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# Greenhouse Gas Emissions of Finland's Information Economy Sector

## A SUPPLY CHAIN PERSPECTIVE

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## Abstract

The environmental benefits and harms of information and communication technology (ICT) have been widely discussed in Finland since 2019. The climate impact of information and communication technology on the environment consists of three channels: procurement, the ICT sector's own carbon footprint, and the impact on other sectors of the economy (incl. public sector). Indeed, focusing solely on one sector's own emissions often leads to misleading conclusions about the industry's carbon footprint. This study examines the evolution of greenhouse gas emissions in the ICT sector and its supply chains in 2008–2019. In addition, the study examines the countries from which greenhouse gas emissions in the ICT sector and its supply chain originate.

# Tiivistelmä

## Informaatiosektorin kasvihuonekaasupäästöt toimitusketjuissa

Informaatio- ja viestintäteknologian (ICT) tuottamista ympäristöhyödyistä ja -haitoista on Suomessa käyty laajaa keskustelua vuodesta 2019. Informaatio- ja viestintäteknologian ilmastovaikutukset ympäristöön muodostuvat kolmen kanavan kautta: hankinnoista, ICT-sektorin omasta hiilijalanjäljestä ja vaikutuksista talouden muihin sektoreihin (ml. julkinen sektori). Keskittyminen yksinomaan yhden sektorin omiin päästöihin johtaakin usein harhaanjohtaviin johtopäätöksiin toimialan hiilijalanjäljestä. Tässä tutkimuksessa käydään läpi kasvihuonekaasupäästöjen kehittymistä ICT-sektorilla ja sen toimitusketjuissa vuosina 2008–2019. Lisäksi tutkimuksessa kuvataan mistä maista ICT-sektorin ja sen toimitusketjun kasvihuonekaasut tulevat.

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**Kiitokset:** Tämä raportti on laadittu osana Suomen itsenäisyyden juhlarahasto Sitran kestävyysratkaisut-teeman työtä ja Business Finlandin rahoittamaa BRIE-ETLA 2019–2023 -tutkimusprojektia. Sitran tavoitteena on vahvistaa luonnon monimuotoisuutta ja vauhdittaa ekologista jälleenrakentamista. Jotta digitalisaatio tukee näitä tavoitteita, tarvitaan lisää tietoa sen positiivisista ja negatiivisista systeemitason ympäristövaikutuksista. Sitran tavoitteena on myös selvittää, millaiset digitaaliset ratkaisut edistävät kiertotalouteen siirtymistä. Tämä raportti tarjoaa uutta tietoa informaatiosektorin ja sen toimitusketjun kasvihuonekaasupäätöistä Suomessa ja kasvihuonekaasupäästödatan saatavuudesta sekä yksilöi aiheeseen liittyviä jatkotutkimustarpeita.

**Keywords:** Information economy sector, Supply chain, Greenhouse gas emissions, Carbon neutrality

**Avainsanat:** ICT-sektori, Toimitusketju, Kasvihuonekaasupäästöt, Päästöintensiteetti

**JEL:** L8, L82, L86, L94

# Contents

# 1 Introduction

The environmental benefits and harms of the information and communication technology (ICT) have attracted a wide-ranging debate (Freitag et al., 2021; George, Merrill & Schillebeeckx, 2021; Lange et al., 2020). The raw materials used in the ICT sector, the production of equipment and services and their use during their life cycle have negative environmental impacts. On the other hand, the ICT sector helps to optimize work efficiency in various industries, the energy consumption of equipment, and emissions with different technologies and applications. The climate impact of the ICT sector thus consists of three channels: the ICT sector's own greenhouse gas emissions (GHG), emissions generated to produce intermediate inputs (i.e., sector procurement) to the sector, and the impact on other sectors of the economy (including public sector). Additionally, there are several issues in measuring the environmental impacts of the ICT sector: the reliability and timeliness of available data, the definition of the sector, GHG emissions in supply chain, and the life cycle of ICT products and services. All these factors can lead to an underestimation of GHG emissions of the ICT sector (Freitag et al., 2021).

Previous studies have yielded mixed results on GHG emissions in the ICT sector. Some research make high predictions about the future energy consumption and emissions of the ICT sector (Andrae & Edler, 2015; Belkhir & Elmeligi, 2018). On the other hand, some research estimate that energy consumption and emissions have started to decline due to improved energy efficiency in information technology (Malmodin & Lundén, 2016, 2018; Malmodin et al., 2010). Previous research has also come to various conclusions about the main sources of emissions in the ICT sector. In addition, estimates of future emission trends based on alternative scenarios vary considerably depending on the assumptions used. Hiekkanen et al. (2021) examined the energy consumption of the information economy sector, which includes the ICT sector and content production, in Finland and in Europe using energy accounting data. The study showed that the information economy sector accounted for 1.1 percent of the total electricity consumption in Finland in 2018. According to the findings of the research, the electricity consumption of the information economy sector increased by 3.4 percent on an annual basis in the period 2011–2018 (Hiekkanen et al., 2021).

Recent research suggests that focusing solely on the ICT sector's own emissions can lead to misleading conclusions about total emissions of the ICT industry. Zhou et al. (2019) show that the environmental impact of China's ICT sector is much higher when accounting for the use of emission-intensive intermediate inputs (especially those from the energy and base materials sectors). Considering these findings, to manage GHG emissions of the ICT sector special attention should be paid to the ICT supply chain.

**The main findings of this study are the following:**

- The share of the information economy sector in Finland's gross domestic product (GDP) was 6.5 percent in 2018 (7.4 percent in 2020). Correspondingly, in 2018, the share of the digital economy in Finland's GDP was 12.6 percent. The GHG emissions of the information economy sector in Finland reached 23 thousand tonnes of CO2 equivalent emissions (CO2e) in 2019 corresponding to 0.04 percent of all Finland's GHG emissions.

- Based on the previous results above, the GHG emission intensity of the information economy sector was 1.5 t CO2e / € million in 2019 (1.6 t CO2e / € million in 2018). The GHG emission intensity of the information economy sector has decreased significantly in Finland over the past ten years. Please note that these figures do not account for the GHG emissions of the information economy sectors' intermediate inputs (i.e., sector procurement).

- In 2018, domestic intermediate inputs accounted for 63 percent and imported inputs for 37 percent of the information economy sector's total intermediates (for first tier of suppliers). The share of domestic contributions has increased in recent years. According to our previous research on global value chains we could use the same split of 63 percent / 37 percent to first tier domestic intermediate inputs – the share of imported inputs would then increase to more than 60 percent (including second tier of suppliers). For further information on value chains and analysis and methodology see our previous research: Ali-Yrkkö et al. 2011, Kalm et al. 2014, Larsen et al. 2018. Based on the findings of the research, there are some signs of outsourcing emissions abroad (the share of imported intermediates from foreign industries J62–63 increased from 7 to 10 percent and the share of inputs

from foreign industries J59–60 increased from 0.5 to 1.9 percent from 2010 to 2018).

- ICT manufacturing sector has a higher GHG emission intensity than ICT services sector. This means that ICT manufacturing pollutes more per unit of economic output compared to ICT services. In general, the inputs to the information economy sector come from industries whose GHG emission intensities are higher than the information economy sector's own GHG emissions intensity. In 2018, GHG emissions of producing intermediate inputs to the information economy sector by other industries were 77 times higher than the information economy sector's own GHG emissions.

- The results described above do not consider the inputs and outputs of streaming service companies operating with the "over the top" business model (OTT business model[1]), as they are not registered in the input-output statistics of the Finnish information economy sector. The GHG emissions of streaming service companies operating under the OTT business model are reported in the input-output statistics of the country in which these company operations are registered.

