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TECHNICAL REPORT

colour inside

Quantification methodology for greenhouse gas emissions for computers and monitors

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QUANTIFICATION METHODOLOGY FOR GREENHOUSE GAS EMISSIONS FOR COMPUTERS AND MONITORS

FOREWORD

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IEC TR 62921, which is a Technical Report, has been prepared by technical area 13: Environment for AV and multimedia equipment, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
100/2381/DTR	100/2448/RVC

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Many organizations are looking to adopt product greenhouse gas emissions reporting mechanisms, including:

- computer and monitor manufacturers, as well as their suppliers and downstream users;
- governmental agencies including France, China, Japan, Korea and the European Commission;
- retailers and non-regulatory agencies.

There have been several international and regional efforts to provide guidance for calculating product greenhouse gas emissions. Some of these efforts include IEC TR 62725, ITU-T L.1410, ETSI TS 103 199, and Greenhouse Gas Protocol ICT Sector Supplement.

Unfortunately, some lack of specificity within these documents allows for variability that can create a significant difference in product greenhouse gas emission results, depending on how a practitioner interprets the information. Throughout the process of developing IEC TR 62725, there was significant discussion regarding the need for further specificity, transparency and pragmatism in methodology guidance for products covered under IEC TC 100, including computers and monitors. There is an urgent need to enable methodologies that offer accurate and defensible estimates of impact in a rapid and effective manner. This Technical Report aims to fill in some of those gaps.

This Technical Report builds upon the structure laid out by IEC TR 62725. Its goal is to support universal streamlined product greenhouse gas methodologies for practitioners, with a further goal of harmonizing the various regional efforts currently in progress.

This Technical Report's quantification methodology aims to be compliant with, and therefore be used within, a number of these broader standards efforts. It will provide detailed guidance for estimating greenhouse gas emissions for computer and monitor products, in order to obtain consistent, accurate results. The benefit of consistent results is that they can assist multiple efforts, including but not limited to:

- supporting customer enquiries;
- instituting sustainable design practices;
- initiating conversations around emissions reduction strategies with suppliers and downstream users;
- targeting data collection within the supply chain in order to address data quality issues.

QUANTIFICATION METHODOLOGY FOR GREENHOUSE GAS EMISSIONS FOR COMPUTERS AND MONITORS

1 Scope

This Technical Report outlines detailed guidance to streamline the quantification of greenhouse gas emissions for computers and monitors. Other audio, video and multimedia products, such as e-readers, phones, tablets, thin clients, workstations and storage equipment, can be included in future revisions of IEC TR 62921.

For this Technical Report, computers and monitors include notebooks, desktops, and liquid crystal display (LCD) monitors.

This Technical Report provides specific guidance for the use of streamlining techniques that minimize cost and resources needed to complete greenhouse gas emissions quantifications. In addition, the product category rules (PCR) section of this Technical Report recommends "state-of-the-art" process and data assumptions in order to reduce uncertainty. Lastly, this Technical Report provides an example of how a calculation could be performed.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
carbon footprint of a product
CFP
sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change

Note 1 to entry: The CO_2 equivalent of a specific amount of a greenhouse gas is calculated as the mass of a given greenhouse gas multiplied by its global warming potential.

Note 2 to entry: Results of the quantification of the CFP are documented in the CFP study report expressed in mass of CO_2e per functional unit,

[SOURCE: ISO/TS 14067:2013, 3.1.1.1]

2.2
comprehensive carbon footprint of a product
carbon footprint of a product (2.1) that is product-specific and includes the carbon impacts for every component and process in that product's life cycle.

2.3
computer
device which performs logical operations and processes data

Note 1 to entry: Computers are composed of, at a minimum: (1) a central processing unit (CPU) to perform operations; (2) user input devices such as a keyboard, mouse, digitizer or game controller; and (3) a computer display screen to output information

[SOURCE: ENERGY STAR® Program Requirements for Computers]

2.4
greenhouse gas emissions
GHG emissions
total mass of greenhouse gases released to the atmosphere over a specified period of time

[SOURCE: ISO 14064-1:2006, 2.5]

2.5
monitor
electronic device that displays a computer's user interface and open programs

[SOURCE: ENERGY STAR® Program Requirements for Displays]

2.6
primary data
data collected from specific processes in the studied product's life cycle

[SOURCE: GHG Protocol Product standard: 2011]

2.7
primary aggregated data
data that are collected directly from suppliers or industry associations on a product type (not specific product) and aggregated

Note 1 to entry: This is an approach in which single components can be sourced from multiple suppliers each with multiple facilities and multiple downstream suppliers. Primary data for every item is impossible.

