GLOBAL ELECTRONICS COUNCIL

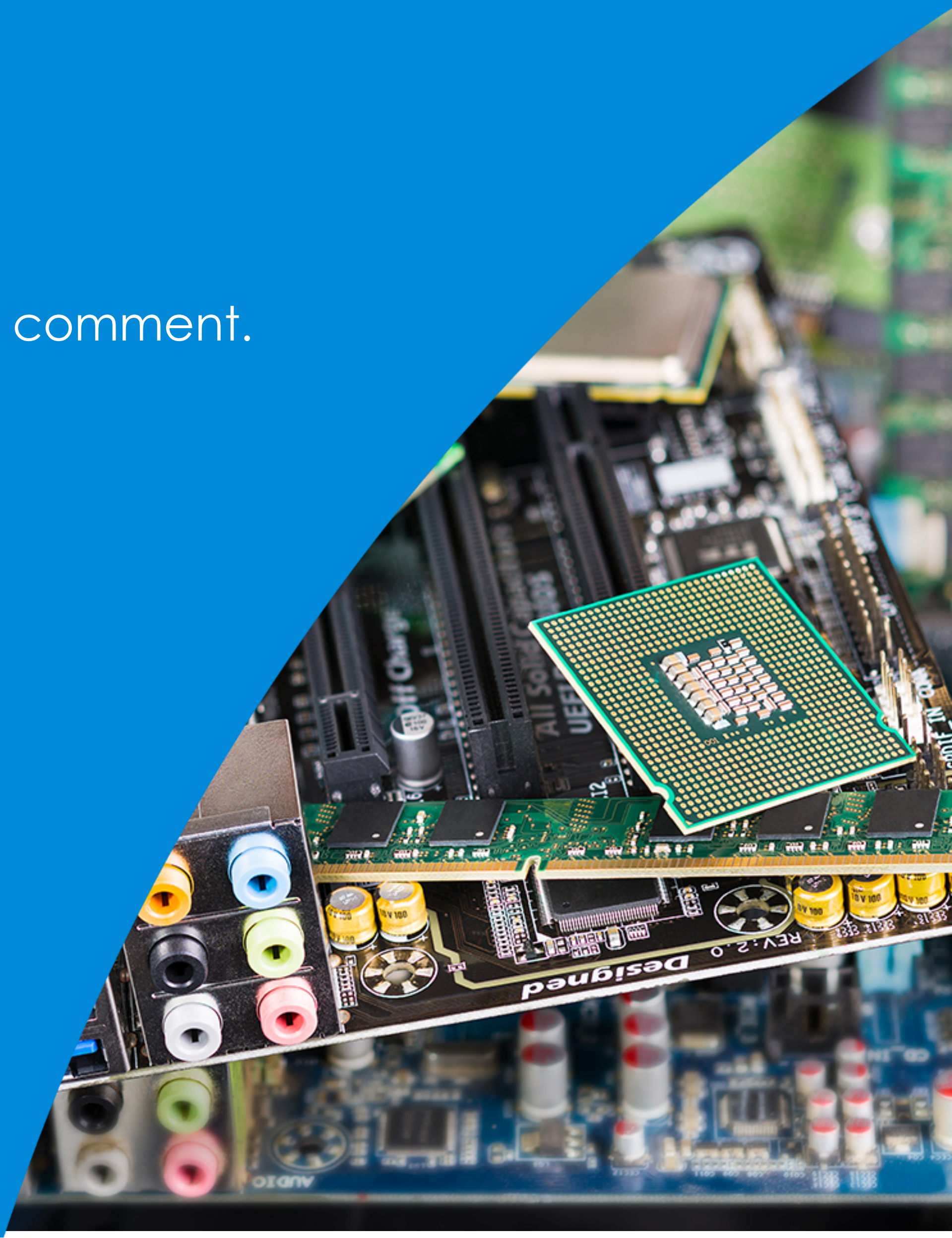
Sustainability for a Connected Future

STATE OF SUSTAINABILITY RESEARCH

CLIMATE CHANGE MITIGATION

Draft report for public comment.

April 1, 2021



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State of Sustainability Research: Climate Change Mitigation

Purpose

The development and release of a State of Sustainability Research (SOSR) report for public consultation is the first step in the EPEAT criteria development process. GEC welcomes stakeholder review of this report and submission of comments, including confirmation that the report identifies priority impacts and mitigation strategies, identification of additional life cycle analyses or data on sustainability impacts; and other mitigation strategies and best practices leading to demonstrable impact reduction.

About GEC

The Global Electronics Council (GEC) is a non-profit that leverages large-scale purchasing power, both public and private sector, as a demand driver for more sustainable technology. By deciding to buy sustainable technology, institutional purchasers can "move the needle" toward a more sustainable world. GEC also helps manufacturers understand the sustainability impacts of their technology, commit to address those impacts, and act to change operational, supply chain, and procurement behaviors. GEC is the manager of the ecolabel EPEAT®, used by more purchasers of electronics than any other ecolabel worldwide.

EPEAT is a comprehensive voluntary sustainability ecolabel that helps purchasers identify more sustainable electronic products that have superior environmental and social performance. EPEAT establishes criteria that address priority sustainability impacts throughout the life cycle of the product, based on an evaluation of scientific evidence and international best practices.

EPEAT Sustainability Impact Priorities

GEC organizes its analysis of sustainability impacts, and the criteria it proposes to reduce these impacts, into the following four priority impact areas of importance to large-scale purchasers of electronic products:

- Climate Change Mitigation
- Sustainable Use of Resources
- Reduction of Chemicals of Concern
- Corporate Environmental, Social, and Governance (ESG) Performance

In this State of Sustainability Research (SOSR) report we identify priority contributors to climate change throughout the life cycle of ICT products and mitigation strategies to reduce these impacts. This SOSR will serve as the evidenced-based scientific foundation for future EPEAT criteria development work.

Climate Change Mitigation: An Imperative for Our Future

Climate change mitigation is at the forefront of sustainable purchasing decisions globally, from the European Union's Green Deal to the United States' 2021 Federal Climate Executive Order, the path is set to achieve net-zero emissions by 2050. To this end, institutional and consumer sustainable purchasing remains an important lever for change. The business sector is similarly invested in mitigating the harmful effects of climate change, as illustrated by efforts from Microsoft's ambitious goal to be carbon negative by 2030 to the actions of Climate Signatory companies that have pledged to be climate neutral by 2040, 10-years ahead of goals set by the United Nations Framework Convention on Climate Change Paris Agreement.

Climate Change Impacts and Mitigation Strategies for the ICT Sector

1. Climate change impacts of the ICT sector

Climate change is creating irreversible damage to the planet and threatening conditions for all life on earth – extreme temperatures and weather conditions, rising sea levels, melting ice caps, and loss of biodiversity have already been documented as a result of climate change. The primary contributor to climate change is the release of greenhouse gases (GHGs) into the atmosphere from the use of fossil fuels for electricity generation and other energy needs. A recent report by the World Economic Forum (WEF) identified the electronics industry as one of the top 8 sectors accounting for more than 50% of global carbon emissions [1].

