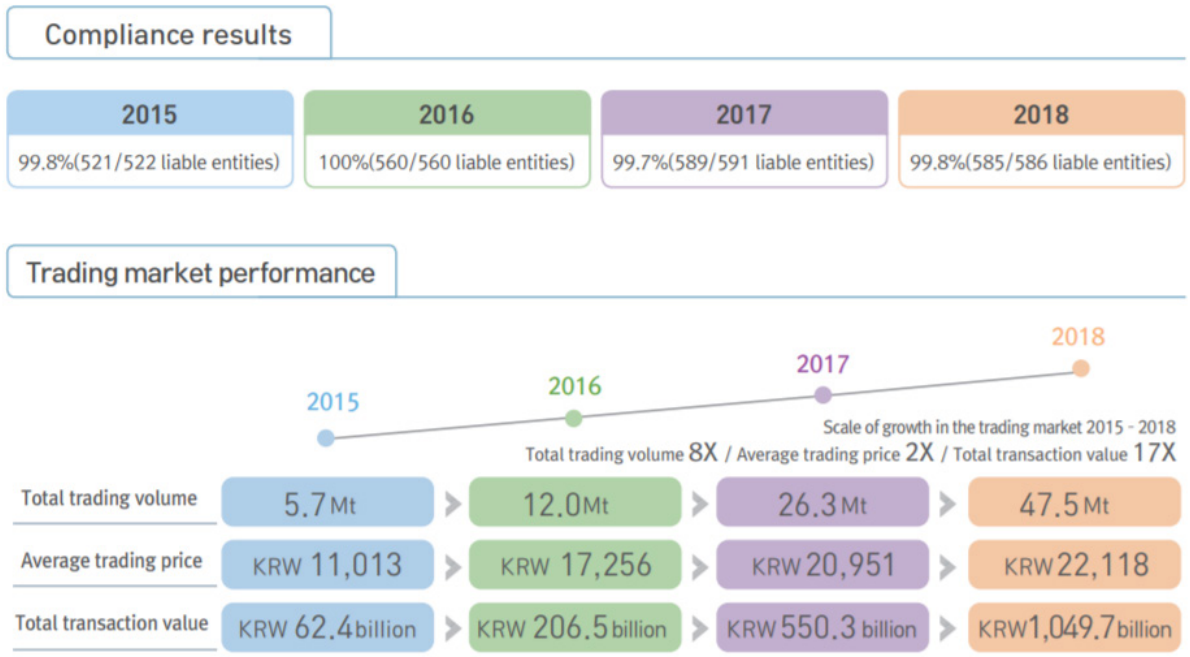
Table B.1. ICT sector taxonomy as classified by the MSIT

Information, Telecommunication, and Broadcasting Equipment	Electronic components	• Semiconductors • Flat panel displays • Sensors • Passive components • Printed circuit boards • Mechanical components
	Computers and peripherals	• Computers • Computer peripheral equipment
	Communication and broadcasting equipment	• Communication equipment • Broadcasting equipment
	Video and audio equipment	• Video equipment • Audio equipment • Other video and audio equipment
	Information and telecommunication applied apparatus and instruments	• Home appliances • Office appliances • Medical instruments • Meters, controllers, analysis Instruments • Electrical equipment • Other information and telecommunication applied apparatus and instruments
Information, Telecommunication, and Broadcasting Services	Telecommunication services	• Wired telecommunications • Wireless and satellite telecommunications • Other telecommunications • Telecommunications resellers
	Broadcasting services	• Terrestrial broadcasting • Pay TV services • Program production and broadcasting • Other broadcasting services
	Information services	• Information infrastructure services • Information mediation services (web search portals) • Internet hosting services
Software and Digital Content	Package software	• System software • Application software
	Game software	• Online games • Mobile games • PC games • Video games • Arcade games
	IT services	• IT consulting and system development • IT system management and support services
	Digital content	• Content development services for publication • Content development services for video • Content development services for music • Content development services for education
	Embedded software	• Embedded software platforms • Industry-specific embedded software

57 https://www.itstat.go.kr/itstat/kor/brmp/BrmpList.html.
58 http://www.tta.or.kr/data/ttas_view.jsp?rn=1&pk_num=TTAK.KO-09.0002/R2.