- With respect to the geography of supply chain (value chain) location, the origin of intermediate inputs to Finland's ICT services sector in 2018 (2020) is as follows: Asia – 35 percent (54%), Europe – 51 percent (38%), North America – 13 percent (6%), and other continents – 1 percent (2%). The origin of intermediate inputs to the ICT manufacturing is as follows: Asia – 61 percent (50%), Europe – 24 percent (34%), North America – 13 percent (13%), other continents – 2 percent (3%). Intermediates imported by Finland's information economy sector are mainly from Asia (mostly China), the United States and some European countries.

**The broader conclusions and key policy recommendations of this study are the following:**

- GHG emissions and emission intensities reported by companies and industries provide an incomplete picture of the environmental friendliness of their economic activities. Reported figures usually do not account for GHG emissions of intermediate goods and services (procured goods and services), as well as other purchasing decisions domestically or abroad, used by companies and industries to produce final products. When considering the entire supply chain (value chain) the reported figures of GHG emissions and emission intensities of companies and industries can significantly change. Based on the above, the focus of measurement and reporting should be shifted to a more comprehensive supply chain (value chain) GHG emission analysis.

- As the economic importance of the digital economy has increased, imports of intermediate inputs (sector procurement) to the information economy sector from abroad have grown significantly over the last ten years. This has led to an increasing share of GHG emissions coming from earlier stages of the supply chain abroad (for more information see e.g. Ali-Yrkkö et al. (2011) and Kalm et al. (2014) as well as Larsen et al. (2018)). Regarding intermediates inputs from abroad, the information economy sector's management should pay particular attention to GHG emissions and emission intensity of economic activities of their procurement abroad. Specifically, documentation, assessment, and measurement of GHG emissions should be requested of intermediate inputs.

- In recent years, Finland has outsourced its GHG emissions abroad to a greater extent in the information economy sector's supply chain. The OTT business model of media services continues to increase the intermediate inputs to the information economy sector from foreign sources, even if the procurement decision in that business model is made by the consumer instead of the companies. The Ministry of Transport and Communications, together with the Ministry for Foreign Affairs, should study the wider effects of the OTT business model, namely digital direct (streaming) services, on Finland's GHG emissions. Service providers operating under the OTT business model should be required to report more detailed on their GHG emissions.

This report continues as follows. In section two, we briefly discuss the previous literature. In section three, we examine the economic developments of the information economy sector and the digital economy sector. The value added of the sectors is a key variable to understanding the GHG emission intensity of the information economy sector and its supply chain. GHG emission intensi-

ty is a measure of emissions by economic activity and is widely used to compare different industries in terms of their environmental performance.[2] In section four, we describe the development of the information economy sector's GHG emissions in 2008–2019 and report the GHG emission intensity of the sector. In section five, we examine domestic and imported intermediate inputs (i.e., sector procurement) to Finland's information economy sector: from which industries and countries they are coming from. We also investigate which domestic industries are the main consumers of the goods and services produced by the information economy sector. To better understand the total GHG emissions of the information economy sector, section six provides some estimates on GHG emissions generated by domestic and foreign industries to produce intermediates to Finland's information economy sector.

# 2 Previous literature

Will the increased use of ICT lead to an increase in energy consumption and emissions, or will ICT help to promote the transition to a greener, lower-emission economy? The ICT sector's raw materials, production and use of equipment and services have negative environmental impacts; on the other hand, the technological solutions provided by the ICT sector help to increase efficiency, optimize energy consumption and reduce emissions. Although the most worrying views of the past research literature on the future of energy consumption and emissions in the ICT sector (Andrae & Edler, 2015) seem to be exaggerated, previous studies have underestimated the role of supply chain in emissions development in the ICT sector. In addition, the consensus in the literature suggests that curbing the future emissions performance of the ICT sector requires not only policy measures but also significant efforts within the industry to curb emissions development (Freitag et al., 2021).

Belkhir and Elmeligi (2018) look at the carbon footprint of the ICT sector – in terms of both production and use – and estimate that it will account for around 3–3.6 percent of global GHG emissions by 2020. If this annual growth of around 5.6 to 6.9 percent were to remain unchanged, the estimate for ICT emission share would be 14 percent in 2040. According to that study, the vast majority of emissions – about two-thirds – come from ICT infrastructure, which includes data centers and communications networks. Andrae and Edler (2015) provide alternative scenarios for the future electricity consumption of ICT and estimate that the share of in-use electricity consumption of consumer equipment will increasingly decrease and be replaced by the growing share of data networks and data centers. The analysis also states that the growing electricity consumption by ICT could, *at worst*, account for up to 23 percent of global GHG emissions by 2030 if the energy efficiency of data networks and data centers does not improve sufficiently. However, these simplified and far-reaching projections are subject to considerable reservations and may lead to erroneous policy conclusions (Koomey & Masanet, 2021).

Koomey and Masanet (2021) go through the pitfalls of previous literature and criticize previous studies for underestimating the improvement in energy efficiency in data centers (Andrae & Edler, 2015) or completely ignoring it (Belkhir & Elmeligi, 2018). According to them, better data and a more careful, accurate and transparent analysis of energy consumption and emissions in the ICT sector would be needed. Koomey and Masanet (2021) warn against making simplified forecasts for information technology electricity consumption that go beyond a few years, as the sector is changing rapidly. As an example, researchers cite the link between the growth of data traffic and energy use: higher data traffic may not be reflected in energy consumption if the improvement in energy efficiency compensates for the growth. On the other hand, the analysis of energy consumption in information technology should look at the whole, not just the individual aspects of the system (Masanet et al., 2020).

Malmodin et al. (2010) look at electricity consumption and GHG emissions in the information economy sector. Based on this review, the main share of GHG emissions in the information economy sector is in-use emissions, although the role of manufacturing is not insignificant. Malmodin and Lundén (2018) analyze the energy and carbon footprint of the information economy sector in 2010–2015. The study finds that the global growth of the information economy sector's carbon footprint had started to decline despite the ever-increasing data traffic. In addition, the results indicated that the environmental impact of the information economy sector was significantly lower than previously forecast. According to this analysis,

the main carbon footprint of the ICT sector is related to endpoint devices – their use, but also their manufacture. Looking at the carbon footprint of the information economy sector, the ICT sector was estimated at 1.4 percent and the content production sector at 1.2 percent of the global carbon footprint. Malmodin and Lundén (2016) estimate that the Swedish information economy sector accounted for 1.9 percent of the country's carbon footprint in 2015, considering foreign production. Of this figure, ICT accounted for 1.2 percent and content production for 0.7 percent. The share of the Swedish information economy sector's carbon footprint in 2015 was lower than in 2010.

Freitag et al. (2021) review estimates in the academic literature on the carbon footprint of ICT and, in the light of these figures, estimate that ICT will account for around 1.8–2.8 percent of global GHG emissions by 2020. However, the analysis points out that there are significant differences in the approaches of previous studies, in addition to which studies systematically underestimate the carbon footprint of ICT by ignoring part of the supply chain in their assessments. Freitag et al. (2021) estimate that, if the impact of supply chain were considered, ICT would account for between 2.1 and 3.9 percent of the global carbon footprint. Existing country-specific evidence also suggests that focusing solely on the ICT sector's own emissions could lead to misleading conclusions about the carbon footprint of the ICT sector. This is explained by the use of emission-intensive intermediates outside the ICT sector. Zhou et al. (2019) show that the environmental impact of China's ICT sector is manifold when the use of emission-intensive intermediate inputs – especially electrical and basic materials, including chemicals, metals and minerals – is taken into account. These carbon sources accounted for more than 80 percent of the ICT sector's emissions. In the light of these findings, the most effective way to control emissions in the ICT sector would be to optimize ICT supply chain comprehensively.

