NOKIA

Beyond the numbers

A deeper dive into the interplay of company footprint, product footprint and circular products

White paper

Susanna Kallio, Pradeep Mahat, Lauri Kuru

This paper provides an overview of environmental impact assessment and reporting for circular products. We first introduce and compare the most widely used standards and guidance for determining product and company environmental footprints. We explain how a product footprint and a company footprint relate to each other by showing the common characteristics and differences between the two approaches. One of the most obvious differences involves the timeframes used for assessment. While a product footprint is determined by quantifying the environmental impact of a product or service over its entire life cycle, which sometimes lasts over a decade, a company footprint typically evaluates the sustainability efforts of the company over a reporting period that spans a single year. We also highlight how the environmental footprint looks from the perspective of manufacturers and users, since there are some differences in the reporting approach To bring this all together, we describe in more detail the environmental impact assessment of a circular product in the context of recent additions to assessment standards, as well as showing manufacturer and user reporting approaches on the environmental impact of circular products.

Contents

Introduction

We live in an era of unprecedented technological advancement, economic growth, global connectivity and collaboration. This combination of factors has led to remarkable progress in education, health, wellbeing and has raised the living standards of billions of people. However, due to rapid industrialization, urbanization and the resources needed to support a growing population, the world is currently facing multiple environmental crises: climate change, pollution, resource scarcity, water shortages and biodiversity loss. Now, more than ever, achieving environmental sustainability is of the utmost importance. To address these environmental challenges, mitigate their impact, and comply with environmental regulations, companies are focused on reducing the negative environmental impact of their products and business operations (a.k.a. footprint) and increasing their positive impact (a.k.a. handprint) on the people and planet.

To succeed, businesses need to define their sustainability goals and monitor and improve their performance against them using measurable metrics and indicators. As the saying goes “what cannot be measured, cannot be improved,” which calls for a standardized way of assessing and reporting environmental impacts. To quantify and evaluate the effectiveness of prevention and mitigation strategies for environmental impacts, the resulting environmental footprint is assessed by identifying the material and energy flows involved, collecting data for these, and mapping them to the related environmental impact.

The circular economy is a concept that has evolved over time, and has been boosted lately by EU regulations. In the past, circularity – when implemented – has often been seen as a “nice to have,” whereas today it is increasingly being recognized as a necessity due to humanity’s insatiable demand for natural resources. One example of a circular economy is a collection program for obsolete mobile phones. Phones are either refurbished or sent for material recycling, a process which will separate at least some valuable metals from the phone. Without the adoption of circular economy practices, we will continue to face problems with resource scarcity and excessive generation of waste and pollution.

This paper presents an approach for assessing the environmental impact of circular products. We first provide an overview of, and a comparison between, the various methodologies and standards available for evaluating the environmental impact of products and companies. We reviewed existing approaches and standards for product footprint and company footprint to study the similarities and differences between them, from both product manufacturer and user perspectives. Building on these methodologies, we describe the updates needed to make them applicable for circular products. Finally, we discuss what the reporting of circular products as part of a company’s footprint means from the perspective of manufacturers and of multiple users.

Circularity and environmental impact

The circular economy is essential for multiple reasons. The pressure on our planet is increasing with the depletion of natural resources and the environmental impact of exponential growth underpinned by linear practices of take, make and dispose. Six out of nine planetary boundaries identified by the planetary boundary framework have already been breached. This framework defines the safe operating limits for Earth's systems and critical processes, within which humanity can continue to develop and thrive without causing irreversible environmental damage [1]. The global extraction of resources is about 100 billion tons today, which has tripled since 1970, and almost doubled since the 2000s [2]. Humanity is currently using almost 1.7 times the Earth's biocapacity, which is the amount of ecological resources the Earth can generate in a particular year. This is the equivalent of using 1.7 Earths [3]. Moreover, the extraction and processing of the Earth's resources contribute half of total global greenhouse gas (GHG) emissions and over 90% of biodiversity loss and water stress [4]. The circular economy is a key element for mitigating these impacts.

The notion of circularity has deep historical origins that cannot be traced back to one event or person. Over time, the generic concept has been developed and refined by different schools of thought. In the 1970s, a closed-loop approach to production processes was presented as the continuation of the cradle-to-cradle concept, from the beginning of one life cycle until the beginning of the next life cycle. Later concepts like biomimicry, blue economy, lifecycle and system thinking, eco-design and industrial ecology made the idea of a circular economy even more robust [5]. At its core, the circular economy is a system in which products and materials are kept in circulation through design and corporate actions with the goal of eliminating waste, pollution and negative environmental impacts. It can tackle global challenges like climate change, biodiversity loss, waste and pollution by decoupling economic activity from the consumption of resources that are very limited on our planet [6].

As awareness of climate change, biodiversity loss and pollution continues to grow among citizens, governments and organizations, the recognition of the need to move to a circular approach is stronger than ever. Today's digital technology can support the transition to a circular economy, for example with the help of virtualization, de-materialization, and transparency [7]. Driven by environmental urgency and enabled by the technological capabilities of the modern world, the time to shift to the circular economy is now. This is also shown by the fact that the circular economy and digital transformation are two of the major trends over the last few decades [8]. The Circularity Gap Report 2024 states that the circular economy has now reached megatrend status with the volume of discussions, debate and articles on the concept almost tripling over the last five years [2]. In recent years, the Ellen McArthur Foundation, a non-profit organization committed to accelerating the transition to a circular economy, has played a significant role in popularizing and advancing the circular economy concept globally among the general public.

Transitioning to a circular economy not only has ecological benefits, but it also has significant economic potential as well. The circular economy is expected to contribute $4.5 trillion in economic value [9] and create millions of new jobs by 2030 [10]. Customers, regulators and industry leaders are increasingly demanding a transition to the circular economy. Achieving this requires the development of circular products with an extended operating lifetime, which keeps them in use longer, rather than simply recycling the materials used to manufacturer them. For example, an extended operating lifetime can be achieved through repair, reuse, and refurbishment. We will describe later in this paper how these processes are considered in determining product and company footprint.

Before going into these details, however, we will look more closely at the current practices and standards for product footprint and company footprint.

Product footprint

The environmental impact of a product, known as product footprint, is assessed using the Life Cycle Assessment (LCA) methodology. LCA is a well-established methodology for assessing the lifetime environmental impact of a product, network, or service. For simplicity, we use the term "product" in this paper to refer to products, networks and services.

LCA has its origins in resource management and energy analysis in the 1960s and 1970s. Since then, LCA has grown into a wide-ranging tool used to explore potential impacts of products on resource depletion and on a variety of other environmental metrics. From 1970 to 1990 there were widely varying approaches, methodologies, terminologies and interpretations of the LCA results, which triggered the demand for a standardized methodology and common theoretical frameworks. The period from 1990 to 2000 is considered to be a decade of standardization for LCA. This period saw significant growth in scientific and coordination activities worldwide, which resulted in many workshops and forums and the publication of various guides and handbooks. The Society of Environmental Toxicology and Chemistry (SETAC) Standards were developed in the 1990s based on a retrospective approach and were used mostly for regulatory purposes. The International Organization for Standardization (ISO) got involved in the standardization of LCA in 1994 and the SETAC standards were later adopted and amended to ISO standards, which resulted in ISO 14040 and ISO 14044 [11]. These are the foundational international LCA standard frameworks upon which most other LCA standards and guidance are built. The ISO LCA standards are high level and leave practitioners with some room for subjectivity in their interpretation, which can influence the results of individual LCA studies. As a result, there are other standards and guidelines that provide more detailed instructions for consistency, quality and relevancy [12], [13].

LCA is a systematic way of identifying, quantifying and assessing the environmental burdens associated with every stage in a product's life cycle, helping companies understand its environmental impact and opportunities for improvement. In ISO 14040, LCA is defined as the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [14]. The scope of an LCA study covers the whole life cycle from raw material acquisition through production and use to the end-of-life of a product. The scope of LCA covering the full product life cycle is also called cradle-to-grave. Some other LCA Inventory types are listed in Table 1.

Table 1. Example of LCA inventory types

LCA inventory types	Description
Cradle-to-grave	Includes emissions from all the life cycle stages: raw material acquisition, production, use, and end-of-life treatment
Cradle-to-gate	Includes emissions from the partial life cycle from material acquisition through to when products leave the factory gate, in other words immediately following production. (e.g. ICT goods ready to be put on the market with no need for further processing)
Cradle-to-cradle	Includes emissions from all the life cycle stages, however it doesn't stop at the grave (end-of-life) and encompasses the processes that makes the materials, products and components (re)usable for another lifecycle
Embodied emissions	Includes emissions from all lifecycle stages except the use stage. Basically, emissions from cradle-to-gate, distribution to the end user, and the end-of-life treatment
Embodied environmental impact	Includes environmental impact from all lifecycle stages except the use stage. In other words, impact from cradle-to-gate, distribution to the end user, and the end-of-life treatment

During an LCA study, environmental impact from different processes and sources are grouped into relevant environmental categories based on their effect on the environment. Since a single environmental impact category alone cannot evaluate the complex environmental impact of an entire product, there are multiple environmental impact categories, including climate change, ozone depletion, land use, resource use, water use, particulate matter, eutrophication, ecotoxicity and human toxicity, that can be evaluated using LCA (See Table 2). Climate change is the most important and widely used impact category. It is also commonly used in company environmental impact assessments, where the indicator is greenhouse gas (GHG) emissions, which are sometimes referred to informally as the carbon footprint.

The impact of climate change is reported as Global Warming Potential (GWP) in carbon dioxide equivalent (CO_2e) units. CO_2e units consider the seven most important Greenhouse gases (GHGs) which date from the Kyoto Protocol and later commitments: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6), and nitrogen trifluoride (NF3) [15]. These different greenhouse gases are converted to a common unit for direct comparison between various gases. For the GWP value, the most common practice is to convert all the emissions into an “equivalent” value of carbon dioxide emission, usually with a 100-year timeframe, where the value of CO_2 is standardized to 1. For example, the GWP values for a 100-year time horizon for methane and nitrous oxide are 27 and 273 respectively [16]. All seven of these GHGs are typically considered when people talk about a product’s carbon footprint.