Appendix C. K-ETS Compliance Results and Trading Market Performance

Figure 18. K-ETS compliance results and trading market performance



Source: GIR 2020

Appendix D. Government Funded Green Data Center R&D Projects (2017-2021)

In the last five years, MSIT has funded several green data center technology R&D projects that focused on improving the operational efficiency of data centers, especially in cooling and power provision systems (see Table D.1).

Table D.1. Green data center technology R&D projects funded by MSIT

Project classification	Project title	Government support	Project details	Applicable areas
Core technology development for energy demand management	Development of energy-saving integrated solutions and facility modules for realizing PUE 1.3x data centers	3 years (2018-2021)	1) Analysis of the energy consumption components in the air conditioning-power system in data centers 2) Development of a software that identifies energy saving priorities and impact analysis	Data center refrigeration and air conditioning
Core technology development for energy demand management	Development of data center energy saving solutions	3 years (2018-2021)	Development of a new type of power supply system: DC[59] - AC[60] including UPS[61] + DC distribution type	Data center refrigeration and air conditioning
Core technology development for energy demand management	Development of next-generation energy saving solutions for high-density and high-efficiency data centers	4 years (2022-2025)	Development of a next generation cooling system for computer rooms and high-density data centers, to the level of 50 kW/rack	Data center refrigeration and air conditioning
Support for new researchers	Development of low-power micro-server SoC, efficient for cloud service	3 years (2014-2017)	Development of ARM-based low-power micro-server SoC (system on a chip)	Computing (advanced RISC machine (ARM) servers, hardware)
Development of startup growth technology	Development of ARM servers and standalone BMC modules for low-power and high-performance data centers	3 years (2018-2021)	Development of ARM servers and standalone BMC modules	Computing (ARM servers, hardware, software)
Support for promising ICT technology	Development of high-performance, low-power 40G server networking acceleration technology for edge cloud data centers	2 years (2017-2018)	Development of an integrated package for Virtual Appliance and Cloud OS, and 10G/40G network interface card with QoS[62]-guaranteed data plane acceleration technology. The development aims to reduce power consumption of servers and provide quality assurance for cloud computing users.	Network

59 DC: Direct current power supply.
60 AC: alternating current power supply.
61 UPS: Uninterruptible power supply.
62 Quality of service.

References

Allen, Mark. 2018. "And the Title of the Largest Data Center in the World and Largest Data Center in US Goes to..." Datacenters.com, June 14, 2018. https://www.datacenters.com/news/and-the-title-of-the-largest-data-center-in-the-world-and-largest-data-center-in.

Belkhir, Lotfi, and Ahmed Elmeligi. 2018. "Assessing ICT global emissions footprint: Trends to 2040 & recommendations." Journal of Cleaner Production 177: 448-463. https://doi.org/10.1016/j.jclepro.2017.12.239.

Burton, P. Scott. 2010. "South Korea's 'Low Carbon, Green Growth' Initiative Spurs Renewable Energy, Carbon Market and Green-Tech Developments in the ROK and Beyond." Hunton & Williams Renewable Energy Quarterly 6. https://www.lexology.com/library/detail.aspx?g=423ec506-b23e-4cac-bad0-24bc67afc8b2.

Cha, Hyunah. 2021. "Telcos scramble to find energy efficiency solutions as energy consumption grows with 5G deployment."Ajunews, January 6, 2021. https://www.ajunews.com/view/20210106122010875.

Choi, Insik. 2021. "Interview with Professor Hwang of KDCC." Kharn, June 6, 2021. http://www.kharn.kr/news/article.html?no=16294.

Donor Tracker. 2021. "South Korea unveils Green New Deal ODA strategy." https://donortracker.org/policy-updates/south-korea-unveils-green-new-deal-oda-strategy

Deloitte. 2020. "Rise of the 'Big 4': The semiconductor industry in Asia Pacific." https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/technology-media-telecommunications/cn-tmt-rise-of-the-big-4-en-082820.pdf.

Global Green Growth Institute (GGGI). 2015. "Korea's Green Growth Experience: Process, Outcomes and Lessons Learned." https://gggi.org/report/koreas-green-growth-experienceprocess-outcomes-and-lessons-learned/.

Global Green Growth Institute (GGGI). 2021. "Greening ODA: extending Korea's leadership on New Green Deal and NetZero into its international partnerships." https://gggi.org/site/assets/uploads/2021/03/Feb-19-2021_Greening-ODA_Frank-Rijsberman.pdf

Globe Newswire. 2021. "Telecom Towers Market—Growth, Trends, COVID-19 Impact, and Forecasts (2021-2026)." June 16. https://www.globenewswire.com/news-release/2021/06/16/2248017/0/en/Telecom-Towers-Market-Growth-Trends-COVID-19-Impact-and-Forecasts-2021-2026.html.