Lange et al. (2020) analyze the link between digitalization and energy consumption and conclude that digitalization seems to lead to an increase in energy consumption. However, the relationship between the use of information and communication technologies and emissions is not unambiguous. Arshad et al. (2020) and Park et al. (2018) find that the use of ICT is linked to rising CO2 emissions. On the other hand, Salahuddin et al. (2016) do not find a significant link between internet use and CO2 emissions. Añón Higón, et al.(2017) find that the relationship between ICT and GHG emissions is non-linear – like the inverted-U curve. In the light of the findings of the study, many developed countries have already reached a point where emissions will decrease as ICT development improves.

Masanet et al. (2020) point out that the growth in electricity consumption in data centers has slowed down due to smart, energy-efficient measures; however, better data would be needed to model data centers' energy consumption in order to guide policy measures. Koot and Wijnhoven (2021) provide calculations indicating that increasing the energy efficiency of data centers is not sufficient to compensate for the increase in data usage. On the other hand, the development of energy efficiency in fixed network data transmission is in line with the improvement in the overall energy efficiency of data processing (Aslan et al., 2018).

Andrae et al. (2017) find that significant savings and emission reductions in energy consumption can be achieved in the ICT sector by paying attention to energy consumption throughout the supply chain. Taken as a whole, the previous literature suggests that assessing the climate footprint of the ICT sector requires a systematic approach that takes into account the whole life cycle and supply chain; in addition, targeted policy and intra-industry measures (such as carbon neutrality or carbon negative targets) are needed to reduce emissions (Freitag et al., 2021). On the other hand, setting and monitoring policy objectives also requires high-quality data and further research to verify energy consumption and emissions in the information economy sector (Masanet et al., 2020).

# 3 Economic development of the information economy sector in Finland

OECD (2002) defines ICT sector as a combination of the ICT manufacturing and the ICT services that capture, transmit and display data and information electronically. The OECD's definition is based on the International Standard Industrial Classification of All Economic Activities (ISIC Rev. 3) and provides a good starting point

for defining which economic activities belong to the ICT sector. The information economy sector is a more general grouping of economic activities that includes both the ICT sector and the information and media sector (OECD, 2011). In this study we use the OECD's definition of the information economy sector (Hiekkanen et al., 2020; Hiekkanen et al., 2021) that relies on the Standard Industrial Classification 2008 (TOL08)[3], which is a national-based version of the EU's classification of economic activities (NACE Rev. 2).

The ICT manufacturing is represented by the NACE's division *C26 Manufacture of computer, electronic and optical products* of section C (Manufacturing). The ICT services are represented by divisions *J58 Publishing activities, J59 Motion picture, video and television programme production, sound recording and music publishing activities, J60 Programming and broadcasting activities, J61 Telecommunications, J62 Computer programming, consultancy and related activities* and *J63 Information service activities* of section J (Information and communication).

## 3.1 How big is the information economy sector?

This section provides a short overview of economic developments of Finland's information economy sector during 1980–2020. Based on national accounts statistics obtained from Eurostat, we examine the developments of the ICT manufacturing and the ICT services industries.

In 2020, the size of the information economy sector measured in value added was about €17.5 billion. This figure includes the contributions of both the ICT manufacturing and the ICT services. The information economy sector was dominated by the industries of the ICT services accounting for 73.5 percent (or €12.9 billion) of the total value added generated by the sector (see Table 1). The industry *J62–63 Computer programming, consultancy and related activities*; *Information service activities* provided 40 percent of the sector's value added. The second largest contributor was the ICT manufacturing (26.5%). The industries *J58 Publishing activities* (14%) and *J61Telecommunications* (13%) followed, while the smallest share was presented by industries *J59–60 Motion picture, video and television program production, sound recording and music*

**Table 1 The shares of the ICT industries in the gross value added of the information economy sector in 2010–2020, %**

| | ICT-manufacturing (C26) | ICT-services (J) | Publishing activities (J58) | Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities (J59–60) | Telecommunications (J61) | Computer programming, consultancy and related activities; Information service activities (J62–63) |
|---|---|---|---|---|---|---|
| 2010 | 44,4 | 55,6 | 10,7 | 5,8 | 15,0 | 24,1 |
| 2011 | 38,5 | 61,5 | 11,5 | 6,3 | 15,4 | 28,3 |
| 2012 | 22,6 | 77,4 | 14,5 | 7,6 | 18,6 | 36,7 |
| 2013 | 29,8 | 70,2 | 13,7 | 6,5 | 16,7 | 33,4 |
| 2014 | 29,8 | 70,2 | 14,6 | 6,5 | 15,2 | 34,0 |
| 2015 | 27,3 | 72,7 | 16,6 | 6,7 | 14,9 | 34,5 |
| 2016 | 28,0 | 72,0 | 16,9 | 6,4 | 14,6 | 34,2 |
| 2017 | 28,5 | 71,5 | 15,1 | 6,3 | 14,0 | 36,1 |
| 2018 | 22,4 | 77,6 | 15,0 | 6,9 | 15,2 | 40,4 |
| 2019 | 23,1 | 76,9 | 13,9 | 6,6 | 14,5 | 41,8 |
| 2020 | 26,5 | 73,5 | 14,1 | 5,7 | 13,3 | 40,4 |

**Source:** Authors' calculations based on Eurostat data.

*publishing activities*; *Programming and broadcasting activities* with about 6 percent of the total value added of the sector.

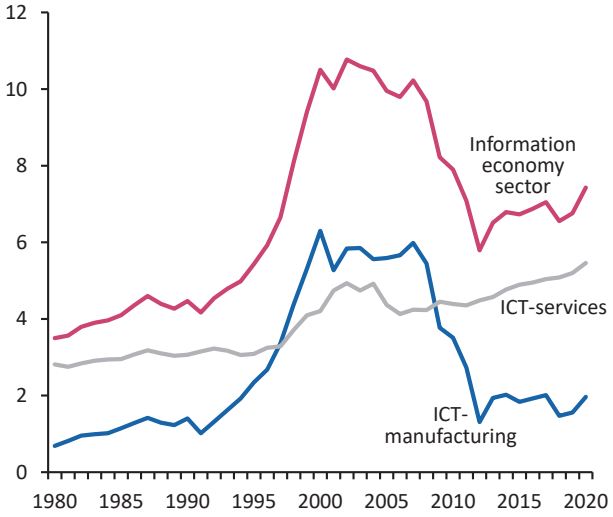
To provide further context to the numbers presented above, Figure 1 shows the shares of the information economy sector and its two sub-sectors in Finland's GDP during the period 1980–2020. In 2020, the information economy sector was nearly equivalent to 7.4 percent of GDP (the shares of the ICT manufacturing and ICT services were 2 percent and 5.5 percent, respectively). The ICT services accounted for most of the ICT activity, as they were about three times larger than the ICT manufacturing when measured in value added terms in 2015–2020. The ratio of the value added in the ICT services relative to GDP grew consistently from 2.8 percent in 1980 to 5.5 percent in 2020. The ratio of value added from the ICT manufacturing to GDP remained rather stable until 1991 and then increased between 1992 and 2000. The highest value was recorded in 2000, where the ICT manufacturing generated value added equivalent to 6.3 percent of the country's GDP. Considering the developments there is a noticeable shift within the sector from manufacturing to services.