Several LCA standards (ISO 14040, ISO 14044, ISO 14067 [17] ITU-T L.1410 and the EU Product Environmental Footprint Method) provide the methodology for life-cycle assessment. The GHG Protocol Product Standard [18] provides an LCA methodology focusing on the climate change impact category only. ITU-T L.1410 was specifically developed for information and communication technology (ICT) products, networks and services, and looks at the flows and activities that are typical for these products. The other standards mentioned above are generic to all products. The GHG Protocol also provides ICT sector guidance with a special focus on ICT services. The product environmental footprint covers the environmental impact caused during the full lifetime of an ICT network infrastructure product. This typically represents a period of more than 10 years, based on the average lifespan of ICT network infrastructure products. With the current path to the transition into the circular economy, and more pressure from regulators to reduce environmental impacts and improve circularity, a product could have multiple uses and owners even after its initial end of use. In case of the operating lifetime extension of a product, the total lifetime environmental impact should also consider the impact of successive uses of the product. Circularity related considerations driven by Nokia are included in the latest revision of the LCA methodology in ITU-T L.1410 standard, effective as of November 2024.

As discussed earlier, LCA methodology can also be used for assessing a product’s environmental impact/footprint on other environmental impact categories beyond climate change. L.1410 and EU PEF list 16 environmental impact categories which are considered to be midpoint indicators (see Table 2). Material use (minerals and fossils), water use, and land use are especially important impact categories in addition to climate change, since they are drivers of biodiversity and geodiversity loss.

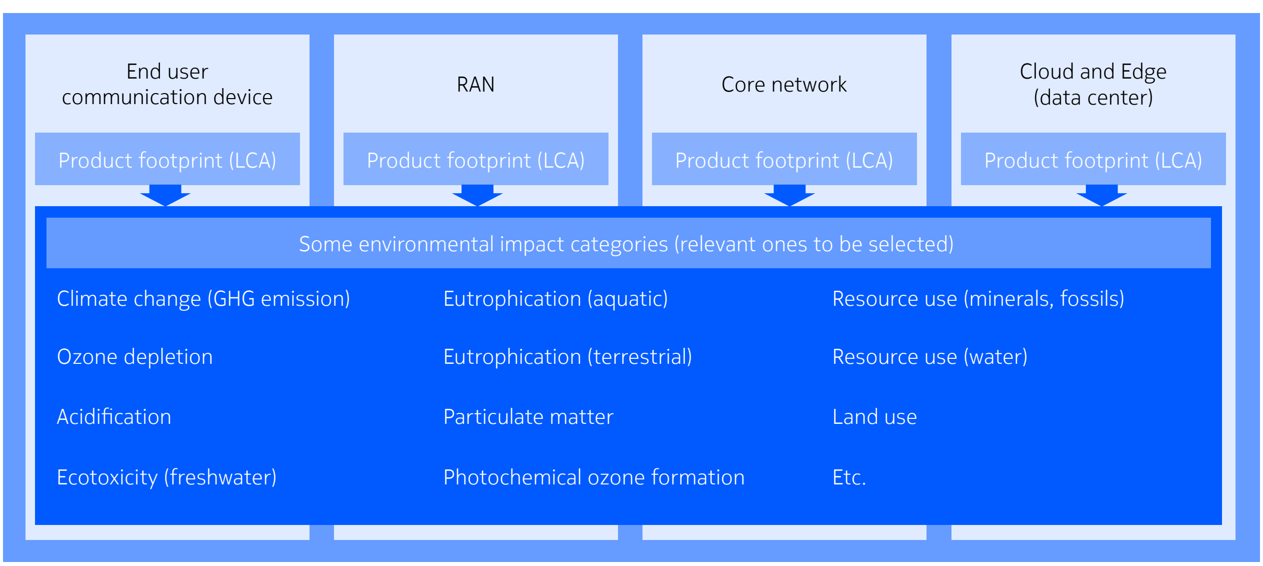
NOKIA

Table 2 – Environmental impact categories [19]

	Midpoint impact categories
1	Climate change (GHG emissions)
2	Ozone depletion
3	Human toxicity, cancer effects
4	Human toxicity, non-cancer effects
5	Respiratory inorganics/particulate matter
6	Ionizing radiation, human health
7	Ionizing radiation, ecosystems
8	Eutrophication, aquatic
9	Eutrophication, terrestrial
10	Photochemical ozone formation
11	Acidification
12	Ecotoxicity, freshwater
13	Land use
14	Resource depletion, water
15	Resource depletion, mineral
16	Resource depletion, fossil

For networks and services, the environmental impact of several products can be combined to assess their overall impact. Figure 1 provides an example of one such case where the overall environmental impact of a mobile network can be derived by combining the environmental impact (product LCAs) of all the products used in the network. It also provides examples of some impact categories.

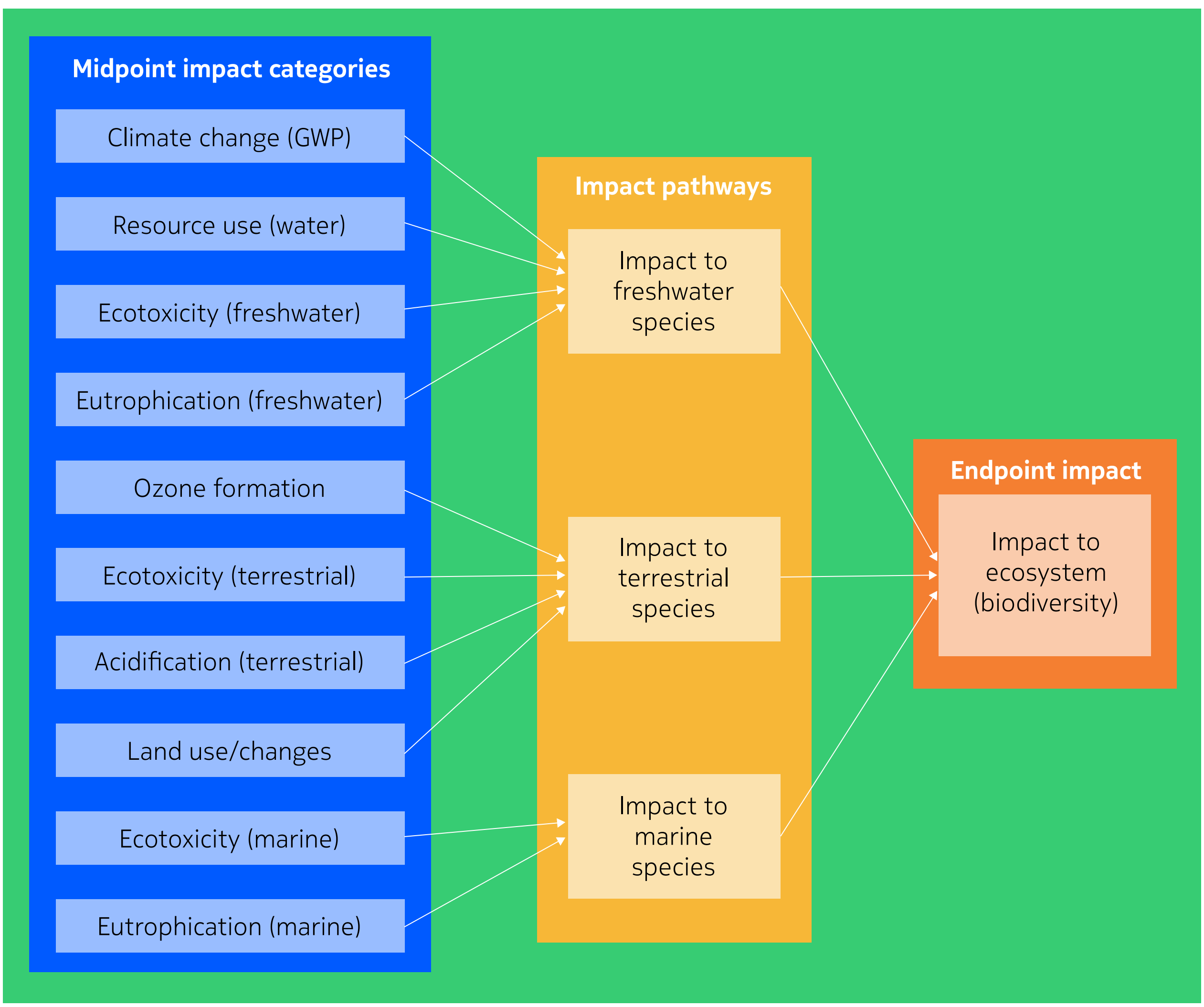
Figure 1: Examples of the environmental impact of a mobile network derived by combining the LCA results of multiple products used in the network and possible environmental impact categories



Relevant impact categories should be selected based on the goal and scope of the LCA study. Looking at results from several impact categories together using a holistic approach gives a wider view of the impact on climate, geodiversity and biodiversity [20]. Sometimes the results from these additional categories can be surprising or non-intuitive, such as a high land use impact from the packaging materials for ICT network products [21]. Land use has not previously been considered as the impact category with the highest impact from ICT products.

Furthermore, the midpoint indicators can be attributed to an endpoint indicator such as impact to ecosystem (e.g., biodiversity), as shown in Figure 2. The midpoint indicators provide the relation to the environmental flows in a cause-effect manner, whereas the endpoint indicators provide comprehensible information regarding the environmental relevance. However, the uncertainty significantly increases for endpoint indicators compared to midpoint indicators [22]. Therefore, most LCA studies use midpoint indicators. However, in some cases, depending on the goal of a LCA study and its intended use, endpoint indicators could be advantageous. Endpoint indicators could provide simplified communication and comprehensible interpretation of the LCA results for decision making to understand the holistic picture.

Figure 2. Some examples of midpoint and endpoint indicators for biodiversity impact and their relation. Illustration is inspired by overview of the impact categories chart of ReCiPe method [22].