In 2020, the total ICT sector footprint is expected to be dominated by data centers (45%), followed by communication networks (24%), smartphones (11%), and computing devices including desktops (7%), displays (7%), and notebooks (6%) (Figure 1) [2].

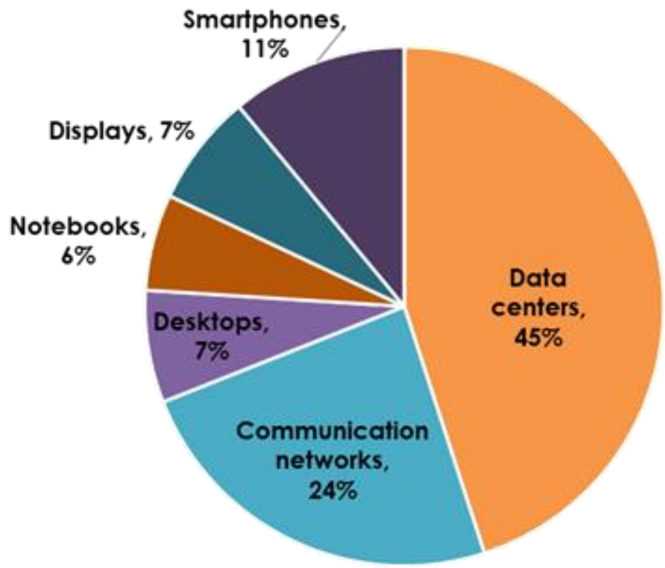


Figure 1.

Relative contribution of various ICT products towards total sector footprint in 2020

The WEF reported that the majority of GHG emissions from the electronics industry are attributed to the supply chain (77%), which includes raw materials mining, manufacture, and assembly of electronic components, as well as transportation of the finished product. The WEF further notes that supply-chain decarbonization presents a "giant opportunity for international climate action". For example, tapping into electricity generated from renewable resources could reduce greenhouse gas emissions by 35%. They estimated that in the electronics supply chain, material and energy efficiency improvements in manufacturing processes could further reduce emissions by ~20%. The WEF also estimates that using low carbon fuels for transportation could cut GHG emissions by 5%. And, extending the life cycle of a product through increased durability and repair, along with high recycling and recovery rates, could further reduce embodied carbon by at least 5% [1].

> Supply-chain decarbonization presents a "giant opportunity for international climate action".
>
> World Economic Forum, 2021

Additionally, the electricity consumed to power electronic products contributes significantly to climate change. While reducing use-stage power consumption of electronic products has been a major focus of programs such as the U.S. ENERGY STAR® program for over a decade, the number of electronic devices and the processing of data has proliferated. The operational electricity consumption of global ICT sector in 2015 was 805 TWh of electricity, which accounts for 3.6% of global energy consumption and 1.4% of the total global carbon dioxide emitted [3]. On a product level, the contribution of use phase emissions ranges anywhere between 14% to 95% of total life cycle GHG emissions.

2. Life cycle carbon footprint

The potential contribution of a product to climate change is estimated by quantifying a product's life cycle carbon footprint. The life cycle carbon footprint of a product is a measure of the total GHG emissions associated from raw material extraction to manufacturing, transportation, customer use, and end of life processing (see Figure 2). There are two major components of the life cycle carbon footprint: embodied carbon and operational carbon associated with product use, as illustrated in Figure 2 below. To put it simply, embodied carbon is all life cycle GHG emissions, except GHG emissions associated with electricity consumption to operate the product. Each of these components are discussed in detail below.

Life cycle carbon footprint = embodied carbon + operational carbon

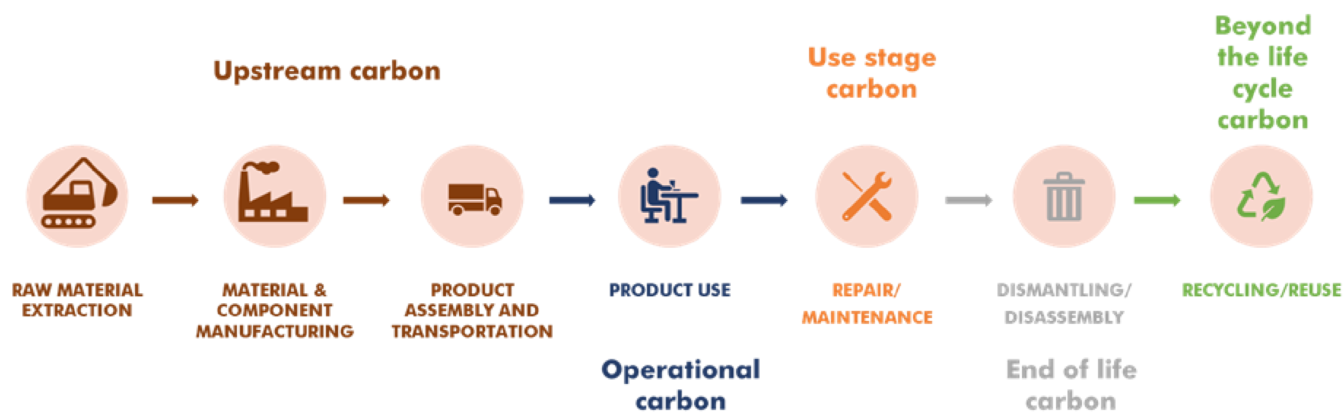


Figure 2. Life cycle carbon footprint of an ICT product

Embodied carbon is the sum of greenhouse gas emissions released from producing, procuring, and assembling the materials and components that make up a product [4]. Contributors to embodied carbon include: upstream carbon, use phase carbon (not including operational carbon), end of life carbon and beyond the life cycle carbon [4].

Embodied carbon =
upstream carbon + use stage carbon + end of life carbon + beyond the life cycle carbon

- Upstream carbon represents the GHG emissions associated with all the activities that occur during the raw material extraction, component production and assembly, and transportation of the final product to the customer.
- Use stage carbon includes the GHG emissions associated with materials and processes required for the upkeep/maintenance of the product. For example, when a user replaces a battery in their phone, the GHG emissions associated with materials and processes required to manufacture a replacement battery is accounted for in use stage embodied carbon. *And a reminder, the GHG emissions associated with the energy required to power the device during the use phase (called Operational Carbon) is not included in use stage embodied carbon.*
- End of life carbon accounts for the GHG emissions released during the disassembly or dismantling process of products for reuse, recycling, or final disposal.
- Beyond the life cycle carbon include GHG emissions or savings incurred due to reuse of components and recycling of materials, as well as the emissions avoided due to using waste as a fuel source for another process.

Note: the scope of this Climate Change Mitigation SOSR excludes the GHG emissions savings from product and component reuse, recycling, and other circularity strategies. These aspects will be discussed in detail in GEC's State of Sustainability Research report on Sustainable Use of Resources.

2.1. Contribution of embodied carbon versus operational carbon

The relative contribution of embodied carbon to the total carbon footprint is dependent on the type of ICT product. For products, such as laptops, smartphones, and tablets, which rely on a battery to power the device, the contribution of embodied carbon is greater than GHG emissions from operating the device over its lifetime. For example, the embodied carbon of a smartphone and tablet accounts for 90% and 84% of the total carbon footprint, respectively (See Figure 3). For products, such as TVs and desktops, which need to be plugged in for the devices to work, the upfront carbon accounts for 31% and 30% of the total, respectively (Figure 3.)