To identify the sources of the economic growth of the ICT services, consider Figure 2 that depicts the shares of the ICT services' industries in 1980–2020. The developments within the ICT services have led to significant structural changes in this sub-sector. For instance, there has been a shift from industry *J61 Telecommunications* towards *J62–63 Computer programming, consultancy, and related activities*; *Information service activities*. In 1980, the share of telecommunications industry accounted for 41 percent and computer programming for 14 percent of the value added of the ICT services. In 2020, the share of telecommunications industry dropped to 18 percent, while the share of computer programming rose to 55 percent of the total value added generated by the ICT services sector.

## 3.2 How big is the digital economy?

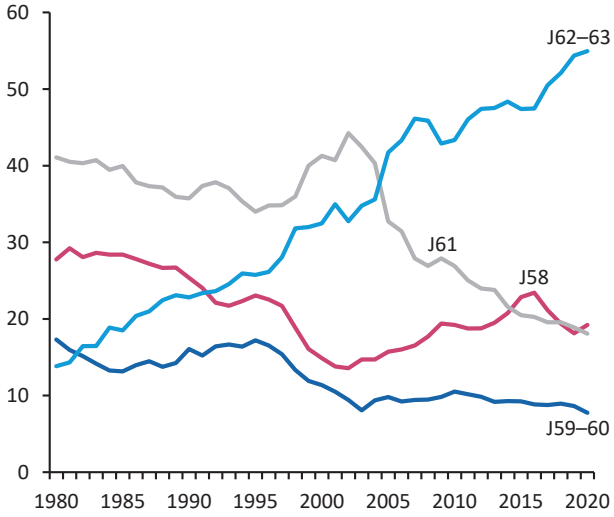
In contrast to the information economy sector that accounts for only certain specific industries, digital economy is a more complex entity that spans across many industries of the economy. The OECD (2020), for instance, proposes the following definition: "*The Digital Economy incorporates all economic activity reliant on, or significantly enhanced by the use of digital inputs, including digital technologies, digital infrastructure, digital services and data. It refers to all producers and consumers, including government, that are utilizing these digital inputs in their economic activities*".

**Figure 1 The share of Finland's information economy sector in the country's GDP and the shares separately for the ICT services and ICT manufacturing in 1980–2020, %**




**Source:** Authors' calculations based on Eurostat data.

**Figure 2 The shares of the ICT services' industries in the ICT services sector in 1980–2020, %**




**Source:** Authors' calculations based on Eurostat data.

A systematic way to measure the digital economy has been taken in an earlier research (see Ali-Yrkkö et al., 2020). To measure the size of Finland's digital economy, in this study we apply an alternative approach that has been initially developed to measure the size of the bioeconomy sector (Kuosmanen et al., 2020). Like the bioeconomy, the digital economy spans across many industries of the economy. Using input-output tables for Finland (2010–2018) as an empirical data, for every industry we first define the shares of ICT-based inputs from the information economy sector in the total input use. We then apply these shares to the value added of the industries to calculate their contributions to the country's digital economy. The size of the digital economy is thus a sum of industry-specific contributions. To illustrate, consider industry O *Public administration and defence; compulsory social security*. In 2018, 17 percent of the total intermediate inputs of industry O came from the information economy sector. The value added of industry O in 2018 was €11.4 billion. Using 17 percent weight, the contribution of this industry to the digital economy of the country was about €1.9 billion in 2018.

To shed light on the size of the digital economy and the size of the information economy sector, Table 2 reports the shares of the digital and information sectors in the country's GDP in 2010–2018. As the digital economy accounts for the contributions of all industries, its share in the country's economy is about twice as high as the size of the information economy sector. Our estimate of the digital economy in 2018 is €29.5 billion, which is 12.6 percent of Finland's GDP. The size of the information economy sector is estimated to be €15.3 billion or 6.5 percent of the GDP in 2018.

Table 3 reports the shares of different industries in the digital economy for the most recent year for which input-output tables for Finland are available (year 2018). The largest contribution to the digital economy was by industries *J62–63 Computer programming, consultancy and*

**Table 2 The shares of the digital economy and information economy sectors in Finland's GDP in 2010–2018, %**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| Digital economy | 13,6 | 13,0 | 11,8 | 12,5 | 12,7 | 12,7 | 13,1 | 13,4 | 12,6 |
| Information economy sector | 7,9 | 7,1 | 5,8 | 6,5 | 6,8 | 6,7 | 6,9 | 7,0 | 6,5 |

**Source:** Authors' calculations based on Eurostat data.

**Table 3 Finland's digital economy in 2018: the contributions to the digital economy by industry, %**

| Industry | Share, % |
|---|---|
| Computer programming, consultancy and related activities; Information service activities (J62–63) | 20,9 |
| Manufacture of computer, electronic and optical products (C26) | 11,6 |
| Telecommunications (J61) | 7,9 |
| Publishing activities (J58) | 7,8 |
| Public administration and defence; compulsory social security (O) | 6,5 |
| Education (P) | 4,3 |
| Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities (J59–60) | 3,6 |
| Wholesale trade, except of motor vehicles and motorcycles (G46) | 3,2 |
| Residential care activities; Social work activities without accommodation (Q87–88) | 3,0 |
| Other industries | 31,4 |

**Source:** Authors' calculations based on Eurostat data.

*related activities*; *Information service activities* (21%). The second largest contributor was the ICT manufacturing with the share of about 12 percent. The next largest industries were industries *J61 Telecommunications* (8%) and *J58 Publishing activities* (8%). Note that the composition of the digital economy (Table 3) is similar to the composition of the information economy sector (Table 1).

# 4 Greenhouse gas emissions of the information economy sector in Finland

This section describes the developments of GHG emissions generated by Finland's information economy sector in 2008–2019. We use statistics of GHG emissions classified by economic activities obtained from Eurostat's air emissions accounts that are tailored for integrated environmental economic analyses.[4]

The total GHG emissions generated by the information economy sector accounted for about 23 thousand tonnes of CO2e in 2019. About half of that was generated by the ICT manufacturing sector and another half by the ICT services sector (see table 4). Since 2008, GHG emissions decreased by 73 percent (GHG emissions generated by the information economy sector accounted for 86 thousand tonnes of CO2e in 2008). The main underlying driver behind the fall of the total GHG emissions of the sector is the decreasing contribution of the ICT services sector. The largest reduction took place in 2015 when emissions fell sharply by about 29 thousand tonnes, or 56 percent.

Table 4 further reports the GHG intensities[5] of the ICT manufacturing and ICT services sectors, which are the emission rates of GHG in CO2e to the value added of these sectors (two columns on the right side of the table). The emission intensity of the ICT services sector decreased substantially during the period from 2008 to 2015. Since then, it stabilized at one tonne of CO2e per million euros of value created. The emission intensity of the ICT manufacturing was about three times larger than the emission intensity of the ICT services in 2015–2019. Even though in terms of levels, the ICT manufacturing and the ICT services have similar contributions to the total emissions of the sector, the ICT services can be considered as a less polluting sector.