A detailed LCA study is a complex and time-consuming task, and not all companies have the resources and skills to perform one thoroughly, especially small-medium enterprises (SMEs). An LCA study requires specialized skills and expertise. Practitioners conducting the study need to understand the implications from several aspects of the product lifecycle, such as raw material acquisition (including mining processes), energy production and type of energy, waste generation, pollution and end-of-life treatment alternatives. They also need to understand the environmental impacts (see different impact categories in Table 2, Figure 1 and 2) relevant to the type of product and its geographical significance considering the entire product life cycle journey, and the material and energy flows of complex supply chain and manufacturing processes. Equally critical is an in-depth understanding of the intensive data collection effort required for a multi-tier global supply chain, as well as other data-related requirements, such as diverse data sources, data availability, quality and uncertainty. The assumptions, modelling and calculations required to be compliant with the standards and requirements of the LCA study add further complexity. The time and resources required for LCA varies significantly based on the complexity of the product and supply chain and the scope of the study. For complex products, a detailed LCA could take a team of 5 to 10 specialists, including materials experts, production experts, waste, energy and data analysts and LCA experts, between 4 and 12 months to complete, depending on the scope, data requirements, data availability and planning required for the study.

Simplified approaches have been developed to address the issue of complexity. A simplified LCA can be used for screening assessments, providing input to customers for Scope 3 reporting, and for the development of a product environmental footprint. Special conditions need to be applied if the results are used for comparative purposes or disclosed to the public to demonstrate product superiority.

A review and comparison of existing LCA approaches

LCAs are a crucial and widely used tool for assessing the environmental impact of products. The results can be valuable for customer communication and company reporting on the impact of products sold, purchased goods and services, capital goods, leased assets, etc. As mentioned earlier, ISO 14040 and ISO 14044 are foundational international LCA standard frameworks upon which most other LCA standards and guidance are built. In this section, we examine the similarities and differences between the other most common LCA standards, in particular the GHG Protocol - Product Standard, ITU-T L.1410/ETSI 203 100, and EU PEF:

- The GHG Protocol Product Life Cycle Accounting and Reporting Standard provides requirements and guidance to quantify and publicly report an inventory of GHG emissions and removals associated with a specific product. [18]
- ITU-T L.1410 provides a methodology for environmental life cycle assessments of ICT goods, networks and services. This standard was developed jointly by ITU-T SG 5 and ETSI TC EE and was published by ITU as Recommendation ITU-T L.1410 and ETSI Standard ES 203 199 respectively, which are equivalent in technical content. [19], [23]
- EU PEF (Product Environmental Footprint) is an LCA-based method for assessing and communicating the potential life cycle environmental impact of products (goods or services) in the European Union. [24]

Table 3 compares GHG Protocol Product Standard, ITU-T L.1410/ETSI 203 199 and EU PEF:

Table 3. High-level comparison of product footprint standards GHG Protocol Product Standard, ITU-T L.1410/ETSI 203 199 and EU PEF

Aspects	GHGP Product Standard	ITU-T L.1410/ETSI 203 199	EU PEF
Year of publication	2011	2012, updated in 2014. Revised in 2024	2013 Revised in 2021
Introduction and purpose	Requirement and guidance for companies to quantify and publicly report an inventory of GHG emissions and removals associated with a specific product	Framework and guidance for ICT sector to complement ISO 14040 and 14044 for life cycle environmental assessment of ICT goods, networks and services	EU recommended Life Cycle Assessment (LCA) methodology to quantify the environmental impacts of products (goods or services)
Approach	Single product, whole life cycle using life cycle perspective. Provides general framework for companies to make informed choices to reduce GHG emissions from product and services they design, manufacture, sell, purchase or use.	Single product, whole life cycle using life cycle perspective: for ICT product, network and services. Part II provides methodology of doing comparative analysis between ICT and reference product system.	Single product, whole life cycle using life cycle perspective. Annex II provides requirements for developing Product Environmental Footprint Category Rules (PEFCR) and performing studies in compliance with an existing PEFCR.
Scope	Global scope for all products. Separate supplement document is available for ICT Sector Guidance with special focus on the ICT services.	Global scope specific for ICT products	Regional scope EU for all products However, its principles and methodologies can be applied globally, depending on the context
Goal and focus	Climate Change impact assessment. GHG emissions and removals	Environmental impact assessment, several impact categories	Environmental impact assessment, several impact categories
Based on	ISO 14040, ISO 14044 and PAS 2050, also ILCD Handbook	ISO 14040, ISO 14044 and ILCD handbook	ISO 14040, ISO 14044, PAS 2050, ILCD Handbook, Draft ISO 14067, ISO 14025, ISO 14020, GHGP, BPX 30-323-0 (ADEME)
LCA stages	1. Material acquisition and pre-processing 2. Production 3. Distribution and storage 4. Use 5. End of life (also includes disassembly and decommissioning)	1. Goods raw material acquisition 2. Production 3. Use 4. Goods end of life treatment Note: Distribution is not a stage, it is a generic process included in different life cycle stages where it takes place.	1. Raw material acquisition and pre-processing (including parts and components) 2. Manufacturing (production of main product) 3. Distribution (and storage) 4. Use 5. End of life (recovery and recycling)
Impact categories	1 category, climate change (GHG emission)	16 midpoint impact categories (see examples in Table 2, Figure 1 and 2)	16 midpoint impact categories (see examples in Table 2, Figure 1 and 2)
Comparative assertions	Does not support	Supports	Supports
Type of review	1st and 3rd party possible, however for external communication 3rd party review is recommended	3rd party review is mandatory for external communication	3rd party review is mandatory for external communication

Aspects	GHGP Product Standard	ITU-T L.1410/ETSI 203 199	EU PEF
Data sources and availability requirements	Primary or secondary Primary data for all process under their ownership or control	Primary or secondary Primary data is preferred	Primary or secondary Modelling of manufacturing shall be based on primary data
Data quality criteria	Assessed based on the following criteria • Completeness • Technological representativeness • Geographical representativeness • Time-related representativeness • Reliability	Assessed based the following criteria: • Completeness • Technological correlation • Geographical correlation • Data age (timeliness) • Methodological appropriateness and consistency • Uncertainty • Data representativeness • Acquisition method • Supplier independence • Cut-off rules (rules of inclusion/ exclusion)	Assessed based on the following criteria: • Completeness • Technological representativeness • Geographical representativeness • Time-related representativeness • Methodological appropriateness and consistency • Precision Shall observe the following principles: relevance, completeness, consistency, accuracy, transparency
Circularity and EoLT allocation	No clear guidance for reuse and refurbished products. Reuse is considered as recycling; hence no extended lifetime is considered. Material recycling: Closed loop (0/100) or recycled content method (100/0).	2024 revision includes circular processes and provides guidance for reuse and refurbished products. Supports extended operating lifetime including prepare for reuse. Material recycling: 50/50, 0/100, 100/0	Mentions that the Product Reuse and Refurbishment shall be considered, but no clear guidance provided, left to the practitioner to redefine the functional unit and reference flow for the assessment. Material recycling: Recycling allocation like 100/0 and 0/100 is not possible Circular footprint formula (CFF) for modelling of recycled content if the circularity-related process results in a product with different product specifications than the original product and EoLT material recycling.
Offsets	Offsets shall not be included in the impact assessment, but reported separately	Offsets are not mentioned	Offsets should not be included in the impact assessment, but reported separately
Cut-off	No guidance for cut-off except 100-0 recycling allocation method.	Guidance for cut-off is available. The cut-off criteria based on mass, energy and environmental significance is allowed	Guidance for cut-off is available. The cut-off criteria based on mass, energy and environmental significance is allowed
Reporting template	Not provided	Provided with the guidance in Annex L	Provided with the guidance in Annex II, Part E
Use of results	Disclosures and performance tracking over time. However, product labelling, environmental and performance claims, comparative assertions are not supported.	Decision making and comparative analysis	Decision making, comparative analysis, product labelling, environmental claims

In summary, the main differences between these three standards are:

- EU PEF and GHGP standards are generic for all products, while ITU-T L.1410 is dedicated to ICT products. GHGP also provides a separate supplement document for ICT Sector Guidance with a special focus on ICT services.
- ITU-T L.1410 and GHGP are global standards while EU PEF is developed for the EU.
- EU PEF and GHGP product standards divide a product's life cycle into five stages, while ITU-T L.1410 only considers four stages. Distribution is not a life cycle stage in ITU-T L.1410, but it is considered as a generic process included in different life cycle stages where it takes place.
- EU PEF and ITU-T L.1410 cover many environmental impact categories, while GHGP standard covers only climate change. Outside of listed environmental impact, EU PEF also allows for additional environmental information that can be reported when relevant, such as information on local site/site-specific impacts, IUCN Red list and national conservation list species with habitats in areas affected by operations, impact on biodiversity, noise impacts, or other environmental information considered relevant within the scope of the PEF study.
- EU PEF and ITU-T L.1410 support comparative assertion and claims regarding the overall environmental impact of one product versus a competing product intended for disclosing to the public, however GHGP does not support this.
- Circularity treatment varies:
  - ITU-T L.1410 revision in 2024 considers circularity-related processes widely, providing guidance for reuse and refurbished products and related processes.
  - EU PEF considers reuse and refurbishment but gives only partial guidance for end-of-life focusing on recycling, including use of Circular footprint formula (CFF, for modelling of recycled content if the circularity related process results in a product with different product specifications than the original product). The product reuse and refurbishment related considerations are mostly left to the practitioner to decide and to be considered by redefining the functional unit and reference flow for the assessment.
  - GHGP product standard provides no clear guidance for circular products (reuse and refurbishment).

In conclusion, we can say that the different product footprint LCA standards are quite well aligned since they are all based on ISO 14040 and 14044. Since ISO 14040 and 14044 only give high-level guidance for practitioners, the more detailed guidance provided by the standards we compared in this section is much needed. However, ITU-T L.1410 is focused on ICT products and includes sufficiently wide guidance for LCA of circular products, since it was recently added to this standard. A similar update to other LCA standards would be very welcome.