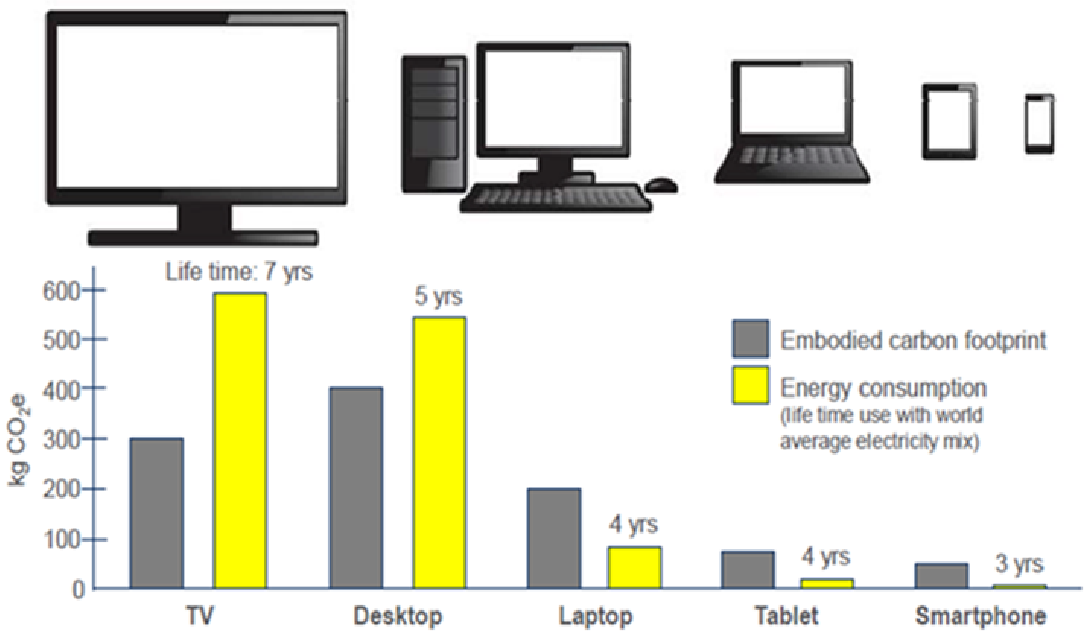


Figure 3. The relative contribution of embodied carbon to the lifetime energy consumption of various ICT devices. *Note that embodied carbon footprint here only includes upstream carbon emissions.* [3]

Similarly, Figure 4 provides an illustration of two high-energy consuming products – network switch and rack server – where operational carbon accounts for over 90% of life cycle carbon emissions, compared to an iPad and smartphone, with operational carbon contributing only 14 -15% of life cycle carbon emissions.

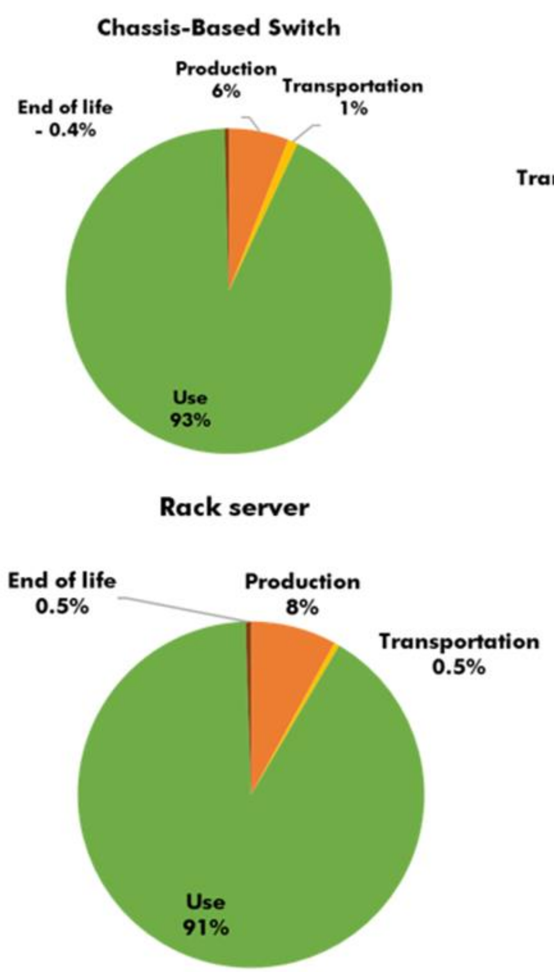


Figure 4. Relative contribution of life cycle stages towards product carbon footprint for example ICT products. *Note that "Use" represents operational carbon. Here, total embodied carbon is sum of production, transportation, and end of life. See Appendix Table 1 for detailed data and sources.*

2.2. Upstream carbon

Figure 4 also illustrates that upstream carbon, which is the sum of carbon emissions from production and transportation life cycle stages, is the largest contributor towards embodied carbon compared to other life cycle components of embodied carbon. Within the upstream stage, the production phase is the largest contributor to embodied carbon. Production phase here includes raw material extraction and production, as well as the activities that are included in the component manufacturing and assembly of a finished product, inclusive of packaging. Depending on the product type, the percentage contribution of production can vary from 5% to 77% of the total carbon footprint of a device (see Figure 5). Transportation generally contributes a smaller portion of upstream embodied carbon in the electronics industry, ranging anywhere from 0.5% to 25% depending on the product category (Figure 5).