As mentioned above, the ICT manufacturing and the ICT services contributed about half and half to the total GHG emissions of the information economy sector in 2019 (11.2 and 11.9 thousand tonnes of CO2e, respectively). Within the ICT services sector, the major contributors were industries *J59–60 Motion picture, video and television*

**Table 4 GHG emissions and GHG emission intensity of the ICT manufacturing and ICT services sectors in 2008–2019**

| | GHG (1000 tonnes of CO2e) | | GHG-intensity, (tonnes of CO2e per million euros)* | |
|---|---|---|---|---|
| | ICT manufacturing | ICT services | ICT manufacturing | ICT services |
| 2008 | 15,5 | 70,5 | 1,3 | 7,5 |
| 2009 | 15,9 | 60,0 | 2,1 | 6,6 |
| 2010 | 13,0 | 56,6 | 1,8 | 6,1 |
| 2011 | 14,2 | 45,5 | 2,4 | 4,8 |
| 2012 | 14,3 | 45,4 | 5,1 | 4,8 |
| 2013 | 19,0 | 40,3 | 4,7 | 4,2 |
| 2014 | 20,3 | 31,7 | 4,8 | 3,2 |
| 2015 | 12,2 | 10,5 | 3,1 | 1,0 |
| 2016 | 15,3 | 11,9 | 3,7 | 1,1 |
| 2017 | 13,1 | 12,0 | 2,9 | 1,1 |
| 2018 | 11,2 | 12,7 | 3,4 | 1,1 |
| 2019 | 11,2 | 11,9 | 3,1 | 1,0 |

* In 2015 prices. **Source:** Eurostat (GHG), authors' calculations based on Eurostat data (GHG intensity).

*programme production, sound recording and music publishing activities; Programming and broadcasting activities* with the relative contribution of 17 percent. The shares of the ICT industries *J62–63 Computer programming, consultancy and related activities; Information service activities* and J61 *Telecommunications* were 12.6 and 13 percent, respectively, and the share of *J58 Publishing activities* was about 9 percent. The ICT manufacturing generated 23 percent of the value created by the whole information economy sector in 2019 (Table 1). However, it was responsible for about half of the information economy sector's emissions (49%) (11.2 tonnes, see Table 4). The ICT services though generated a value added of 77 percent (Table 1) and emissions of 51 percent (11.9 tonnes, see Table 4).

# 5 A supply chain perspective

## 5.1 Information economy sector's inputs and outputs

This section examines which industries are the main providers of intermediate inputs to the information economy sector and identify which industries rely on the outputs of this sector. We use Eurostat's symmetric input-output tables for Finland[6], which are industry-by-industry matrices of domestic production and imports, that are available for years 2010–2018. Based on the standardized data of national accounts, input-output tables represent monetary flows within an economy. They show how domestic production and imports of goods and services in an economy are used by industries for intermediate consumption and final use.

To examine the sources of intermediate inputs to the information economy sector, the total use of intermediate consumption[7] can be decomposed to the four sourcing possibilities:

1. Domestic intra-sector intermediate consumption
2. Domestic inter-sector intermediate consumption
3. Imports of intra-sector intermediate consumption
4. Imports of inter-sector intermediate consumption.

The *intra-sector intermediate* consumption are the inputs to the information economy sector that are produced by the ICT industries. For example, goods produced by the ICT industry *C26 Manufacture of computer, electronic and optical products* are used as inputs in the ICT industry *J62–63 Computer programming, consultancy and related activities; Information service activities*. The *inter-sector intermediate* consumption are the inputs to the information economy sector that are produced by non-ICT industries. For example, services provided by industry *M72 Scientific research and development* are used as intermediate inputs in *C26 Manufacture of computer, electronic and optical products*.

Table 5 reports the shares of domestic and imported (intra- and inter-sector) intermediates in the total intermediate consumption of the information economy sector in percentage. The use of the domestic intermediates by the sector increased from 55 to 63 percent between 2010 and 2018. The use of imported inputs declined from 45 to 37 percent during the same period. The larger share of domestic inputs in intermediate consumption is mainly caused by the large use of domestic inter-sector intermediate consumption. For instance, in 2018, 36 percent of the total intermediates were supplied by domestic non-ICT industries and 27 percent by the information economy sector itself.

**Table 5 The shares of domestic and imported (intra- and inter-sector) intermediate inputs in total intermediate consumption of Finland's information economy sector, %**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| Domestic intra-sector inputs | 21,1 | 22,0 | 19,7 | 22,2 | 22,8 | 25,1 | 25,1 | 25,0 | 26,7 |
| Domestic inter-sector inputs | 34,2 | 36,3 | 37,2 | 40,6 | 41,5 | 40,6 | 41,0 | 37,1 | 36,3 |
| Imported intra-sector inputs | 14,4 | 14,4 | 12,0 | 9,0 | 10,0 | 10,3 | 11,1 | 14,2 | 13,9 |
| Imported inter-sector inputs | 30,4 | 27,3 | 31,2 | 28,2 | 25,7 | 24,1 | 22,8 | 23,6 | 23,0 |

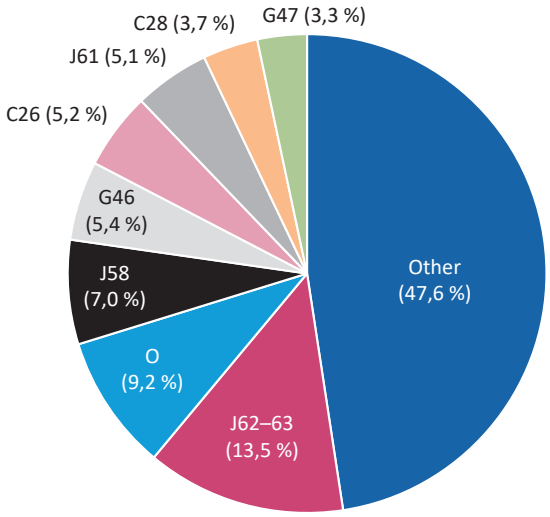
**Source:** Authors' calculations based on Eurostat data.

Focusing specifically on domestic intermediates, Figure 3 shows the shares of intermediate inputs from domestic industries to the information economy sector in year 2018. The three main domestic suppliers of intermediate inputs were the industries: *J62–63 Computer programming, consultancy and related activities; Information service activities* (21%), *J58 Publishing activities* (9%) and *J61 Telecommunications* (6%). Of the total intermediate consumption 5 percent came from domestic industries *G46 Wholesale trade, except of motor vehicles and motorcycles* and 5 percent from *C18 Printing and reproduction of recorded media*.

Figure 4 shows the shares of imported intermediate inputs of foreign industries used by Finland's information economy sector in 2018. The three main suppliers were the foreign industries: *C26 Manufacture of computer, electronic and optical products* (23%), *M72 Scientific research and development* (21%) and *J62–63 Computer programming, consultancy and related activities; Information service activities* (11%).

Regarding the outputs of the information economy sector to other industries, in 2018 the information economy

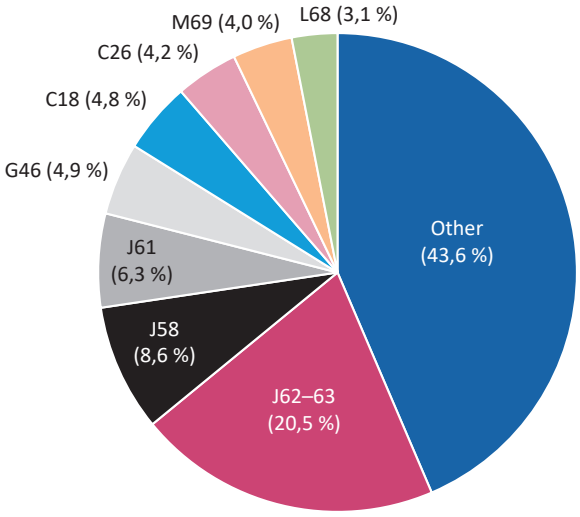
**Figure 5 The output shares: outputs from Finland's information economy sector to other industries in 2018, %**




J62–63 Computer programming, consultancy and related activities; Information service activities; O Public administration and defence; compulsory social security; J58 Publishing activities; G46 Wholesale trade, except of motor vehicles and motorcycles; C26 Manufacture of computer, electronic and optical products; J61 Telecommunications; C28 Manufacture of machinery and equipment n.e.c.; G47 Retail trade, except of motor vehicles and motorcycles.