Company footprint

Today, more and more companies are reporting their environmental impact as a result of growing environmental awareness, changing market expectations and regulatory requirements. Companies are expected to report their sustainability achievements and impacts on environmental, social and governance (ESG) metrics annually. Typically, companies report on several environmental indicators, such as GHG emissions, renewable energy use, waste and circularity, along with their targets and status updates, as Nokia does in Nokia People and Planet [25], the Nokia Annual Report and Form 20-F [26].

When only GHG emissions are considered, a company's annual environmental impact is also called its company environmental footprint or company carbon footprint. The focus of this paper is annual carbon footprint reporting, which includes the environmental impact from the products that have been sold and purchased during the reporting year; the energy used and waste generated in operations and transportation; and the impact from other business overhead, such as business travel, employee commuting, and company office buildings.

The Greenhouse Gas Protocol Standards (GHGP) and GRI Standards (GRI)[27] are widely used methodologies and standards for company-level reporting. The GHGP Standard provides guidance to organizations for preparing their GHG emissions inventory and GRI 305 [28] provides a framework for reporting and managing the emissions. Other standards providing guidance for company footprint include:

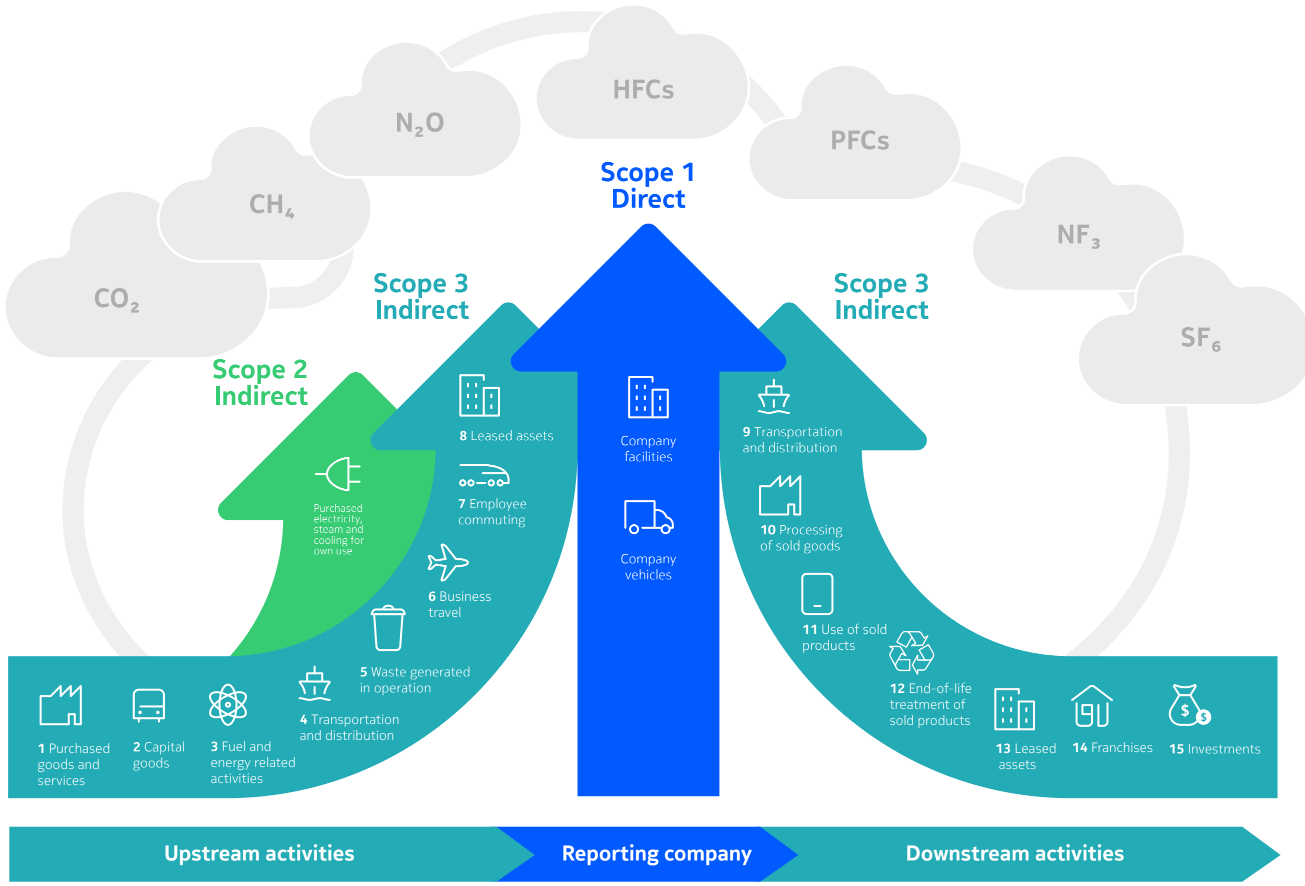
- ISO Standards: ISO 14064-1 which provides guidance to organizations for the quantification and reporting of GHG emissions and ISO/TR 14069 using the principles and process from ISO 14064-1. [29], [30]
- ICT industry-specific standards: For the ICT sector, ITU-T L.1420 [31] provides a methodology for energy consumption and for a GHG emissions impact assessment of information and communication technologies (ICT) in ICT and non-ICT organizations. This builds on the GHG Protocol standard by adding sector-specific guidance. Complementing ITU-T L.1420, Scope 3 Guidance for telecommunications operators was developed together by GSMA, GeSI and the ITU to harmonize methods for telecommunication operators to assess and report their Scope 3 GHG emissions [32].

EU Standard: EU has published its EU OEF [33] method for Organisation Environmental Footprint.

When reporting company footprint, GHG emissions are usually separated into three different scopes of emissions: Scope 1, 2 and 3 (see Figure 3).

- Scope 1 are direct emissions from the sources that are owned or controlled by the reporting company
- Scope 2 are indirect emissions from the generation of purchased energy (electricity, heat and/or steam)
- Scope 3 are other indirect emissions resulting from the sources in the value chain that are not owned or directly controlled by the reporting organization. Scope 3 emissions are typically the largest and most complex category to assess since they encompass a broad range of activities

Figure 3. GHG emissions separated into Scope 1, 2 and 3 according to GHG protocol



According to the GHG Protocol, Scope 3 reporting is optional, however it is crucial for understanding the full climate impact of a company and its supply chain. The Greening Digital Companies Report 2024 [34], prepared jointly by the ITU and the World Benchmarking Alliance (WBA), states that over 80% of emissions from a digital company belong to Scope 3 emissions. For example, around 99% of Nokia's total emissions are Scope 3 emissions and 97% of total emissions are from the use of Nokia products sold [35]. Even though Scope 3 emissions are by definition outside the company's direct control, companies can play an important role in reducing these emissions. By working together with their suppliers and customers, companies can reduce their own GHG emissions as well as those of their customers and suppliers.
For example, they can encourage suppliers to make the shift from fossil fuels to renewable energy for manufacturing their products. They can encourage their customers to do the same for energy used by the products they've sold to them. These steps will reduce the GHG emissions of all three parties involved (the manufacturer, suppliers, and customers). The GHG Protocol provides a separate standard with guidance and methodologies to quantify Scope 3 [36] accounting and reporting, which complements The GHG Protocol Corporate Accounting and Reporting Standard [15]. Recently, the EU mandated the reporting of Scope 3 emissions for companies of a certain size in its Corporate Sustainability Reporting Directive (CSRD) [37].

Scope 3 emissions are divided into 15 distinct categories to provide a systematic framework for organizing, understanding, and reporting on the diversity of business activities within a company's value chain. These categories are mutually exclusive to avoid any double counting. Scope 3 categories are separated based on whether the activities take place upstream or downstream in the value chain. These categories are listed below [36].

Scope 3 Categories of upstream activities:

- Category 1: Purchased goods and services
- Category 2: Capital Goods
- Category 3: Fuel and energy-related activities not included in Scope 1 or 2
- Category 4: Upstream transportation and distribution
- Category 5: Waste generated in operation
- Category 6: Business travel
- Category 7: Employee commuting
- Category 8: Upstream leased assets

Scope 3 Categories of downstream activities:

- Category 9: Downstream transportation and distribution
- Category 10: Processing of sold intermediate products
- Category 11: Use of sold products
- Category 12: EoLT of sold products
- Category 13: Downstream leased assets
- Category 14: Franchises
- Category 15: Investments

A review and comparison of existing company footprint approaches

Even though there are different standards and guidance available for GHG emissions calculations, most companies use the GHG Protocol Corporate Accounting and Reporting Standards [34]. According to the GHG Protocol, at least 92% of Fortune 500 companies that respond to the Carbon Disclosure Project (CDP) directly or indirectly use GHG protocol standards [38]. At the time of writing this paper, the GHG Protocol Corporate standards are undergoing revisions, and the revised standards are expected to be published during the second half of 2026 [39].

Table 4 provides a high-level comparison of four standards for company carbon footprint reporting.

Table 4 High-level comparison of the main company footprint standard GHG Protocol Corporate Standard with three other company footprint standards

Aspects	GHG Protocol corporate standard	ISO 14064-1	ITU-T L.1420	EU-OEF
Year of publication	2001	2018	2012 Revision ongoing	2013 Revised in 2021
Introduction and purpose	Standard for companies for developing GHG inventory, accounting and reporting of emissions.	The quantification and reporting of greenhouse gas (GHG) emissions and removals at organizational level.	The quantification and reporting of greenhouse gas (GHG) emissions by two approaches: (1) Impact of ICT activities in non-ICT organizations using L.1410 to access the impact of ICT in organization. (2) Impact of ICT organizations.	Methodology developed by EU which uses Life cycle approach for Organisation Environmental Footprint Method.
Approach	Inventory of company's activities (measurement or modelling)	Inventory of company's activities (measurement or modelling)	Inventory of ICT company's activities (measurement or modelling). Life cycle approach for emissions from ICT use in non-ICT companies.	Life cycle approach
Impact categories	GHG emissions	GHG emissions	GHG emissions (and/or energy consumption)	16 Impact categories are possible Normalised and weighted results as absolute values. Weighted results as single score.
GHG removals	Can be considered	Can be considered	Not considered	Can be considered
Scope and categories	Scope 1 direct Scope 2 indirect (energy) Scope 3 Other indirect in 15 categories	Not divided into scopes but uses the term "categories" mixing GHGP scopes and categories into different 6 categories.	Same as GHGP	No scopes and categories as in GHGP
Data	Primary or secondary data	Primary or secondary data	Primary or secondary data	Primary, secondary or proxy data
Cut-off	Cut-off not mentioned but allows processes to be excluded similarly as cut-off and also based on data gaps.	Cut-off not mentioned but asks for explanation and justification for the exclusion of any significant GHG sources or sinks from the quantification.	Shall comply with the cut-off principles described in ITU-T L.1410, only applies to Scope 3 categories.	Cut-off is allowed for processes and elementary flows to be excluded up to 3.0% (cumulatively).
Offsets	Required to be reported separately	Required to be reported separately	Doesn't mention offset	Required to be reported separately.