Greenhouse Gas Inventory and Research Center of Korea (GIR). 2020. "K-ETS Summary Report (Phase II: 2018-2020)." https://www.gihoo.or.kr/download/downloadFile.do;jsessionid=CiGYkoNILOg81Vc4frwDUDZS9YY-Q71CKzBeUQt3hN7pXiaEJJaZ7w19PKM-whduBd?attFileNo=19152.

Green Technology Center (GTC). 2020. "A Supporting Project to Acquire Technology Certification of the Green and Climate Technology Field for Overcoming the COVID-19 Crisis." https://www.gtck.re.kr/gtck/gtcPublication.do?mode=view&boardNo=17&articleNo=2198.

International Carbon Action Partnership (ICAP). 2019a. "ETS Detailed Information: Korea Emissions Trading Scheme." Last Update: August 9, 2021. https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=47.

International Carbon Action Partnership (ICAP). 2019b. "ETS Detailed Information: EU Emissions Trading System (EU ETS)." Last update: October 29, 2019. https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems[]=.

International Energy Agency (IEA). 2017. "Digitalization and Energy." Paris. https://www.iea.org/reports/digitalisation-and-energy.

International Telecommunication Union (ITU). 2018. "Recommendation ITU-T L.1450, Methodologies for the assessment of the environmental impact of the information and communication technology sector." https://www.itu.int/rec/T-REC-L.1450/en.

International Telecommunication Union (ITU). 2020. "Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement. Recommendation ITU-T L.1470."

Kim, Jiseon. 2021. "Number and Size of Data Centers Continue to Increase in South Korea." Korea IT News, March 17, 2021. https://english.etnews.com/20210317200001.

Korea Data Center Council (KDCC). 2020. "Korea Data Center Market 2020-2023." https://www.digitalcentre.technology/wp-content/uploads/2020/06/KDCC-report.pdf.

Korea Environment Institute (KEI). 2016. "Eco-label Certification System (ECS) in Korea." https://www.greengrowthknowledge.org/national-documents/eco-label-certification-system-ecs-korea.

Ko, Sangwon et al. 2014. 2013 Modularization of Korea's Development Experience: ICT R&D System and Policy, Korea Information Society Development Institute (KISDI). https://www.kdi.re.kr/kdi_eng/publications/publication_view.jsp?pub_no=13688

KT Corp. 2020. ESG (Environmental, Social, and Governance) Report 2020. https://corp.kt.com/eng/html/sustain/possibility/sustainability.html?menuid=trigger_sustainability_03.

Lawrence, Andy. 2019. "Is PUE actually going UP?" Uptime Institute Blog, May 15, 2019. https://journal.uptimeinstitute.com/is-pue-actually-going-up/.

LG U+. 2019. Sustainability Report 2019. https://www.uplus.co.kr/cmg/engl/coif/pelu/RetrievePeLuCsr05.hpi?mid=10384.

Malmodin, Jens, and Dag Lundén. 2018. "The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015" Sustainability 10 (9): 3,027. https://doi.org/10.3390/su10093027.

Ministry of Environment (ME). 2020a. "K-ETS Phase III GHG Trading Permit Allocation Plan" (in Korean). https://ors.gir.go.kr/home/board/read.do?menuId=2&boardMasterId=4&boardId=44.

Ministry of Environment (ME). 2020b. "Green Procurement Guidelines for 2021." http://www.me.go.kr/home/web/policy_data/read.do?pagerOffset=0&maxPageItems=10&maxIndexPages=10&searchKey=&searchValue=&menuId=10277&orgCd=&condition.orderSeqId=7669&condition.rnSeq=40&condition.deleteYn=N&seq=7668.

Ministry of Environment (ME). 2021. "Analysis of the emission trading system in 2019, emission decreased by 2.3% compared to the previous year" (in Korean). http://www.me.go.kr/home/web/board/read.do?boardMasterId=1&boardId=1428870&menuId=286.

Ministry of Knowledge Economy (MKE). 2009. "Green IT Industry Strategy." January. https://www.korea.kr/archive/expDocView.do?docId=21133.

Ministry of Science and ICT (MSIT). 2018. "A Study on Realities of Actual Conditions for the Activation of Data Center Industry Ecosystem." https://scienceon.kisti.re.kr/srch/selectPORSrchReport.do?cn=TRKO201800039182.