**Source:** Authors' calculations based on Eurostat data.

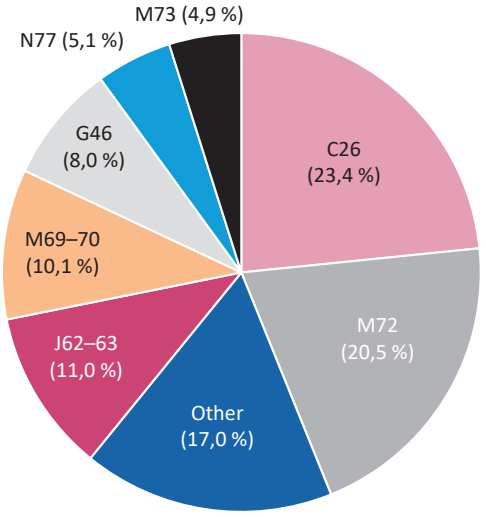
**Figure 3 The shares of domestic intermediate inputs (by industry) used by Finland's information economy sector in 2018, %**




J62–63 Computer programming, consultancy and related activities; Information service activities; J58 Publishing activities; J61 Telecommunications; G46 Wholesale trade, except of motor vehicles and motorcycles; C18 Printing and reproduction of recorded media; C26 Manufacture of computer, electronic and optical products; M69 Legal and accounting activities; L68 Real estate activities.

**Source:** Authors' calculations based on Eurostat data.

**Figure 4 The shares of imported intermediate inputs (by industry) used by Finland's information economy sector in 2018, %**




C26 Manufacture of computer, electronic and optical products; M72 Scientific research and development; J62–63 Computer programming, consultancy and related activities; Information service activities; M69–70 Legal and accounting activities; Activities of head offices; management consultancy activities; G46 Wholesale trade, except of motor vehicles and motorcycles; N77 Rental and leasing activities; M73 Advertising and market research.

**Source:** Authors' calculations based on Eurostat data.

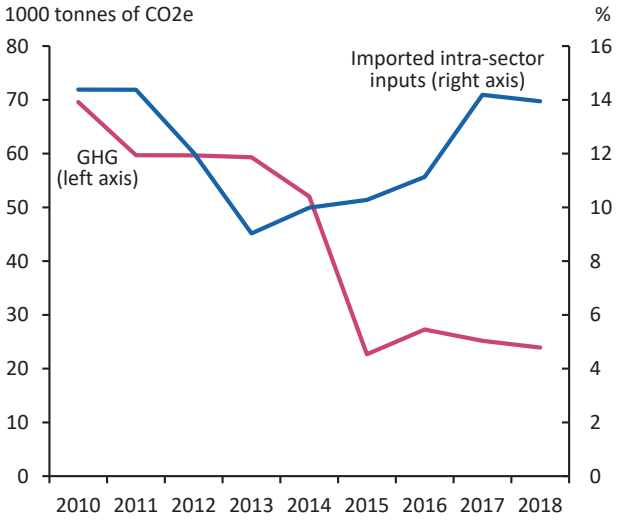
sector itself used 33 percent of its produced goods and services and 67 percent served as inputs to other industries (see Figure 5). The main users of ICT goods and services produced by Finland's information economy sector were industries *J62–63 Computer programming, consultancy and related activities; Information service activities* (14%), *O84 Public administration and defence; compulsory social security* (9%) and *J58 Publishing activities* (7%).

## 5.2 Outsourcing of GHG emissions

GHG emissions generated by the information economy sector has been in decline (see Section 4). However, these figures do not take explicitly into account outsourcing of emissions (carbon leakage). Rather than produce goods and services domestically, some of the production can be outsourced overseas and thus a part of pollution outsourced too. In this section we investigate signs of outsourcing emissions by Finland's information economy sector. More specifically, we examine imported intermediates from foreign ICT industries to the domestic ICT industries using input-output tables. Outsourcing would imply an increase in the share of intra-sector imports relative to other sources.

Figure 6 illustrates the emissions generated by Finland's information economy sector (red line) (in 1000 tonnes of CO2e) and the share of imported intermediate inputs in the total intermediate consumption (blue line) in 2010–2018. GHG emissions of the information economy sector have been declining since 2013. However, the share of imported intermediates has been increasing. These opposite trends can be seen as a sign of carbon leakage.

**Figure 6 Finland's information economy sector's GHG emissions (in thousand tonnes of CO2e) and the share of imported intra-sector intermediates in total intermediate consumption (in %) in 2010–2018**




**Source:** Eurostat (GHG); authors' calculations based on Eurostat data (the share of imported intra-industry inputs in total intermediate consumption).

**Table 6 The shares of imported intra-sector intermediates in total intra-industry intermediate consumption in 2010–2018, %**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| Manufacture of computer, electronic and optical products (C26) | 32,0 | 31,0 | 29,3 | 20,0 | 25,1 | 24,5 | 25,0 | 23,3 | 21,3 |
| Publishing activities (J58) | 0,5 | 0,5 | 0,6 | 0,6 | 0,4 | 0,2 | 0,2 | 0,5 | 0,4 |
| Motion picture, video and television programme production, sound recording and music publishing activities; Programming and broadcasting activities (J59–60) | 0,5 | 0,6 | 0,7 | 0,8 | 0,5 | 2,0 | 1,9 | 1,9 | 1,9 |
| Telecommunications (J61) | 0,6 | 0,4 | 0,7 | 0,5 | 1,0 | 0,7 | 0,8 | 0,6 | 0,7 |
| Computer programming, consultancy and related activities; Information service activities (J62–63) | 7,0 | 7,0 | 6,7 | 7,0 | 3,4 | 1,7 | 2,8 | 9,8 | 10,0 |

**Source:** Authors' calculations based on Eurostat data.

Table 6 reports to which foreign ICT industries domestic emissions were outsourced. The table presents the shares of imported intra-industry inputs to Finland's information economy sector in the total intra-industry intermediate consumption. The largest share of intermediates came from the ICT manufacturing sector (about 21% in year 2018). The share of inputs from the foreign ICT industries *J62–63 Computer programming, consultancy and related activities; Information service activities* increased from 7 percent in 2010 to 10 percent in 2018 (the main importer was domestic industry J62–63).

## 5.3 Information economy sector's imported inputs and their origin

This section investigates from which continents/regions and countries inputs to Finland's information economy sector came from in 2008–2020. We use statistical databases of the Finnish Customs[8] on international trade in goods statistics that are available for both import and export.[9]

Table 7 reports the shares of imported inputs to the ICT services (Panel A) and the ICT manufacturing (Pan-