2.8
product category rules
PCR
set of specific rules, requirements and guidelines for quantification and communication on the carbon footprint of a product for a specific product category

[SOURCE: ISO/TS 14067:2013, 3.1.4.12, modified — deleted "for developing Type III environmental declarations"]

2.9
secondary data
process data that are not from specific processes in the studied product's life cycle

[SOURCE: GHG Protocol Product standard: 2011]

2.10
state-of-the-art
<data and processes> developed stage of technical capability at a given time as regards to products, processes and services, based on the relevant consolidated findings of science, technology and experience

[SOURCE: ISO/IEC Guide 2:2004, 1.4, modified — "<data and processes>" has been added before the definition.]

2.11
streamlined carbon footprint of a product
carbon footprint of a product (2.1) that involves some level of simplification compared to a comprehensive carbon footprint

Note 1 to entry: Typical approaches to streamlining a product carbon footprint calculation consist of simplifying data collection and/or reducing the number of data inputs required.

2.12
uncertainty analysis
systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability

Note 1 to entry: Uncertainty information typically specifies quantitative estimates of the likely dispersion of values and a qualitative description of the likely causes of the dispersion.

[SOURCE: ISO 14040:2006, 3.33]

3 Symbols and abbreviations

CFP	carbon footprint of a product
DQI	data quality inventory
DR	distinction rate
EE product	electrical and electronic product
EoL	end-of-life
FS	false signal rate
HDD	hard disk drive
ICs	integrated circuits
ICT	information and communications technology
kg CO_2e	kilograms of carbon dioxide equivalent
kWh	kilowatt per hour
LCD monitor	liquid crystal display monitor
LCI	life cycle inventory
LCIA	life cycle impact assessment
LCT	life cycle thinking
ODD	optical disk drive
PAIA	product attribute to impact algorithm
PCR	product category rules
PSU	power supply unit
PWB	printed wiring board
SSD	solid state drive
TEC	typical energy consumption
VT	validation team

4 Principles

4.1 Comparing streamlined CFP to comprehensive CFP

4.1.1 General

The carbon footprint of a product estimates the total potential contribution of a product to global warming by quantifying all significant greenhouse gas emissions and removals over the product's life cycle. Comprehensive CFPs are product-specific and include the carbon impacts for every component and process in that product’s life cycle. A comprehensive CFP takes a significant amount of resources, time, and data-demands to complete.

Given these challenges, streamlined CFP approaches are critical, particularly in industries such as the information and communications technology (ICT) industry, which have complex products and rapid product-development cycles. The streamlined approach reduces the amount of time and resources needed for data gathering and calculation in order to achieve the needed level of accuracy. Therefore, the streamlining approach follows the rule that only the materials, components and processes that are associated with the most significant product carbon impacts are included in the analysis.

While many different definitions of a streamlined CFP exist, the common characteristic is that they all involve some level of simplification, as compared to a comprehensive CFP. With comprehensive CFPs rarely being executed, it is this collection of streamlined CFP approaches that represent a common approach to CFP. These streamlined approaches, when executed according to recognized practices, reduce the burden of a CFP, while still allowing the necessary goals of the CFP to be achieved (see Figure 1).