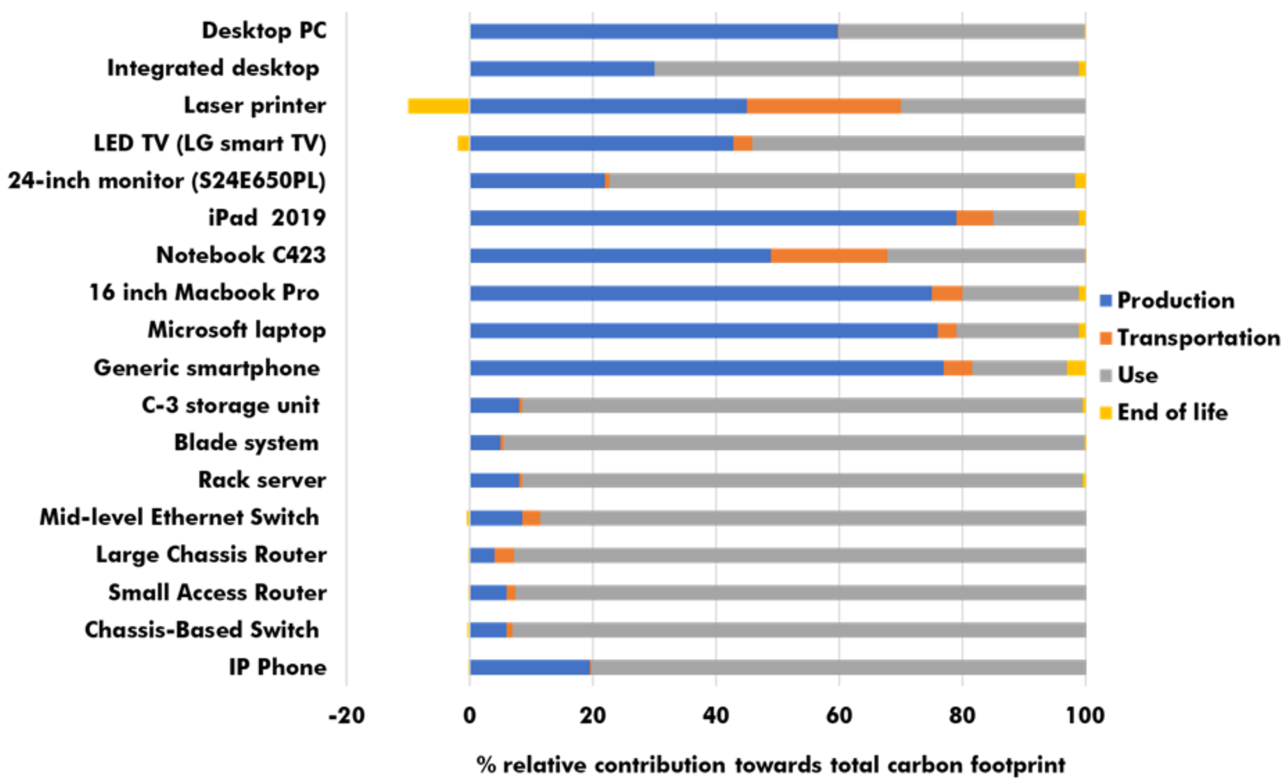


Figure 5. Relative contribution of life cycle stages towards total carbon footprint for various ICT devices. *Note: See Appendix Table 1 for the detailed data and references*

Priority Components

Figure 6 represents the relative contribution of components and upstream activities towards upstream embodied carbon of various product categories. As illustrated, components, such as printed circuit boards, integrate circuits (ICs), and diodes, contribute the largest towards upstream embodied carbon [5]. The contribution of these components together can vary anywhere between 5% to 80% of total upstream embodied carbon depending on the product type.

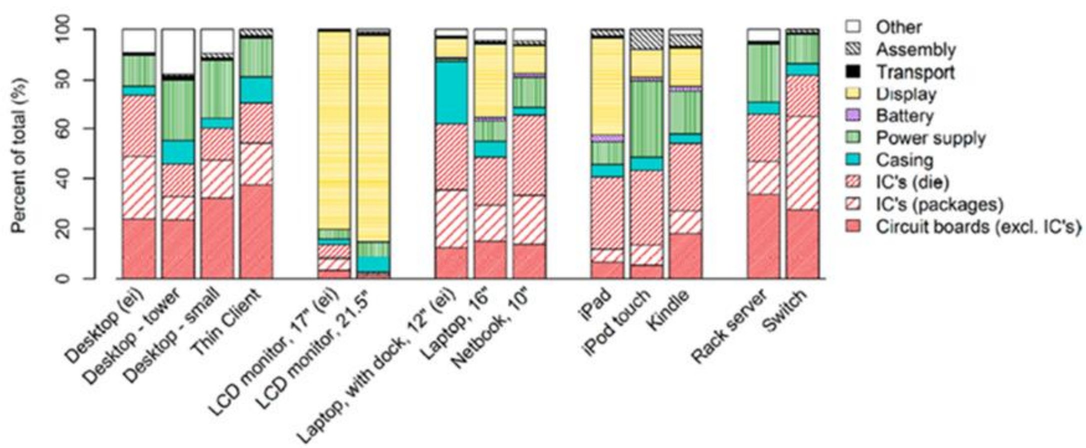


Figure 6. The contribution of various components and upstream activities towards the upstream embodied carbon [5]

For products with a display, the display is also a top contributor towards upstream embodied carbon. And, the contribution of the display component increases with screen size, as seen for LCD monitor 17 inch and 21.5 inch in Figure 6.

GHG emissions from component manufacturing can be attributed to two factors: energy consumption and use of fluorinated compounds during the manufacturing process (See Figure 6). According to data from the U.S. Environmental Protection Agency (EPA) Greenhouse Gas Reporting Program (GHGRP), in 2019 electronics manufacturing facilities in the U.S. emitted 5.9 million metrics tons CO2e.[1] Out of the total emissions, 83% of

[1] Electronics manufacturing facilities included semiconductors (inclusive of light-emitting diodes), micro-electromechanical systems (MEMS), liquid crystal displays (LCDs), and photovoltaic cells (PV).

emissions are attributed to F-GHGs, and the remaining 17% are attributed to carbon dioxide and nitrous oxide emissions, which are released during the combustion of fossil fuels to produce electricity [6]. Assembly and transportation activities during the upstream life cycle contribute the smallest relative percentage [5].

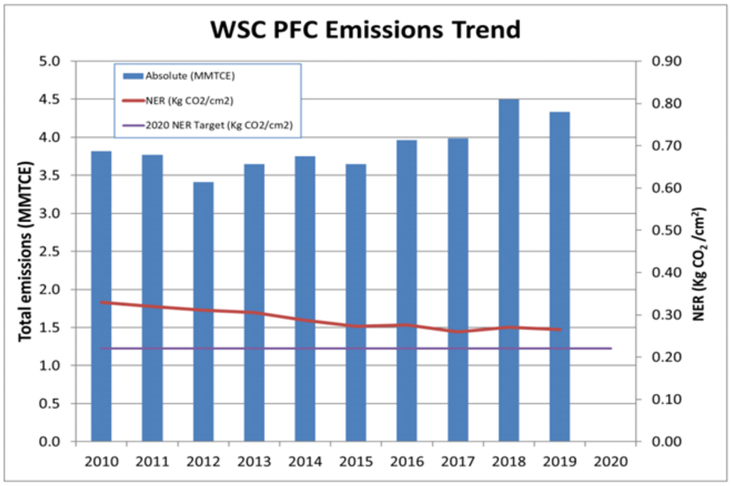
Absent intervention, embodied carbon of ICT devices is bound to increase in the future due to rapid innovation cycles and declining product life spans [7].

2.2.1. Fluorinated greenhouse gas emissions

F-GHGs are thousands of times more potent than CO_2 emissions and hence a significant contributor to the potential for irreversible damage to earth's climate [8]. Fluorinated greenhouse gases (F-GHG) are commonly used in the manufacturing of flat panel displays and semiconductors for various purposes such as etching, cleaning, and cooling. Some of the commonly used F-GHGs include hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride [8]. This is not a static list, however. For example, in 2016 the semiconductor industry added reporting of newly used gases CH_2F_2, C_4F_6, C_5F_8 and C_4F_8O, and in 2019 these gases represented 7% of semiconductor global F-GHG emissions [9].

Semiconductor Industry

The World Semiconductor Council (WSC), which consists of the Semiconductor Industry Associations in China, Chinese Taipei, Europe, Japan, Korea, and the United States, published data on total perfluoro compound (PFC) emissions (a type of F-GHGs) from 2010 to 2019 (see Figure 7) [9]. As per the data, the absolute emissions of F-GHGs increased by 13.5% from 2010 to 2018 attributed to increased production of semiconductors [10], while the normalized emission rate (i.e., emissions per unit) decreased by 19.6% during the same time period. From 2018 to 2019, the most recent years reported, total emissions decreased by 2%.