Aspects	GHG Protocol corporate standard	ISO 14064-1	ITU-T L.1420	EU-OEF
Circular products use guidance	Not mentioned	Not mentioned	Not in current version. Revision ongoing. Supplement document to ITU-T L.1420 - Scope 3 Guidance for telecommunications operators developed together with GSMA, GeSI and ITU provides guidance on how to consider circular (reused and refurbished) products	Not mentioned
Reporting and verification	Provides guidance for reporting GHG emissions and verification	Provides guidance for reporting as well as example template. Refers to other ISO standards (e.g., ISO 14064, ISO 14065, ISO 14066) for verification guidance	Provides guidance for reporting to inform external and internal parties. Refers to ISO 14064 for verification guidance	Provides guidance for reporting and verification of the environmental footprint
Target setting	Possible	Possible	Doesn't consider	Doesn't consider

In summary, the main differences between these four standards are:

- ITU-T L.1420 focuses on ICT sector or ICT activities in non-ICT organizations, while the others are not sector-specific.
- GHGP and ISO 14064-1 consider target setting in addition to assessment and reporting, whereas ITU-T L.1420 and EU OEF focus only on assessment and reporting.
- GHGP and ITU-T L.1420 use the same scopes and categories, while EU OEF does not use these terms. Even though the categories in ISO 14064-1 roughly match with GHGP scopes and categories, they are not differentiated as scopes and there is some contradictory naming of categories compared to GHGP.
- EU OEF uses a life cycle approach similar to product LCA, however GHGP and ISO 14064-1 use accounting based on inventory of a company's activities. ITU-T L.1420 allows both approaches: inventory of a company's activities for ICT companies and a life cycle approach for GHG emissions emerging from the use of ICT products in non-ICT companies.
- EU OEF allows the possibility of using 16 impact categories, including GHG emissions, while the other standards are focused on GHG emissions only.
- GHG removals and offsets can be considered in the assessment of all these standards except in ITU-T L.1420, which doesn't mention these.

The current standards do not provide clear guidance on how to consider emissions from purchased goods that are previously used and how to allocate emissions between different users. The Supplement document to ITU-T L.1420 - Scope 3 Guidance for Telecommunications Operators, developed together with GSMA, GeSI and ITU (see [32]), provides some guidance on how to consider circular (reused and refurbished) products. Similar guidance on the aspects related to circular economy would be beneficial for all the company footprint reporting standards.

In addition to the standards mentioned above, market regulation also shapes the reporting environment. The EU is a pioneer in this area, requiring large listed companies to report according to European Sustainability Reporting Standards (ESRS) starting from fiscal year 2024 (reporting expected in 2025) under the Corporate Sustainability Reporting Directive (CSRD). ESRS E1 specifies the required climate change-related disclosures, which cover a broad range of topics. Where the standards discussed above are largely focused on GHG emissions performance and impact, ESRS also requires companies to report on their climate change-related governance, strategy, transition plans, resilience, risks and opportunities, processes, policies and actions. ESRS calculation guidance leans strongly towards the GHG Protocol. While some alternatives are allowed, especially Scope 2 emissions calculations, ESRS mandates the use of market-based and location-based methods according to GHG protocol.

In conclusion, there are major differences between the different company footprint standards, starting from the concept level scoping and categorization of the environmental impact. However, most people are familiar with Scopes 1-3 from the GHG Protocol Corporate reporting standard and most of the big companies are reporting according to that standard. Therefore, the reported company footprints for these companies are in alignment and following the same principles. Moreover, with the increase in circularity related consideration and activities in companies, more guidance in circular economy related aspects would be beneficial for company footprint reporting as well.

Relationship between product and company footprint

In this section, we bring together the methods described in the previous sections by comparing the product footprint and company footprint methods from different perspectives to clarify the relationship between them. We present this in relation to the following aspects:

- Purpose and target audience
- Environmental impact category
- Timeframe
- System boundaries
- Data quality, availability and data sources

Purpose and target audience

The requirement for companies to report annually on their environmental performance originates from the markets and regulations. Similar to financial reporting, a company's sustainability actions and performance need to be declared at regular intervals. The target audience for a company's sustainability reporting, (e.g. the Nokia annual report [26] and Nokia People and Planet [25]) is made up of investors, regulators, customers, sustainability experts and the general public.

In contrast, the motivation for assessing product footprint originally came from a company's internal needs and demand from customers to better understand the environmental impact of products and to find ways of improving them, i.e., to reduce their environmental impact. LCA offers good insight into high-impact areas which companies can tackle. Today, customers are increasingly requesting LCA information for the products they intend to purchase so they have the data they need to meet company reporting requirements. LCA information helps companies provide relevant stakeholders with quantitative data on the environmental impact of their products. As a result, the target audience for LCA is made up of internal designers and product managers, the staff responsible for producing the company's annual environmental report, customers and possibly regulators in the future. The regulatory use might come with the upcoming Digital Product Passport (DPP) from ESPR regulation [40] as a possible requirement to provide the environmental impact or carbon footprint of a product.

Environmental impact category

When performing a product LCA study, the environmental impacts are typically assigned to a relevant impact category, such as climate change, ozone depletion, acidification, eutrophication, toxicity, water use, land use, etc. The selection of impact categories should reflect a comprehensive set of environmental issues related to the product being studied, taking the goal and scope of the study into consideration. [38]

A company footprint, on the other hand, typically focuses only on carbon footprint reporting according to the GHG Protocol. The strong focus on this single impact category is the result of several factors, including awareness of climate urgency, data availability, the Paris Agreement and net-zero emissions targets from most of the governments and the companies around the world. The Paris Agreement is a legally binding international treaty on climate change that was adopted by 196 parties at the UN Climate Change Conference (COP21) in Paris, France, in December 2016. The goal of the agreement, which calls for a significant reduction of the risks and impacts of climate change [41], was "stopping the increase in the global average temperature to well below 2°C above preindustrial levels" and pursuing efforts to "limit the temperature increase to 1.5 °C above pre-industrial levels." This Paris Agreement also prompted most of the governments and companies around the world, including Nokia, to set their net-zero emissions targets.

Nokia has committed to science-based targets to reach net-zero emissions across the value chain (Scope 1, 2 and 3) by 2040 [35].

Under new EU CSRD legislation, companies are also required to report on other environmental impact categories. Beginning in 2025, large-listed companies in the EU need to report on pollution, water and marine resources, biodiversity and ecosystem, resource use and factors related to circular economy, when these aspects are considered material for them according to the double materiality concept.

Timeframe perspective

As mentioned earlier, company environmental impact reporting is typically conducted annually and covers the impacts from the previous full year, whereas the product LCA timeframe expands to cover the full life cycle of the product from raw material acquisition until the last end-of-life treatment.

In company reporting, the environmental impact associated with products can be divided into two groups: (1) Products sold by the reporting company; and (2) products purchased by the reporting company during the reporting period.

For products sold by the reporting company (group 1 above), the full lifetime environmental impact of these products is included. This can be determined by a product LCA calculation. The full product life cycle expands beyond one year to cover the use of the product in the future (e.g., a period of 10 years for some network infrastructure products). The discrepancy between the different timelines is handled in company reporting by reporting only the impact from the products sold during the reporting period. Because it's not possible to have exact information about products that are still out in the field in use, this information is not reported. This reporting assumption is commonly accepted as the best model to estimate the company environmental impact.

For products purchased by the reporting company (group 2 above), the total cradle-to-gate emissions from purchased products, services and capital goods is typically accounted for in the reporting year during which the company purchased or acquired them. Cradle-to-gate emissions are emissions arising from the partial life cycle of ICT products or parts, from material acquisition up to the point at which they leave the factory gate (i.e., immediately following production). The activities included in cradle-to-gate don't necessarily happen during the same year, but they are reported for the year when the product was purchased by the reporting company. This is the most widely used approach based on the GHG Protocol, even though this approach differs from the one described by ISO 14064-1: 2018, which allows companies to depreciate emissions in line with economic depreciation of the product.