Ministry of Science and ICT (MSIT). 2021a. "Establishment of the Strategy for Technology Innovation for carbon neutrality." March. https://english.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&pageIndex=5&bbsSeqNo=42&nttSeqNo=495&searchOpt=ALL&searchTxt=.

Ministry of Science and ICT (MSIT). 2021b. "Strategy of Technology Innovation for Carbon Neutralization." Presentation. 2021 CTCN ASIA-PACIFIC Forum. https://www.ctc-n.org/sites/www.ctc-n.org/files/1.3_Strategy%20of%20technology%20innovation%20for%20carbon%20neutralization_Mr.%20Doyoon%20Kim.pdf.

Ministry of Science and ICT (MSIT). 2021c. "Carbon Neutral Technology Innovation Strategy—10 Core Technology Development Directions" (in Korean). http://www.ctpp.re.kr/home/#0.

Montevecchi, F., T. Stickler, R. Hintemann, S. Hinterholzer. 2020. Energy-Efficient Cloud Computing Technologies and Policies for an Eco-Friendly Cloud Market. Final Study Report. Vienna: European Commission. https://digital-strategy.ec.europa.eu/en/library/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market.

Niederhafner, Stefan. 2014. "The Korean Energy and GHG Target Management System: An Alternative to Kyoto-Protocol Emissions Trading Systems?" TEMEP Discussion Paper No. 2014: 118. Available at SSRN: https://ssrn.com/abstract=2508143 or http://dx.doi.org/10.2139/ssrn.2508143.

OECD (Organisation for Economic Co-operation and Development). 2002. Measuring the Information Economy 2002. Paris: OECD Publishing. https://www.oecd-ilibrary.org/science-and-technology/measuring-the-information-economy-2002_9789264099012-en.

Osmotherly, Kieron. 2019. "The new shape of the global telecom tower industry." TowerXchange, December 9, 2019. https://www.towerxchange.com/the-new-shape-of-the-global-telecom-tower-industry/.

Pew Research Center. 2021. "In Response to Climate Change, Citizens in Advanced Economies Are Willing to Alter How They Live and Work."

SK Telecom. 2020. Sustainability Report 2019. https://www.sktelecom.com/en/csr/download/persist.do.

The Government of the Republic of Korea. 2020a. 2050 Carbon Neutral Strategy of the Republic of Korea Towards Sustainable and Green Society. December. https://www.greengrowthknowledge.org/national-documents/2050-carbon-neutral-strategy-republic-korea-towards-sustainable-and-green-society.

The Government of the Republic of Korea. 2020b. The Korean New Deal. https://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948.

The Government of Republic of Korea. 2021. "The 38th meeting of the international Committee for International Development and Cooperation." https://www.korea.kr/news/pressReleaseView.do?newsId=156460573#site-map-layer

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 2012. "Low Carbon Green Growth Roadmap for Asia and the Pacific: Case Studies and Policy Papers." https://www.unescap.org/resources/low-carbon-green-growth-roadmap-asia-and-pacific-case-studies-and-policy-papers#.

United Nations Framework Convention on Climate Change (UNFCCC). 2020a. The Republic of Korea's Update of its First Nationally Determined Contribution. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Republic%20of%20Korea%20First/201230_ROK%27s%20Update%20of%20its%20First%20NDC_editorial%20change.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2020b. "Telecoms Sector Agrees Pathway to Net Zero Emissions." February 28. https://unfccc.int/news/telecoms-sector-agrees-pathway-to-net-zero-emissions

World Bank. 2003. "ICT and MDGs." https://documents1.worldbank.org/curated/en/538451468762925037/pdf/278770ICT-010mdgs0Complete.pdf.

World Bank. 2009. "Measuring foreign direct investment in the area of information and communication technology (Vol. 2) : Deliverable 1 - definition of the ICT Sector." https://documents.worldbank.org/en/publication/documents-reports/documentdetail/757361468248669440/deliverable-1-definition-of-the-ict-sector.

World Bank. (forthcoming) Information and Communication Technology (ICT) and Climate Change - Direct Greenhouse Gas Emissions of the ICT Sector

Yonhap News Agency. 2021. "(LEAD) Moon: S. Korea to set higher goal of cutting emissions, submit it to U.N. this year." April 22, 2021. https://en.yna.co.kr/view/AEN20210422006051315.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