**Table 7 The shares of imports to Finland's ICT services sector (Panel A) and the ICT manufacturing sector (Panel B) in 2008–2020, %**

| | Europe | North Africa | Rest of Africa | Middle East | Rest of Asia | North America | Middle America | South America | Oceania |
|---|---|---|---|---|---|---|---|---|---|
| **A. ICT services** | | | | | | | | | |
| 2008 | 67,37 | 0,00 | 0,16 | 0,87 | 20,02 | 10,32 | 1,19 | 0,01 | 0,06 |
| 2009 | 58,91 | 0,01 | 0,03 | 1,38 | 29,96 | 8,15 | 1,52 | 0,01 | 0,03 |
| 2010 | 51,37 | 0,00 | 0,01 | 0,78 | 34,81 | 11,82 | 1,17 | 0,01 | 0,04 |
| 2011 | 36,98 | 0,00 | 0,03 | 0,25 | 45,02 | 16,39 | 1,29 | 0,00 | 0,03 |
| 2012 | 34,35 | 0,00 | 0,01 | 0,15 | 59,07 | 5,64 | 0,74 | 0,01 | 0,03 |
| 2013 | 43,45 | 0,00 | 0,01 | 0,05 | 50,94 | 5,25 | 0,25 | 0,02 | 0,03 |
| 2014 | 48,81 | 0,76 | 0,00 | 0,19 | 44,41 | 4,85 | 0,97 | 0,01 | 0,01 |
| 2015 | 43,30 | 0,27 | 0,00 | 0,12 | 50,43 | 4,43 | 1,42 | 0,00 | 0,02 |
| 2016 | 45,91 | 0,03 | 0,01 | 0,21 | 42,73 | 9,97 | 1,15 | 0,00 | 0,01 |
| 2017 | 44,28 | 0,01 | 0,00 | 0,26 | 45,06 | 9,70 | 0,67 | 0,00 | 0,02 |
| 2018 | 51,16 | 0,01 | 0,02 | 0,29 | 34,98 | 12,77 | 0,68 | 0,00 | 0,10 |
| 2019 | 45,19 | 0,00 | 0,02 | 0,39 | 48,24 | 5,38 | 0,70 | 0,01 | 0,05 |
| 2020 | 33,86 | 0,00 | 0,02 | 0,32 | 58,33 | 5,40 | 2,06 | 0,00 | 0,02 |
| **B. ICT manufacturing** | | | | | | | | | |
| 2008 | 18,21 | 0,01 | 0,03 | 0,64 | 76,91 | 3,32 | 0,81 | 0,04 | 0,04 |
| 2009 | 20,51 | 0,01 | 0,05 | 0,89 | 71,92 | 5,67 | 0,83 | 0,07 | 0,05 |
| 2010 | 24,98 | 0,01 | 0,02 | 0,72 | 66,51 | 7,17 | 0,49 | 0,03 | 0,07 |
| 2011 | 22,81 | 0,02 | 0,01 | 0,28 | 69,72 | 6,70 | 0,36 | 0,03 | 0,07 |
| 2012 | 24,34 | 0,01 | 0,03 | 0,40 | 66,40 | 8,25 | 0,31 | 0,13 | 0,13 |
| 2013 | 37,02 | 0,01 | 0,04 | 0,52 | 50,57 | 11,29 | 0,39 | 0,03 | 0,15 |
| 2014 | 27,70 | 0,01 | 0,04 | 0,28 | 53,69 | 17,47 | 0,56 | 0,06 | 0,19 |
| 2015 | 30,44 | 0,01 | 0,02 | 0,37 | 50,51 | 17,53 | 0,95 | 0,05 | 0,11 |
| 2016 | 26,77 | 0,01 | 0,02 | 0,19 | 53,48 | 18,57 | 0,80 | 0,08 | 0,08 |
| 2017 | 29,79 | 0,01 | 0,02 | 0,23 | 58,75 | 10,49 | 0,60 | 0,04 | 0,07 |
| 2018 | 24,32 | 0,01 | 0,05 | 0,19 | 60,71 | 12,81 | 1,79 | 0,05 | 0,07 |
| 2019 | 22,58 | 0,03 | 0,02 | 0,16 | 58,61 | 16,24 | 2,23 | 0,03 | 0,09 |
| 2020 | 34,31 | 0,01 | 0,03 | 0,14 | 49,99 | 13,04 | 2,35 | 0,05 | 0,08 |

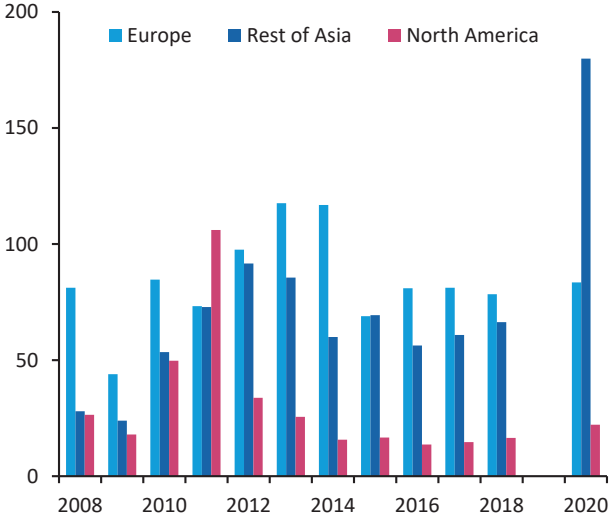
**Source:** Authors' calculations based on Finnish Customs data.

el B) from Europe, North Africa, Rest of Africa, Middle East, Rest of Asia, North America, Middle America, South America and Oceania in total imports. The major importers of intermediate inputs to the information economy sector were Europe, the rest of Asia and North America. During 2008–2020, the ICT services shifted its imports from Europe to Asia. Imports to the ICT manufacturing from Europe and North America increased, but imports from Asia decreased. In 2020, about half of imported inputs to both subsectors originated from Asia.

In 2020, 34 percent of imports to the ICT services originated from Europe and 58 percent from the rest of Asia. More specifically, 38 percent of total imports came from China, 8 percent from the Netherlands, 6 percent from Germany, and 5 percent shares came from Ireland, Sweden, Thailand, Vietnam and Japan. In the same year, 50 percent of imports to the ICT manufacturing were from the rest of Asia, 34 percent from Europe and 13 percent from North America (from the USA). More specifically, 21 percent of imports came from China, 13 percent from the USA, 11 percent from Malaysia, 8 percent from Germany, 5 percent from Taiwan and another 5 percent from Estonia.

Imported intermediates from foreign industries *J62–63 Computer programming, consultancy and related activities;*

**Figure 7 The three largest importers to Finland's industry *J62 Computer programming, consultancy and related activities* in 2008–2018 and 2020, million euros (in 2015 prices)**




**Source:** Authors' calculations based on Finnish Customs data.

*Information service activities* increased to 10 percent in 2018 (Table 6). These served mainly as inputs to the domestic ICT industry J62. Figure 7 illustrates the three major importers to this industry, which were Europe, the rest of Asia and North America and indicates to which continents emissions were outsourced. More precisely, in 2020, 55 percent of imports came from China, 7 percent from the USA, 7 percent from Germany and 5 percent from Hungary.

# 6 Greenhouse gas emissions of the information economy sector and its inputs

GHG emissions of the information economy sector were discussed in section 4 and summarized in the second column of Table 8 for period 2010–2018. These figures, however, do not consider emissions generated by other industries (domestic and foreign) to produce intermediate inputs to Finland's information economy sector. Utilizing three data sources, namely Eurostat's domestic and import input-output tables, national accounts aggregate by industry and air emissions accounts, this section provides some estimates on GHG emissions generated by domestic and foreign industries to produce intermediates to Finland's information economy sector.[10]

GHG emissions generated by domestic industries are reported in the third column of Table 8. These figures reveal that emissions of the information economy sector alone are much smaller, when emissions to produce intermediates to this sector are not considered. Our estimate for GHG emissions generated by domestic industries to provide inputs to the information economy sector in 2018 reached 1,852 thousand tonnes of CO2e, while the GHG emissions of the information economy sector was only 24 thousand tonnes of CO2e. The results highlight that the information economy sector's inputs are produced by industries whose emission intensities are higher than those of the information sector.