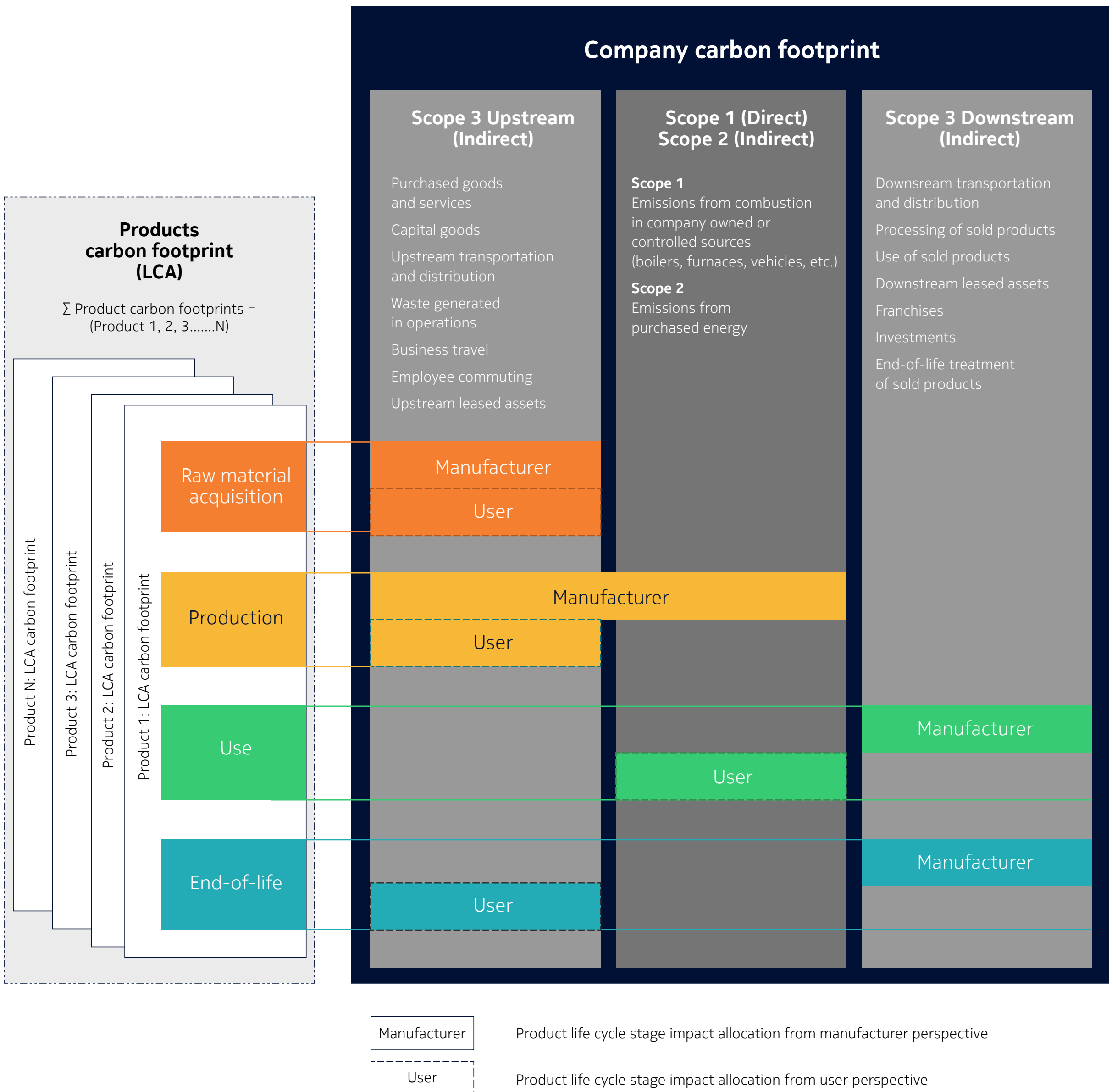
Timewise, a product may experience different forms of extended lifetime or multiple lives, for example by means of reuse or refurbishment. In full product LCA, extended lifetime is also included in the assessment when it's within the scope and intended use of the LCA result. This cradle-to-grave assessment means that the total lifetime impact of the product is considered, including all life cycle(s) and all life cycle stages of the product starting from raw material acquisition to the final end-of-life. This may consist of multiple life cycles through reuse and refurbishment. It is possible that a same product used by one user (or company) will be reused by another user (or company) with or without refurbishment. An assessment boundary shall be established at the point where the current life cycle ends, and a new life cycle starts (second use). The LCA for circular products, and reporting from the manufacturer's and user's perspective, is discussed in more detail in the section "Company footprint for circular products."

System boundaries

Figure 4 shows system boundaries for both company footprint and product footprint. In this figure, we show the company footprint according to the GHG Protocol Corporate Standard. For comparability, only GHG emissions/carbon footprint are considered in this example because company footprint often focuses on carbon footprint. Company carbon footprint consists of three scopes: Scope 1, Scope 2 and Scope 3, reflecting the company's own activities, upstream activities and downstream activities in its value chain. In Figure 4, for company carbon footprint activities, the upstream Scope 3 emissions are presented to the left and downstream scope 3 emissions are presented to the right of the Scope 1 and Scope 2 emissions, reflecting the material and resource flows in and out of the company. These activities are relevant for the product footprint as well, as illustrated in Figure 3. The cumulative carbon footprints of all the products sold by the company during the reporting period are part of the carbon footprint of the company, including the use stage and end-of-life treatment due to the impact from the downstream value chain. Similarly, the cumulative carbon footprints of all the products purchased by the company during the reporting period are part of the upstream company carbon footprint. In the case of purchased products, only the cradle-to-gate emissions are included for the purchase year and the rest of the environmental impacts of the product are taken into account as they materialize during the upcoming years in use and end of life.

In Figure 4, the light grey block labeled "Product Carbon Footprint (LCA)" on the left shows the life cycle stages of a product: raw material acquisition, production, use, and end of life. The product footprint should account for the impact from all these stages together, along with the impact from the generic processes that reoccur several times throughout these stages, such as transportation and travel. The different life cycle stages of the product correspond to the different scopes of company carbon footprint, as presented in the violet block labeled "Company Carbon Footprint." However, it is worth noting that product manufacturers and users cannot assign identical impacts to different reporting scopes. For instance, the emissions from the use of the sold product falls under downstream Scope 3 category 11 of the manufacturer, but for the user these emissions fall under Scope 2 (or Scope 1 if the energy is directly generated by the user). In some cases, for example, when the operation is outsourced, or network infrastructure is shared between different operators, the use stage emissions of the product may fall under Scope 3 emissions from the network operator's perspective. However, even in these cases, the use-stage emissions will fall under Scope 1 or 2 from the perspective of the user of the product. Figure 4 shows these differences between scopes from the user and manufacturer perspective for each LCA stage. This figure primarily reflects the manufacturer's perspective; however, the figure also illustrates the user perspective using a dotted line that is the same colour as the respective box showing each life cycle stage. The manufacturer's production process falls under Scope 1, 2 and/or 3 emissions depending on the energy source and potential use of subcontractors for production.

Figure 4: Relationship between company and product carbon footprint



Data quality, availability and data sources

The GHG impacts from the product life cycle can theoretically be allocated to different company reporting GHG scopes, as illustrated in Figure 4. In reality, product LCA and company reporting have typically been done separately using different methodologies. Today, however, companies often request and report embodied or cradle-to-gate emissions from LCA in their company reporting because the source and quality of the data is very important for both product footprint and company footprint assessments. This is especially the case with ICT products, networks and services due to the rapid evolution and development of the technology. Data used in an LCA study should have minimum bias and be as low uncertainty as possible. It should also be specific with respect to time, geography and technology. Primary data is always preferred over secondary data and extrapolation. Primary data is defined as process-specific data obtained by direct measurement of the energy or business activity [31]. Primary data is requested from suppliers who deliver material, parts and components for the product. Secondary data is made up of non-process specific data obtained from external sources other than direct measurement of the energy or business activity [31]. Commercial databases are typically used to retrieve secondary data needed for LCA.

Full LCAs need precise information about product materials and the different activity flows associated with the product's full lifetime. Full LCAs of all the individual products are seldom available for determining company footprint since LCA is a complex and time-consuming tool. More and more telco operators are requesting cradle-to-gate emissions from their suppliers for the products they purchase. This brings partial LCA into their company reporting when the manufacturer provides the cradle-to-gate emissions based on LCA calculations for their products. However, since a company's supply chains might include thousands of suppliers, it is a common practice to use representative data from a select number of top-tier suppliers, rather than having to collect data from all suppliers. For example, in 2023, Nokia conducted business with about 10,000 suppliers, yet 80% of the total supplier spend was distributed across about 300 suppliers [35].

Instead of full product LCA-based data, a company footprint can fill the gaps using simplified methods of allocating emissions associated with products and services sold or purchased by the reporting company. Some examples include the supplier-specific allocation and spend-based method or the industrial average method:

- The supplier-specific allocation method involves collecting upstream emissions data from the suppliers at a company, business unit, facility or activity level, together with physical or economic activity data. This method provides an effective way of estimating emissions specific to the individual suppliers.
- The spend-based (financial data) method, also known as the industrial average method, involves estimating emissions using relevant secondary emission factors, such as industry average and the economic value of goods and services purchased. An alternative method involves collecting data based on the mass or other relevant measure of product or service purchased. The result is multiplied by the relevant secondary emission factor, for example the average emissions per unit of product or service [32].

Often some combination of these approaches is used. As mentioned earlier, many companies are asking suppliers to share the product carbon footprint calculated by LCA so they can understand and report embodied emissions. Collecting and improving data is a continuous journey and an iterative process. During the initial years of Scope 3 reporting, companies were often compelled to use lower-quality data due to data availability issues and the effort required. Over time companies can and should improve the quality of data by replacing lower-quality data with higher-quality and primary data [32].

Data quality is also associated with the energy emission factors in relation to energy consumption. The electricity grid emission factors can be location based or market based. A location-based emission factor is the average grid emissions intensity from the location where energy consumption occurs, for example, the country-level average electricity emissions factor. A market-based emissions factor is made up of emissions from electricity that companies have purposefully chosen and purchased. In that case, the emissions factor is available for example from contractual instruments, energy certificates and/or information from energy supplier [42]. This is relevant for Scope 2 emissions as well as Scope 3 category 11, which is the use of the sold products.

Due to the complexity of supply chains in the ICT industry, it is not always possible to obtain primary data. When secondary data is used, a proper justification and explanation must be provided in the reporting of LCA [19]. For company reporting, companies are expected to have a good data inventory management system and a plan that will help them continually improve the quality of data over time [36].