In 2019 electronics manufacturing facilities in the U.S. emitted 5.9 million metrics tons CO2e. Out of the total emissions, 83% of emissions are attributed to F-GHGs.

US EPA, 2016

Figure 7. F-GHG emission trends in Semiconductor Industry as reported by WSC [9]

Flat panel manufacturing industry

EPA reported the total F-GHG emissions from the flat panel manufacturing industry from 2000 to 2020, showing a steady increase in emissions (Figure 8). COVID -19 has increased demand for display products, such as TVs, monitors, laptops, as people are adapting to work from home; increasing LCD panel production may further increase F-GHG emissions [11].

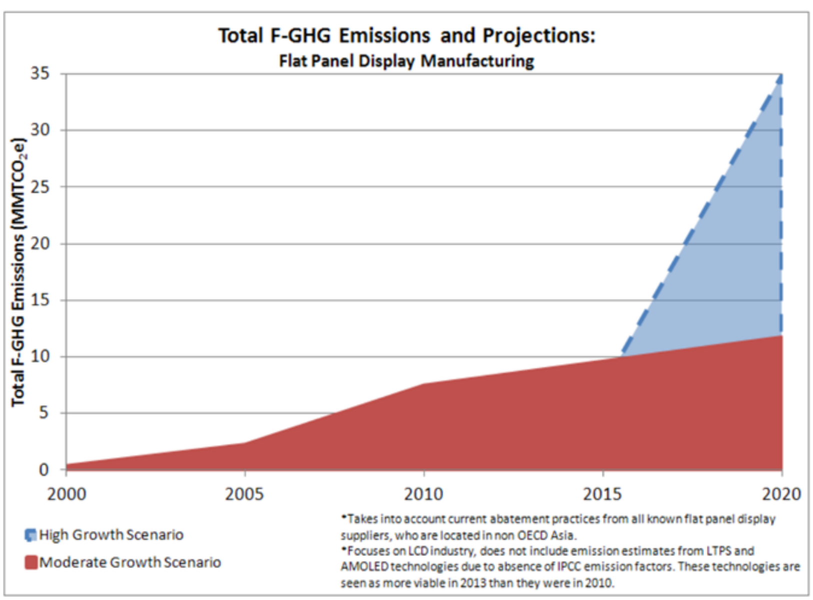


Figure 8. Global F-GHG emissions from Flat Panel Display manufacturing [8]

2.3. Product use phase emissions (Operational Carbon)

Figure 9 illustrates the electricity consumption trends for product categories in the non-residential ICT sector in 27 European Union countries (EU27) from 2010 to 2025. As illustrated, the total electricity consumption is projected to increase by 12% in 2025 when compared to 2010. Out of total non-residential ICT electricity consumption, data centers, telecommunications, and electronic displays account for more than 70% of energy consumption for all the years evaluated[12]. This is mainly due to increase in data traffic and bandwidth driven mainly by video sharing. As per the EU27 ICT impact study, close to 85% of the bandwidth of the data centers is taken by video on demand, movies, social media clips and game streaming[12]. Electronic displays increase is mainly driven by increasing resolution. Public ICT is another category that is seeing a rise in energy consumption due to increase in use of hotspots and security cameras[12].

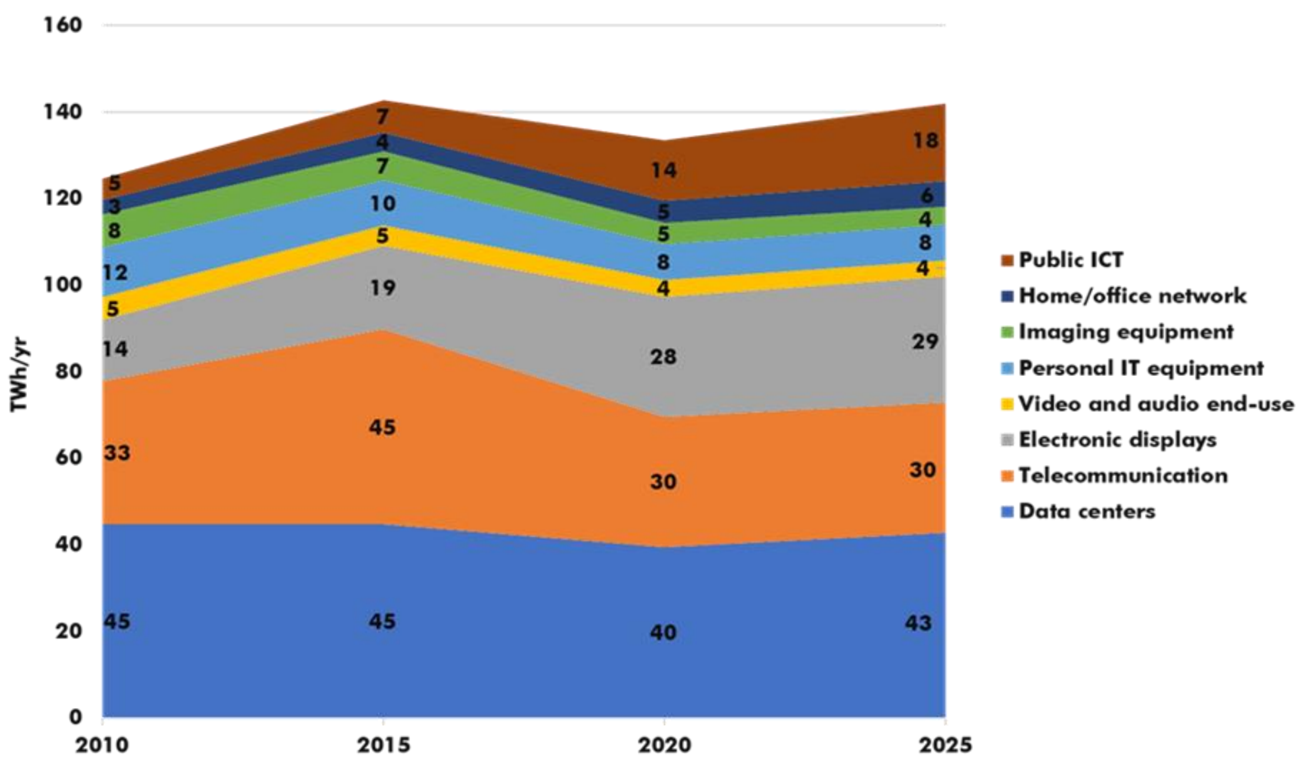


Figure 9. Electricity consumption trends of product categories in EU27 for non-residential sector [12]

The energy consumption of a product, which is the driver of product use phase emissions depends on various factors, including product size, whether battery powered or plug in, type of battery and its efficiency, customer behavior, mode, and power rating. For example, Figure 10 illustrates the difference in energy consumption across various ICT devices per year. Products that need to be plugged in to work generally consume more electricity than products that are battery powered. In addition to energy consumption, use phase GHG emissions are also driven by the grid mixes of the electricity used, especially in data centers, which includes high energy consuming products, such as servers and network equipment.