GHG emissions generated by foreign industries are reported in the last column of Table 8. If foreign industries

**Table 8 GHG of Finland's information economy sector and GHG of other sectors that provided intermediate inputs to the information sector, 1000 tonnes of CO2e**

| | Information economy sector's GHG | Domestic industries' GHG | Foreign industries' GHG |
|---|---|---|---|
| 2010 | 69,6 | 3050 | 458,0 |
| 2011 | 59,7 | 2770 | 537,5 |
| 2012 | 59,7 | 2653 | 461,7 |
| 2013 | 59,3 | 2609 | 468,3 |
| 2014 | 52,0 | 2481 | 447,7 |
| 2015 | 22,7 | 1880 | 436,2 |
| 2016 | 27,3 | 1909 | 508,0 |
| 2017 | 25,2 | 1704 | 469,0 |
| 2018 | 23,9 | 1852 | 445,2 |

**Source:** Eurostat (GHG of Finland's information economy sector), author's calculations based on Eurostat data (GHG of domestic and foreign industries).

have the same emission intensity rates as Finland's industries, our estimates for GHG emissions generated by foreign industries to produce inputs to Finland's information sector reached 445 thousand tonnes of CO2e in 2018. However, regarding the results, it should be noted that our assumption about the emission intensity may be too positive. For instance, energy production in Finland is considerably cleaner compared to many other countries. Furthermore, given the realistic manufacturing conditions to produce goods and services, GHG emissions can be even higher.

# 7 Results

The share of the information economy sector in Finland's gross domestic product (GDP) was 6.5 percent in 2018 (7.4 percent in 2020). Correspondingly, in 2018, the share of the digital economy in Finland's GDP was 12.6 percent. The GHG emissions of the information economy sector in Finland reached 23 thousand tonnes of CO2e in 2019 corresponding to 0.04 percent of all Finland's GHG emissions. Based on the previous results above, the GHG emission intensity of the information economy sector was 1.5 t CO2e / € million in 2019 (1.6 t CO2e / € million in 2018). The GHG emission intensity of the information economy sector has decreased significantly in Finland over the past ten years. Please note that these figures do not account for the GHG emissions of the information economy sectors' intermediate inputs (i.e., sector procurement).

In 2018, domestic intermediate inputs accounted for 63 percent and imported inputs for 37 percent of the information economy sector's total intermediates (for first tier of suppliers). The share of domestic contributions has increased in recent years. According to our previous research on global value chains we could use the same split of 63 percent / 37 percent to first tier domestic intermediate inputs – the share of imported inputs would then increase to more than 60 percent (including second tier of suppliers). For further information on value chains and analysis and methodology see our previous research: Ali-Yrkkö et al., 2011, Kalm et al., 2014, Larsen et al., 2018. Based on the findings of the research, there are some signs of outsourcing emissions abroad (the share of imported intermediates from foreign industries J62-63 increased from 7 to 10 percent and the share of inputs from foreign industries J59–60 increased from 0.5 to 1.9 percent from 2010 to 2018).

ICT manufacturing sector has a higher GHG emission intensity than ICT services sector. This means that ICT manufacturing pollutes more per unit of economic output compared to ICT services. In general, the inputs to the information economy sector come from industries whose GHG emission intensities are higher than the in-

formation economy sector's own GHG emissions intensity. In 2018, GHG emissions of producing intermediate inputs to the information economy sector by other industries were 77 times higher than the information economy sector's own GHG emissions. The results described above do not consider the inputs and outputs of streaming service companies operating with the "over the top" business model (OTT business model), as they are not registered in the input-output statistics of the Finnish information economy sector. The GHG emissions of streaming service companies operating under the OTT business model are reported in the input-output statistics of the country in which these company operations are registered.

With respect to the geography of supply chain (value chain) location, the origin of intermediate inputs to Finland's ICT services sector in 2018 (2020) is as follows: Asia – 35 percent (54%), Europe – 51 percent (38%), North America – 13 percent (6%), and other continents – 1 percent (2%). The origin of intermediate inputs to the ICT manufacturing is as follows: Asia – 61 percent (50%), Europe – 24 percent (34%), North America – 13 percent (13%), other continents – 2 percent (3%). Intermediates imported by Finland's information economy sector are mainly from Asia (mostly China), the United States and some European countries.

# 8 Conclusions and policy recommendations

GHG emissions and emission intensities reported by companies and industries provide an incomplete picture of the environmental friendliness of their economic activities. Reported figures usually do not account for GHG emissions of intermediate goods and services (procured goods and services), as well as other purchasing decisions domestically or abroad, used by companies and industries to produce final products. When considering the entire supply chain (value chain) the reported figures of GHG emissions and emission intensities of companies and industries can significantly change. Based on the above, the focus of measurement and reporting should be shifted to a more comprehensive supply chain (value chain) GHG emission analysis.

As the economic importance of the digital economy has increased, imports of intermediate inputs (sector procurement) to the information economy sector from abroad have grown significantly over the last ten years. This has led to an increasing share of GHG emissions coming from earlier stages of the supply chain abroad (for more information see e.g. Ali-Yrkkö et al. (2011) and Kalm et al. (2014) as well as Larsen et al. (2018)). Regarding intermediates inputs from abroad, the information economy sector's management should pay particular attention to GHG emissions and emission intensity of economic activities of their procurement abroad. Specifically, documentation, assessment, and measurement of GHG emissions should be requested of intermediate inputs.

In recent years, Finland has outsourced its GHG emissions abroad to a greater extent in the information economy sector's supply chain. The OTT business model of media services continues to increase the intermediate inputs to the information economy sector from foreign sources, even if the procurement decision in that business model is made by the consumer instead of the companies. The Ministry of Transport and Communications, together with the Ministry for Foreign Affairs, should study the wider effects of the OTT business model, namely digital direct (streaming) services, on Finland's GHG emissions. Service providers operating under the OTT business model should be required to report more detailed on their GHG emissions.

# Endnotes

1 The OTT business model refers to a media service that is provided to a customer (consumer) directly via the Internet. The OTT business model bypasses the local distribution platform and is operated by companies such as Elisa, Telia and DNA, which traditionally act as distributors and controllers of similar domestic content. The origin of the OTT business is difficult to identify without the producers and distributors of the media service themselves disclosing the origin of the service and its greenhouse gas emissions.

2 GHG emission intensity is an indicator that is part of the EU Sustainable Development Goals (SDG) indicator set, which are embedded in the European Commission's Priorities under the European Green Deal. The indicator is used to monitor progress towards sustainable development. The SDG Global Indicator Platform, accessed 12 December 2021: https://sdg.tracking-progress.org/indicator/9-4-1-carbon-dioxide-emissions-per-unit-of-value-added/.

3 Standard Industrial Classification TOL 2008, Statistics Finland, accessed 12 December 2021: https://tilastokeskus.fi/en/luokitukset/toimiala.

4 Eurostat, Air emissions, accessed on 20 October 2021: https://ec.europa.eu/eurostat/web/environment/air-emissions.

5 GHG intensity is an indicator that is part of the EU Sustainable Development Goals (SDG) indicator set, which are embedded in the European Commission's Priorities under the European Green Deal. The indicator is used to monitor progress towards sustainable development.

6 Input-output tables, Eurostat, accessed on 22 October 2021: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=naio_10_cp1750&lang=en.

7 Intermediate consumption measures the value of the goods and services consumed as inputs by a process of production, See Eurostat, accessed on 22 October 2021: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Intermediate_consumption.

8 Finnish Customs, Statistical Database, accessed on 22 November 2021: https://uljas.tulli.fi/v3rti/db/0.

9 More information about classifications is available on pages of Customs, accessed on 22 November 2021: https://tulli.fi/en/statistics/nomenclatures-and-classifications.

10 We account for all industries (NACE Rev. 2) that provided inputs to Finland's information economy sector. For example, in 2018, 63 domestic and 38 foreign industries provided inputs to Finland's information economy sector.

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