Summary of the differences between product and company footprint

In summary, the main differences between product and company footprint are:

- **Purpose and target audience:** A company footprint is intended for reporting to investors, regulators, customers, sustainability experts, and the public as part of a sustainability report that highlights the company's sustainability activities. A product footprint helps the product design team as it works to reduce the product's environmental impact. It enables companies to provide quantitative data on the environmental impact of a specific product to relevant stakeholders and its customers' procurement teams to acquire products with lower environmental impact. Product footprint is also becoming increasingly relevant for annual environmental reporting and in the future will be relevant for regulators.
- **Environmental impact category:** Product footprint can include several environmental impact categories, including GHG emissions, mineral use, land use, and water use, whereas company footprint mostly focuses on GHG emissions only. It will expand to other categories with CSRD regulation.
- **Timeframe:** Product footprint provides the environmental impact over the product's full lifetime, from raw material acquisition until end of life, while company footprint reports environmental impact from one year of business operations.
- **System boundaries:** The focus of the product footprint is on the impact of one product at a time, while the company footprint includes all operations, activities, purchases and products sold during the reporting year.
- **Data quality, availability and data sources:** Detailed material and activity flows are needed to calculate the full LCA of a product footprint, while company reporting often uses, at least partially, some allocation methods, based on financial data or other factors, for company footprint assessment.

Table 5 Summary of differences between company and product footprint

Aspect	Company footprint	Product footprint
Purpose	Show progress in company's sustainability.	Find high-impact areas and reduce environmental impact by design choices as well as to demonstrate how to reduce embodied emissions and to provide quantitative data on environmental impact of a product to relevant stakeholders.
Target audience	Investors, regulators, customers, sustainability experts and public.	Product design team, annual environmental reporting, and customers. In the future, possibly regulators.
Environmental impact category	Typically, climate change, to be expanded in EU due to CSRD.	Several impact categories, depending on the used standard, e.g. 16 categories in EU PEF and ITU-T L.1410.
Timeframe	Typically company activities for the reporting year (one year)	Full product life cycle, from raw material acquisition, design production and use until end-of-life treatment.
System boundaries	All company activities for one year. For GHG emissions, divided into scope 1, scope 2 and scope 3.	All flows and activities during the product life cycle taking into account all life cycle stages.
Data quality, availability and data sources	At least partially, based on allocation methods, e.g. from financial data.	Detailed material and activity flows needed.

Product footprint of circular products

As described above, the product footprint is assessed using LCA. Until recently, LCA standards only included some aspects of the circular economy, such as repair as part of maintenance, allocation methods for recycled content in production, and the recycling of materials at the end of life. Recycling-based approaches are not well-suited for handling refurbished products, which are not going through processes that would dismantle the products down to material level. Clear, standardized guidance on conducting LCA studies for circular products was lacking in the standards, which introduced an element of subjectivity into the process for those conducting these studies. This gap motivated Nokia to initiate a revision of ITU-T L.1410 with the goal of updating this standard to reflect current practices and provide more guidance for applying LCA to circular products. Nokia's contributions on this topic were discussed with other industry members in the ITU-T meetings. The outcome of these discussions is included in the revised ITU-T L.1410 published in November 2024, which now includes guidance for circular processes in the LCA methodology. A general description is included in L.1410 section 6.2.3.3.6 and Appendix XIV and further details are included in various other sections in L.1410.

The updated guidelines in L.1410 include the assessment of circular processes for refurbishment and direct reuse. The basic principle is that a product may be sent to either recycling and final disposal or to refurbishment or direct reuse when it reaches end-of-use. If the product is sent to refurbishment, the decision point marks the beginning of a new life cycle, and the refurbishment processes are performed in the production stage of the new life cycle. This process is outlined in Figure 6, which illustrates the shift from a linear life cycle (shown in Figure 5) to a circular life cycle from the beginning until end-of-life waste treatment or landfill.

Figure 5. Life cycle stages for products in a single life cycle

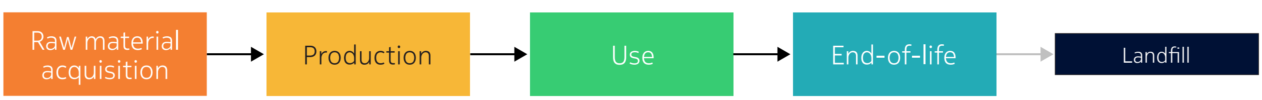
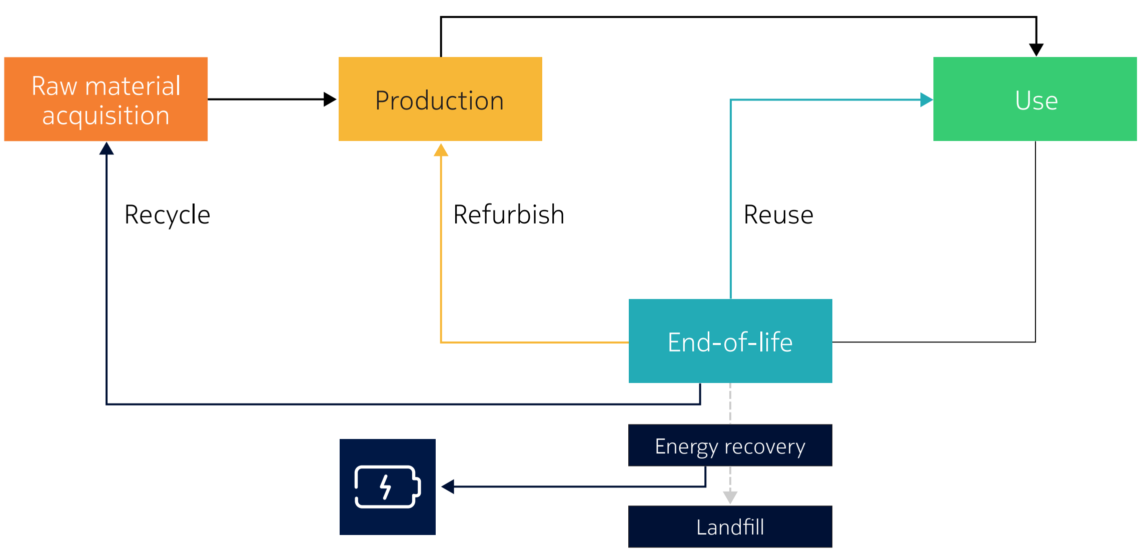


Figure 6. Life cycle stages and transitions between them for circular products with multiple life cycles



Example: Circular product flows for LCA

In this section, we provide a specific example of the flows illustrated in Figure 6. This example is based on a typical Nokia 4G base station product, which is deployed in a small-town location. Before completing the sale, Nokia has calculated LCA for the base station radio and informed the customer about its embodied environmental impact and its energy consumption. Table 6 shows one possible method for reporting embodied environmental impact, in this case for climate change, water use and land use.

Table 6: Example reporting template for embodied environmental impact

Embodied emissions				
Network Infrastructure Equipment Unit	LCA Methodology (Year performed)	Climate Change (kg CO_2e/unit)	Water Use (m^3 World e/unit)	Land use (Points)
Radio unit #1	2020	value 1	value 2	value 3
Refurbished radio unit #1	2024	value 4	value 5	value 6

After the 4G base station radio has been in use for several years, the operator notices that it is not functioning optimally. Instead of repairing it, the operator decides to replace it with another base station unit. The operator sends the product to the Nokia Take-back service where it is inspected and deemed to be a good candidate for refurbishment. Since there is constant demand for this model, including refurbished products, the product is forwarded to refurbishment, instead of sending it for material recycling.

In refurbishment, necessary parts and components are replaced, the product is re-assembled, tested, and made ready for sale as a refurbished product.

After refurbishment, Nokia calculates a new LCA for this product, since we now know more about its first life and also that it is targeted to enter its second life. The original cradle-to-gate environmental impact and the energy consumption during its first life are environmental impacts that have already occurred. The new LCA takes into account the energy consumption, the new parts and components introduced, and the end-of-life treatment of replaced parts and components as performed in the refurbishment processes. When this refurbished base station product is sold again, Nokia can inform the new customer about the original cradle-to-gate emissions of the product, as well as the emissions from the refurbishment processes and end-of-life treatment. The customer is also provided with information about the energy consumption of the refurbished product, because it may be different from the energy consumption of the original base station if there was an upgrade done during the refurbishment.

Company footprint for circular products

In this section, we will explore what circular products mean in the context of the company footprint. Because company footprint is different for the manufacturer and user of the product, we show these perspectives here separately.

Circular product from the manufacturer's viewpoint

For their own reporting, manufacturers must consider all product life cycles from cradle-to-grave. Refurbishment processes are taken into account when assessing production stage impacts. It should be noted that use-stage emissions of refurbished products should not be double-counted, since the use stage emissions across all life cycles from cradle-to-grave are usually taken into account already when the product is sold the first time.

Circular product from the user's viewpoint

Circular product introduces the challenge of boundary allocation between emissions reporting of the first user of the circular product and the second. If not handled properly, this could result either in double counting of the emissions or burden shifting, depending on the system boundary set by the LCA practitioner.

To support product users in their reporting in case of refurbished products, it is a good practice to also make available the information about emissions arising from the refurbishment processes. This includes the raw material acquisition for the new parts and components which are introduced to the product during refurbishment, as well as the end-of-life treatment of the removed parts and components, and the production-stage emissions for the refurbishment process.

The user doesn't have to consider product life cycles associated with previous or future owners of the product. Applying assessment boundaries so that they cover one life cycle makes the assessment convenient. Cradle-to-gate emissions include the emissions either from initial manufacturing in the case of a new product, or from refurbishment processing in the case of a refurbished product. The revised ITU-T L.1410 also helps to establish a clear assessment boundary between the first and successive lives of a product which makes it convenient to allocate emissions of first use and successive use to the respective user.

As mentioned earlier, a circular product's total lifetime environmental impact considers the impact of all successive uses of the product during all life cycles from cradle-to-grave. However, in the case of company Scope 3 reporting, the first user of a product does not need to consider subsequent operating time associated with reuse or refurbishment, while the user of a reused or refurbished product does not need to consider the environmental impact associated with the first life cycle of the product, which includes raw materials acquisition, production, transportation and impact of its first use [32]. Still, for transparency reasons, it is good practice to inform the customer who is buying a refurbished product about the cradle-to-gate emissions from the first life cycle.