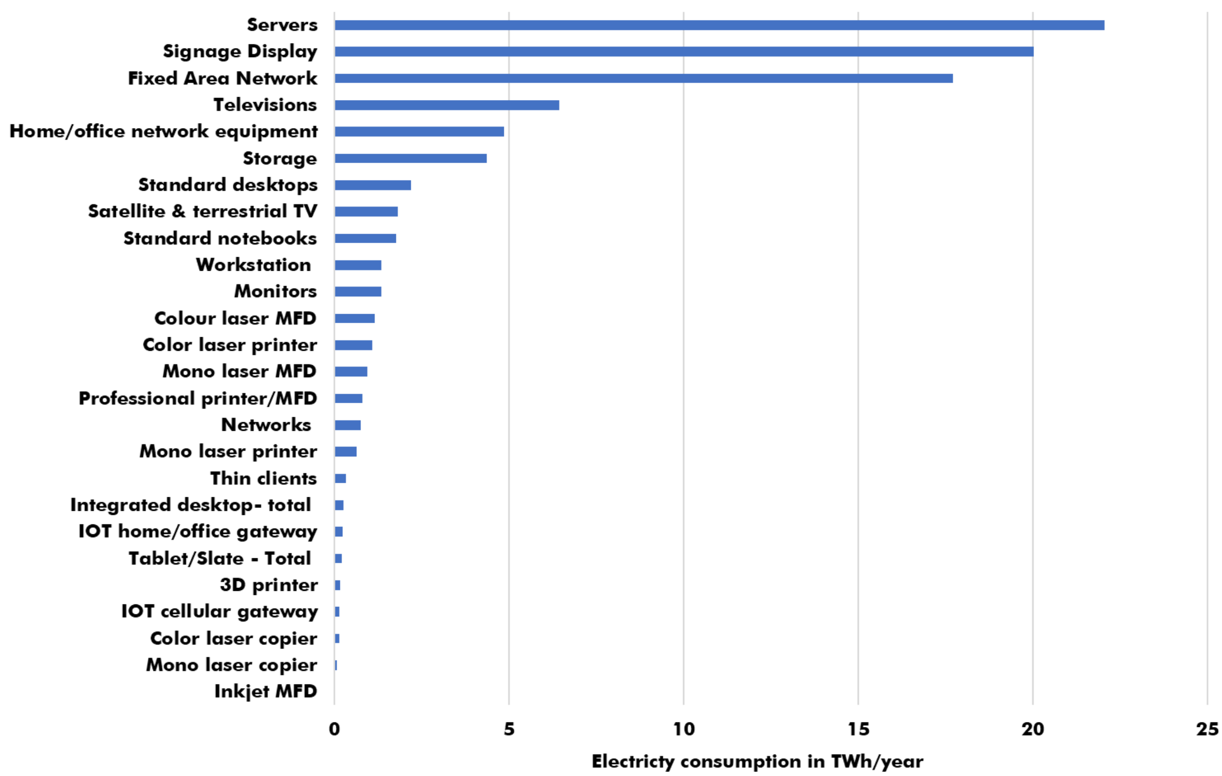


Figure 10. Energy consumption of various products in EU27 for non-residential ICT sector [12]

3. Strategies to reduce climate change impact

3.1. Product carbon footprint or life cycle assessment

This State of Sustainability Research report summarizes publicly available LCA data and provides a good indication of the GHG emission hotspots in the life cycle of ICT products. Preparing a customized analysis of GHG emissions -- either as a part of a life cycle assessment (LCA) or a product carbon footprint of the product – is a valuable tool for pinpointing specific materials, components, and operations that contribute the greatest to GHG emissions for a specific product system. Life cycle assessment or carbon footprints should take a holistic view -- from extraction of raw materials to product end-of-life. These tools also enable analysis of alternative scenarios, such as sourcing electricity from renewable energy sources instead of fossil fuels, alternate product transportation modes, and material substitutions.

3.2. Reducing Embodied carbon from upstream sources

There is an increasing recognition of the significant contribution of upstream carbon to life cycle GHG emissions of ICT products, as illustrated in earlier section of this report. While not specific to the ICT sector, models of global energy systems developed by the International Renewable Energy Agency (IRENA) indicate that "the combination of use of renewable energy and energy efficient technologies can potentially achieve 90% of the carbon reductions required to limit global temperature rise to a maximum of 2 degree above pre-industrial levels with a 66% probability in line with the Paris Agreement goals"[13].

Strategies to reduce upstream carbon are discussed below.

- Energy efficient manufacturing

Improving energy efficiency in the manufacture of components and product assembly can provide a significant reduction in upstream embodied carbon of a device. Facilities that manufacture the following components should be prioritized as they are the largest contributors to embodied carbon, as previously shown: printed circuit board (PCB), integrated circuits (ICs), diodes, and displays. A product-specific LCA or carbon footprint with customized supplier data may identify additional or alternative components for consideration.

While execution of discrete energy efficiency projects leads to results, there is increasing recognition of the value of applying a systems-based, continuous improvement approach to energy management, similar to ISO 90001 for quality management and ISO 14001 for environment management. For example, 3M and Schneider Electric worked with the U.S. Department of Energy (DOE) to assess the benefits of implementing *ISO 50001 - Energy Management Systems* in their facilities [14]. The findings of this analysis show that ISO 50001 certified facilities outperformed non- ISO 50001 certified facilities and continued to do so over time. See Figure 11. While the benefits vary by facility, on average, U.S. DOE estimates that one can achieve a 4% to 5% reduction in total emissions by implementing ISO 50001[2]. There are tools provided by U.S. DOE, such as the ISO 50001 Impact Estimator Tool [15] (IET 50001), which can be used by a manufacturer to evaluate their own individual benefits from implementing ISO 50001.

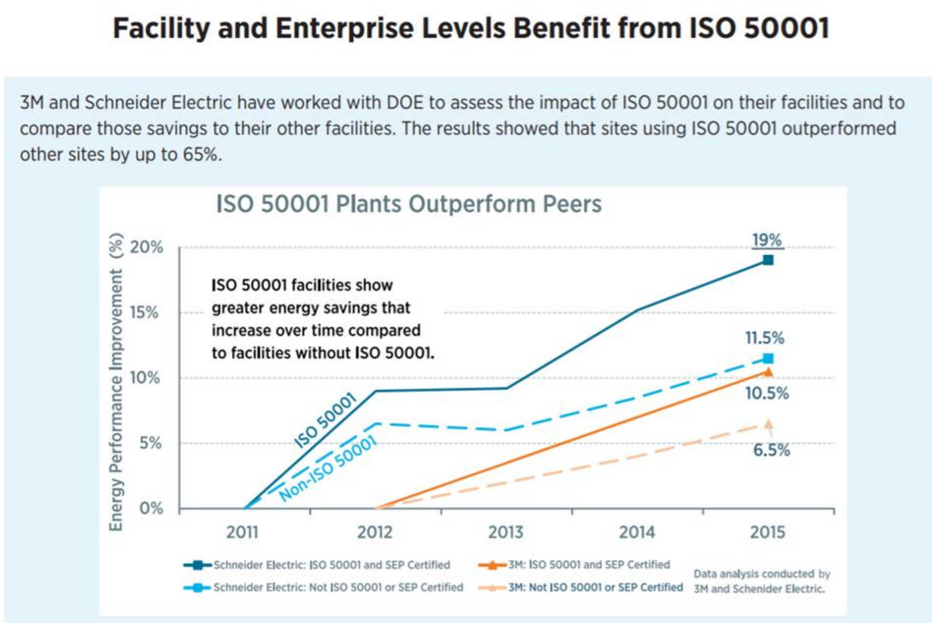


Figure 11. Comparison of savings with and without ISO 50001 implemented energy management systems[14]