However, caution needs to be taken when allocating an environmental burden to different life cycles. We don't want to encourage users to abandon products early that are still functioning perfectly. It does not make much sense to do so, both economically and ecologically. There is an apparent risk of greenwashing in such a case if the second user can avoid the full environmental load of the manufacturing of this relatively new product. There are also the risks of burden shifting and double accounting if the environmental load of this product is avoided by both first and second users or accounted for by both. For instance, the cradle-to-gate emissions of the product are already reported as Scope 3, category 1, Purchased goods and services emissions of the first user, and the second user will again report almost the full cradle-to-gate emissions due to the product being relatively new. Regulation would be welcome to prevent this kind of misuse of circularity.

Conclusions

In this document, we introduced the environmental impact assessment of circular products in accordance with the 2024 updates to the LCA standard, ITU-T L.1410, to support LCA for circular products. To provide a full perspective, we described the product footprint and company footprint approaches. We began by examining the differences between product environmental footprint standards, then the differences between company environmental footprint standards, and finally the difference between company environmental footprint and product environmental footprint.

There are many differences between the company environmental reporting standards. These are not well harmonized in their approaches and terminologies. Better alignment of these approaches and terminologies would be beneficial. Irrespective of this, we acknowledge that the GHG Protocol company reporting standards are the ones most widely used across different industries. Also, the GHG Protocol standard approach for separating emissions into Scopes 1 – 3 is globally recognized and the most widely accepted approach for reporting emissions.

On the other hand, product LCA standards are all based on a common approach adopted from ISO 14040 and ISO 14044. Therefore, the biggest difference is that only ITU-T L.1410 is specific to ICT products, network and services. Since circular practices have only become more popular lately, the standards published a decade ago cannot reflect that perspective. In June 2022, Nokia initiated the revision of ITU-T L.1410 to include this new guidance on LCA for circular products with the goal of putting these practices more widely in use. This standard has now been published and includes guidance for practitioners on how to take into account refurbishment and reuse processes which go beyond plain material recycling. This will align the assessment of circular processes in the product footprint and increase the visibility of the environmental impact of refurbished and reused products. To avoid hiding circularity-related impacts, our advice is to inform the second owner of the product about the embodied environmental impacts coming from both the first and the second life cycle of the product.

On a conceptual level, LCA can be partially mapped to company reporting, and companies have started to ask for LCA or cradle-to-gate emissions from purchased products to use that information in their company reporting. However, there are differences in the product and company environmental footprint so that full mapping from product LCAs to form a company footprint is very challenging. The biggest limiting factor is data availability, which leads to extrapolation, such as the supplier-specific allocation method for company footprint, while LCA requires detailed material and activity flows for interpreting the product environmental impact. Currently, company footprint is mostly limited to climate change impact while LCA can cover many more environmental impact categories. Since LCA covers the full life cycle of the product from the very beginning until its final end-of-life, company reporting can be challenging, especially for circular products that change owner between life cycles.

The significance and role of LCA and product footprint is also becoming more important in company reporting with an increase in regulatory scrutiny and an increase in the overall environmental awareness within companies and among the general public. Customers request information on embodied emissions of products for their procurement and company annual environmental reporting. The result is that the linkage between a company footprint and the product footprint is becoming stronger.

Currently, company environmental reporting standards do not provide clear guidance for circular product use, in other words how to allocate emissions of first use and successive use of a circular product to the respective users. The Supplement document to ITU-T L.1420 provides some guidance on how to consider circular (reused and refurbished) products. Similar guidance for circular economy-related aspects would be beneficial for all company environmental reporting standards, as many companies are transitioning to the circular economy and are increasingly using reused and refurbished products. Clear standards and transparent regulation covering the various aspects of the circular economy would be helpful.

Considerations for circularity assessment and the circular economy for company and product environmental footprint are relatively new methodologically compared to LCA. Therefore, Nokia is continuing to contribute actively to several other circularity and circular economy-related standards to ensure the necessary guidelines and requirements are in place to make circular economy a reality.

References

[1] Planetary boundaries Stockholm Resilience Centre, Stockholm University Planetary boundaries - Stockholm Resilience Centre

[2] The Circularity Gap Report 2024 CGR 2024 (circularity-gap.world)

[3] Global Footprint Network Home - Global Footprint Network

[4] Global Resource Outlook 2024 Global Resources Outlook 2024 | UNEP - UN Environment Programme

[5] Ellen MacArthur Foundation, "Schools of thought that inspired the circular economy" https://www.ellenmacarthurfoundation.org/schools-of-thought-that-inspired-the-circular-economy

[6] Ellen MacArthur Foundation, "What is a circular economy?" https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

[7] Ellen MacArthur Foundation, "The circular economy in detail" https://www.ellenmacarthurfoundation.org/the-circular-economy-in-detail-deep-dive

[8] Circular Economy Trends – Potential Role of Emerging Technologies https://www.researchgate.net/publication/366069139_Circular_Economy_Trends_-_Potential_Role_of_Emerging_Technologies/link/63908f3d11e9f00cda2711ea/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

[9] World Economic Forum, "Making the $4.5 trillion circular economy opportunity a reality" https://www.weforum.org/impact/helping-the-circular-economy-become-a-reality

[10] Effects of the Circular Economy on Jobs https://www.iisd.org/system/files/2020-12/circular-economy-jobs.pdf

[11] ISO 14044:2006, "Environmental management — Life cycle assessment — Requirements and guidelines," ISO 14044:2006 - Environmental management — Life cycle assessment — Requirements and guidelines

[12] Jeroen B. Guinee - Life cycle assessment: past, present and future https://www.rilem.net/images/publis/917db4447994958c78e8f7a51ca2677d.pdf

[13] Marcelle C. McManus and Caroline M. Taylor - The changing nature of life cycle assessment https://www.sciencedirect.com/science/article/pii/S0961953415001609?via%3Dihub

[14] ISO 14040:2006, "Environmental management — Life cycle assessment — Principles and framework" https://www.iso.org/standard/37456.html

[15] The GHG Protocol, "A Corporate Accounting and Reporting Standard revised edition", March 2004, https://ghgprotocol.org/corporate-standard

[16] IPCC AR6 Chapter 7: The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity. Chapter 7: The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity (ipcc.ch)

[17] ISO 14067:2018, "Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification" https://www.iso.org/standard/71206.html

[18] The GHG Protocol, "Product Life Cycle Accounting and Reporting Standard," https://ghgprotocol.org/product-standard

NOKIA

[19] ITU-T L.1410, "Methodology for environmental life cycle assessments of information and communication technology goods, networks and services." https://www.itu.int/rec/T-REC-L.1410-201412-I

[20] Pia Tanskanen; Jussi Isoaho; Susanna Kallio; Ali Rezaki, Connecting ICT with nature - a holistic view on target setting and impact assessment, 2023, https://www.researchgate.net/publication/379697377_CONNECTING_ICT_WITH_NATURE_-A_HOLISTIC_VIEW_ON_TARGET_SETTING_AND_IMPACT_ASSESSMENT

[21] Jussi Isoaho; Susanna Kallio; Pia Tanskanen, Circular Economy Best Practices for Biodiversity and Geodiversity Preservation Through an LCA Approach, 2024, https://ieeexplore.ieee.org/document/10631191r

[22] National Institute for Public Health and the Environment, Netherlands "A harmonized life cycle impact assessment method at midpoint and endpoint level Report I: Characterization" https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf

[23] European Telecommunication Standards Institute https://www.etsi.org/deliver/etsi_es/203100_203199/203199/01.04.00_50/es_203199v010400m.pdf

[24] "EU Product Environmental Footprint Method," https://eur-lex.europa.eu/resource.html?uri=cellar:75e0de0f-5e6d-11ec-9c6c-01aa75ed71a1.0019.02/DOC_2&format=PDF

[25] https://www.nokia.com/about-us/sustainability/sustainability-downloads/

[26] Nokia has filed its Annual Report on Form 20-F for 2023 and published its Nokia in 2023 Annual Report | Nokia

[27] GRI Standards https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/

[28] GRI 305: Emissions 2016, "Framework for reporting and managing the emissions." https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/

[29] ISO 14064-1: 2018, "Quantification and reporting of GHG emissions and removals at organizational level" https://www.iso.org/standard/66453.html

[30] ISO/TR 14069: 2013, "Guidance on quantification and reporting of GHG for organizations." https://www.iso.org/standard/43280.html

[31] ITU-T L.1420, "Methodology for energy consumption and GHG emissions impact assessment of information and communication technologies (ICT) in ICT and non-ICT organizations." https://www.itu.int/rec/T-REC-L.1420-201202-I/en

[32] GSMA, GeSI, and ITU, "Scope 3 Guidance for Telecommunications Operators," Scope-3-Guidance-2023.pdf. https://www.gsma.com/solutions-and-impact/connectivity-for-good/external-affairs/wp-content/uploads/2023/07/Scope-3-Guidance-2023.pdf

[33] EU Organization Environmental Footprint Method, https://environment.ec.europa.eu/system/files/2021-12/Annexes%203%20to%204_0.pdf

[34] International Telecommunication Union (ITU) and World Benchmarking Alliance (WBA), "Greening Digital Companies Report 2024: Monitoring emissions and climate commitments." https://www.itu.int/en/ITU-D/Environment/Pages/Publications/GDC-24.aspx

[35] Nokia People and Planet Report 2023 https://www.nokia.com/sites/default/files/2024-03/nokia_people_and_planet-2023.pdf

[36] The GHG Protocol, "Corporate Value Chain (Scope 3) Accounting and Reporting Standard," https://ghgprotocol.org/corporate-value-chain-scope-3-standard

[37] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464

[38] GHG Protocol Website, "For companies and organizations" https://ghgprotocol.org/companies-and-organizations

[39] GHG Protocol Corporate Suite of Standards and Guidance Update Process, https://ghgprotocol.org/ghg-protocol-corporate-suite-standards-and-guidance-update-process

[40] EU Eco-design requirements for sustainable products Regulation https://eur-lex.europa.eu/eli/reg/2024/1781/oj/eng

[41] United Nations Framework Convention on Climate Change, "The Paris Agreement" https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf

[42] The GHG Protocol, "GHG Protocol Scope 2 Guidance: An amendment to the GHG Protocol Corporate Standard" https://ghgprotocol.org/sites/default/files/Scope2_ExecSum_Final.pdf