[2] Communications with and data provided by U.S. DOE staff

- Use of electricity generated from renewable sources in manufacturing facilities

The grid energy mix plays an important role in increasing or decreasing GHG emissions from manufacturing facilities. Electricity generated from renewable energy sources, such as solar, wind and hydropower, emit fewer greenhouse gases, which lowers total upstream embodied carbon of the product. As cited earlier in the report, WEF estimated that sourcing electricity from renewable resources could reduce GHG emissions in the electronics supply chain by 35% [1].

- Reducing F-GHG emissions in manufacturing

Over the last decade, many suppliers in the flat panel manufacturing and semiconductor industries have taken voluntary steps to reduce their F-GHG emissions. Many participating suppliers of the World Display Industry Cooperation Committee (WDICC), which includes the LCD industry associations in Korea, Taiwan, and Japan implemented strategies to address their emissions, including installing abatement technologies on production lines in their newer generation fabs [8]. As a result, they were able to reduce F-GHG emissions by 10.1 MMTCE, to where aggregate emissions totaled 1.75 MMTCE in 2010 [8]. Members of the World Semiconductor Council (WSC) reduced F-GHG emissions 32% from 2000 to 2010 [9]. From 2010 to 2018, their absolute F-GHG emissions increased by 13.5%, however, normalized emissions (kgs of CO_2 eq per area of silicon wafers) decreased by 19.6%. This implies operational controls have become more effective in reducing F-GHG gases, but that total production and total net F-GHG emissions are increasing. ICT brands play an important role in driving change in their supply chains through procurement, and specifically in setting the expectation and holding suppliers accountable for monitoring and reduction of F-GHG emissions in the manufacture of components purchased for their products.

3.3. *Product energy efficiency*

Improving energy efficiency of products reduces product use phase GHG emissions of ICT devices. While specific methods to improve energy efficiency vary by product type, best practice guidance developed by governments and standards bodies is available. Some prominent examples are provided below.

- U.S. ENERGY STAR Program for ICT equipment

The U.S. ENERGY STAR Program is a voluntary energy efficiency program that is managed by the U.S. EPA and the U.S. DOE. The main objective of this program is to help businesses and individuals save money while protecting the environment through better energy efficiency. The criteria set by the program varies with the product category, and generally covers power supplies and energy consumption requirements during all operational modes of a product. ICT product categories currently covered under ENERGY STAR include:

- Data center equipment: Includes data center storage, servers, large network equipment, small network equipment
- Office equipment: Includes computers, imaging equipment, monitors
- Consumer electronics: Includes televisions

The relative efficiency of ENERGY STAR certified products, as compared to conventional products is shown in Table 1 for select product categories.

Product category	% more efficient than conventional models
TV	25
Computers	25 – 40
Monitors	7
Imaging equipment	35
Servers	30
Small network equipment	20

Table 1: Comparison of energy efficiency of ENERGY STAR certified products to conventional models [16]

For further information, please refer to the ENERGY STAR website directly.

- 80 Plus® for power supplies

80 Plus is a voluntary program used to rate power supplies in computers, servers, and data center devices based on their reliability and efficiency. The performance specifications require multi-output power supplies in computers and servers to be 80% or greater energy efficient at 20%, 50% and 100% of rated load with a true power factor of 0.9 or greater. The specifications of the program are summarized in Table 2 below.

80 PLUS Certification	115V Internal Non-Redundant				115V Industrial			
% of Rated Load	**10%**	**20%**	**50%**	**100%**	**10%**	**25%**	**50%**	**100%**
80 PLUS	-	80%	80%	80% PFC ≥ 0.90	-			
80 PLUS Bronze	-	82%	85% PFC ≥ 0.90	82%	-			
80 PLUS Silver	-	85%	88% PFC ≥ 0.90	85%	80%	85% PFC ≥ 0.90	88%	85%
80 PLUS Gold	-	87%	90% PFC ≥ 0.90	87%	82%	85% PFC ≥ 0.90	90%	87%
80 PLUS Platinum	-	90%	92% PFC ≥ 0.95	89%	85%	90% PFC ≥ 0.95	92%	90%
80 PLUS Titanium	90%	92% PFC ≥ 0.95	94%	90%	-			
80 Plus Certification	**230V EU Internal Non-Redundant**				**230 V Internal Redundant**			
% of Rated Load	10%	20%	50%	100%	10%	20%	50%	100%
80 PLUS	-	82%	85% PFC ≥ 0.90	82%	-			
80 PLUS Bronze	-	85%	88% PFC ≥ 0.90	85%	-	81%	85% PFC ≥ 0.90	81%
80 PLUS Silver	-	87%	90% PFC ≥ 0.90	87%	-	85%	89% PFC ≥ 0.90	85%

80 PLUS Gold	-	90%	92% PFC ≥ 0.90	89%	-	88%	92% PFC ≥ 0.90	88%
80 PLUS Platinum	-	92%	94% PFC ≥ 0.95	90%	-	90%	94% PFC ≥ 0.95	91%
80 PLUS Titanium	90%	94% PFC ≥ 0.95	96%	94%	90%	94% PFC ≥ 0.95	96%	91%

Note: PFC means "Power factor correction" or "Power factor controller"

Table 2. 80 PLUS program specifications [17]

- EU Code of Conduct for ICT

The EU Code of Conduct (CoC) for ICT is a voluntary policy instrument started in 2000. The main objective of the CoC is to develop policies to reduce energy consumption of ICT equipment. The CoC sets power consumption levels for energy- efficient ICT equipment. The power consumption levels are unique to a product category. The main areas of the Code of Conduct for ICT include:

- External power supply units (EPS)
- Digital TV services
- Broadband equipment
- Data centers Uninterruptible power supplies (UPS)

For further details, please refer directly to the EU's Code of Conduct website.

- Battery charger system efficiency

The U.S. DOE and the U.S. State of California Appliance Efficiency Regulations establish requirements for energy efficiency of battery charging systems. The California and U.S. Federal standards are reported to increase battery charger energy efficiency by 10% [18], generating total electricity savings of 18 billion kilowatt hours per year, which is equivalent to 8.6 million metric tons of avoided CO_2 emissions per year [19].

- Optimizing customer operations

In addition to energy efficient technologies, working with customers to optimize effective use of software/hardware, and encourage sourcing of renewable energy would further reduce to the overall ICT footprint. This is especially important for data centers since the ICT equipment is highly configurable and customized for the operation.

- Additional resources

ENERGY STAR for typical electrical consumption of a product, 80PLUS specifications for power supply unit efficiency guidelines and the European Union's Code of Conduct for ICT all contribute to reducing use phase energy consumption. Additional potential resources include ASHARE Thermal Guidelines for Data Processing Environments and Voluntary Agreements inclusive of test procedures and continuous improvement targets.

3.4. Product transport emissions reduction

There are various factors influencing product transport GHG emissions, including logistics, packaging weight, mode of transportation, and type of fuel source used. Product life cycle assessment can help manufacturers identify the sources of transportation carbon emissions, and potential mitigation strategies for these problem areas. For example, HP was able to avoid 25,000 tonnes of CO2e emissions in 2019 by switching the mode of transportation from air to ocean between Asia and the Americas, Europe, and other countries within Asia [20].

There are several tools available that can help manufacturers calculate emissions from product transportation, including the Global Logistics

Emissions Council (GLEC), EPA SmartWay program, Clean Cargo Working Group, Green Freight Asia, and the United Nations Climate & Clean Air Coalition. These tools can help companies track, report, and reduce GHG emissions, improve energy and fuel efficiency, set goals, and improve overall environmental performance [20]. For example, Schneider Electric, one of the participants in the U.S. EPA's SmartWay program, reduced product transportation emissions 4.13% from 2018 to 2019 [21] .

4. Standardization

Table 3 summarizes relevant standards and voluntary programs that can provide a foundation for product definitions, best practices, and benchmarks.

Focus	Standard
Product Carbon Footprint	GHG Protocol Product Standard: ICT Guidance (GHG Protocol: 2013)
	CFP-PCR:2013: Carbon Footprint of Products Communication Program (Japan)
	PIT PAIA (2014) LCA of ICT devices based on attributes
	PEFCR Pilot: Product Environmental Footprint Category Rule (ICT)
	ISO/TS 14067, Carbon footprint of products – Requirements and guidelines for quantification and communication
Life cycle Assessment	ISO 14040, Environmental management – Life cycle assessment – Principles and framework
	ISO 14044, Environmental management – Life cycle assessment – Requirements and guidelines
Energy efficiency in manufacturing	ISO 50001 Energy Management
Product energy efficiency	U.S. ENERGY STAR Program for ICT equipment
	IEC test procedures for ICT equipment
	EU Code of Conduct for ICT
	EU Energy Labeling Programs for ICT
	ASHRAE TC 9.9 Thermal Guidelines (3rd Edition)
Battery charger efficiency	U.S. Department of Energy (DOE) regulation (10 CFR 430.32)
	California Appliance Efficiency Regulations (Title 20)
Power supplies	80 Plus® Program
Product transport	Global Logistics Emissions Council Framework (GLEC)
	U.S. EPA SmartWay

Table 3. Overview of relevant sustainability standards for ICT devices

5. Summary of recommended criteria

This State of Sustainability Research report serves as the evidenced-based scientific foundation for criteria development for the EPEAT ecolabel. Table 4 provides a summary of mitigation strategies and best practice resources by product life cycle stage, as identified throughout this report.

Impact	Mitigation strategy	Best Practices/ Resources	Criterion Focus
Life cycle carbon	Conduct product carbon footprint or full LCA to identify product specific hotspots	ISO 14067, ISO 14040, ISO 14044	Product, Manufacturer, Supply Chain
Upstream embodied carbon	Reduce energy consumption in component and manufacturing facilities	Implement facility energy efficiency programs; energy management systems that meet ISO 50001	Manufacturer operations and supplier facilities
	Reduce carbon intensive energy sources in component and manufacturing facilities	Source electricity from renewable energy sources	Manufacturer operations and supplier facilities
	Reduce F-GHG emissions in semiconductor and flat-panel manufacturing	Use of strategies, such as source reduction, abatement technologies and, or safer alternatives	Component manufacturers
	Assess product transport GHG emissions, identify opportunities for reduction, and establish reduction goals	GLEC framework, EPA SmartWay program, Clean cargo working group, Green freight Asia	Supply Chain
Product use phase GHG emissions	Improve product energy efficiency	ENERGY STAR, 80 Plus (Power supplies), European Union's Code of Conduct for ICT, US	Product

		DOE battery charger efficiency regulation	

Table 4. Summary of mitigation strategies for priority climate change impacts of ICT products

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Appendix

Percentage						
Product category	Example products	Source	Production	Transportation	Use	End of life
Network Equipment	IP Phone	LNE report[22]	19.5	0.2	80.5	-0.2
	Chassis-Based Switch		6	1	93.4	-0.4
	Small Access Router		5.95	1.45	92.8	-0.2
	Large Chassis Router		4	3.2	93	-0.2
	Mid-level Ethernet Switch		8.5	3	89	-0.5
Servers	Rack server	EU report[23]	8	<1	91	<1
	Blade system		5	<0.5	94.4	<0.5

Data storage	C-3 storage unit	EU report [23]	8	<0.5	91	<0.5
Smart phone	Generic smartphone	Fair phone [24]	77	4.6	15.4	3
Computers and Displays	Microsoft laptop	Microsoft[25]	76	3	20	1
	16-inch Mac book Pro	Apple[26]	75	5	19	<1
	Notebook C423	ASUS[27]	48.9	18.9	32.2	0.01
	iPad (7th generation)	Apple[28]	79	6	14	<1
	24-inch monitor (S24E650PL)	Samsung[29]	22	0.7	75.6	1.7
	Desktop PC	Marudut et al [30]	59.83	0.09	40	0.07
	Integrated desktop	Subramanian et al [31]	30	NA	69	1
TVs	LED TV (LG smart TV)	Climate report[32]	42.8	3.06	54.08	-2
Imaging Equipment	Laser printer	Xerox [33]	45	25	30	-10

Table 1. The percentage contribution of life cycle stages towards total carbon footprint of various ICT product categories. *

* Notes:

1. Production – includes raw material extraction and manufacturing, as well as component manufacturing and assembly of a parts and packaging
2. Transportation – includes transportation of a finished product from manufacturer to distribution centers and finally to the customer
3. Use – includes emissions associated with the energy consumed to power the device during product use phase estimated over the average life span of a product
4. End of life – includes emissions from end-of-life treatment pathways

ICT devices	Electricity consumption in 2020 (TWh/year)
Inkjet MFD	0.02
Mono laser copier	0.05
Color laser copier	0.12
IOT cellular gateway	0.14
3D printer	0.15
Tablet/Slate - Total	0.19
IOT home/office gateway	0.23
Integrated desktop- total	0.24
Thin clients	0.33
Mono laser printer	0.63
Networks	0.74
Professional printer/MFD	0.8
Mono laser MFD	0.93
Color laser printer	1.08
Colour laser MFD	1.15
Monitors	1.33
Workstation	1.34
Standard notebooks	1.77
Satellite & terrestrial TV	1.8
Standard desktops	2.18
Storage	4.35
Home/office network equipment	4.86
Televisions	6.44
Fixed Area Network	17.7
Signage Display	20.01
Servers	22.05

Table 2. Energy usage of various ICT products [12]