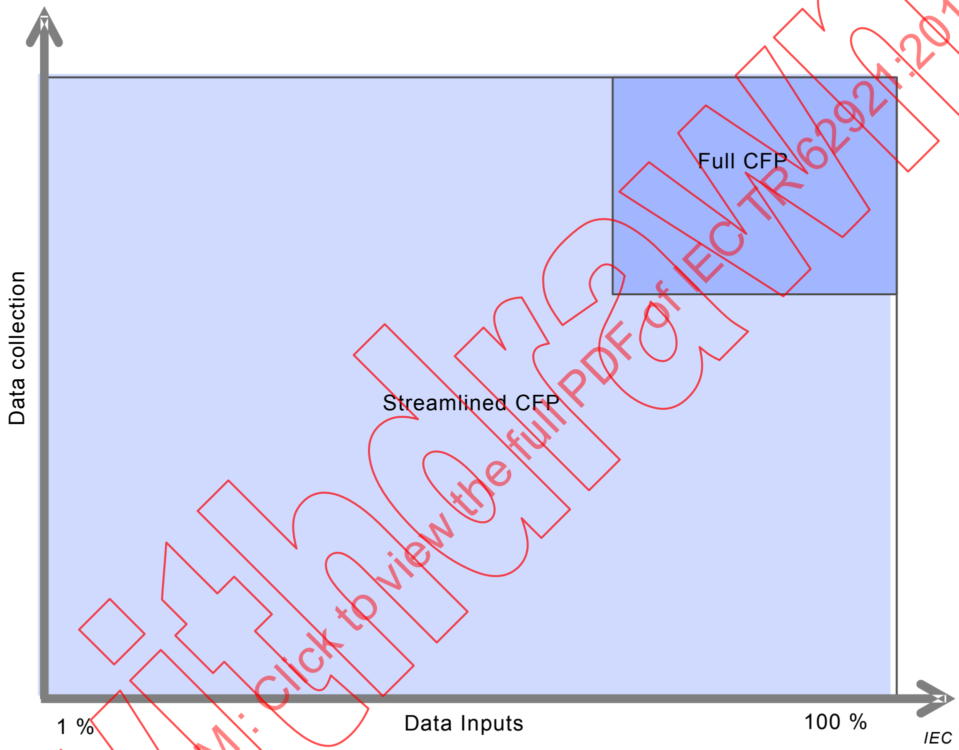

Figure 1 – Depiction of how streamlined CFP fits into comprehensive CFP

4.1.2 Level of streamlining

While streamlined CFPs are clearly less resource-intensive, the extent of streamlining that is possible is entirely dependent on the goal of the CFP and, more specifically, the questions that the CFP is attempting to answer. Typically, the more general the questions are that need to be answered, the more streamlined the CFP can be.

For example, high-level product CFPs, focused on understanding the overall impact of a product or which life cycle phases dominate product impact, can be completed using a streamlined CFP. For such cases, the additional resolution and specificity provided through a more comprehensive CFP are not needed.

However, if information is needed to assess specific materials or design choices around a product (i.e. evaluating materials used in packaging, or evaluating trade-offs in product design), then a more specific and detailed analysis is warranted. In this case, improved data collection and more primary data input can be required, leading to a more comprehensive CFP. In general, the more specificity that is required in the CFP results, the more comprehensive the CFP will need to be.

4.2 Viability of streamlined CFP

4.2.1 Streamlining in IEC TR 62725

Streamlined methodologies that apply a trial estimation approach are described in IEC TR 62725:2013, 6.4 and 6.5, and Annexes B and D. Rather than applying a quantitative cut-off threshold (e.g. less than 5 % of the total estimated emissions can be excluded from the CFP analysis) as described in IEC TR 62725, in the streamlined approach a high level statistical analysis using available data and Monte Carlo simulations is performed to determine the life cycle activities that are the biggest contributors to impact and uncertainty. Targeted data collection is then performed, based on this analysis, to confirm impacts and further reduce uncertainty to desired levels. Use of a streamlined approach informs the appropriate cut-off criteria in view of the workability and availability of the process data.

4.2.2 Metrics for streamlining

In order to determine whether the result of a CFP analysis is sufficient given the degree of uncertainty present in all aspects of the calculation (see 4.2.4), measures of resolution are often calculated. This can be done as part of a sensitivity check in order to determine the ability of the CFP analysis to find significant differences between different studied alternatives, as described in ISO 14044.

One common way to assess whether a result is "good enough" to answer the question posed is to determine how much overlap there is between the sampled distribution corresponding to the product of interest and a variety of related alternatives. (For example, this could be a comparison of the product of interest with another product utilizing a different set of materials or architecture.) When the uncertain CFP of the product of interest overlaps considerably with the uncertain CFP of the alternative, then it would be inappropriate to declare that the two have different CFPs. If there is little overlap, then one could confidently identify a difference and therefore which of the two alternatives had the lower CFP.

There are several terms used to describe this degree of overlap (i.e. between the estimated CFP of the product of interest and the estimated CFP of an alternative) including the comparison indicator, distinction rate (DR), or false signal rate (defined below). For this discussion, distinction rate will be used to signify how distinct the product of interest is from a selected baseline. Distinction rate essentially quantifies the frequency at which one of the alternatives has a distinctly lower CFP than the other alternative or a prescribed benchmark (described subsequently).

To calculate the distinction rate between the product of interest (B) and the baseline or benchmark (A), the expected distribution for CFP_B as well as for CFP_A should be sampled via statistical simulation, such as through Monte Carlo sampling. The formulation for this distinction rate (DR) is then expressed as:

$$DR = P\,(CFP_B < CFP_A)$$

where

DR is the distinction rate;

P is the probability;

CFP_B is the CFP for the product of interest;

CFP_A is the CFP for some baseline comparison product.

The probability of $CFP_B < CFP_A$, can be estimated directly from the Monte Carlo simulation results by comparing scenario pairs CFP_A and CFP_B and calculating the relative frequency where $CFP_B < CFP_A$. The false signal rate (FS) is a specific version of the distinction rate defined as the frequency of observing a result where the CFPs of the products are comparatively different (higher than or lower than the other) than would be expected based on the relative position of the mean CFP (μ, μ_A for product A and μ_B for product B). That is:

$$FS = \begin{cases} P(CFP_B < CFP_A), \text{ where } \mu_A < \mu_B \\ P(CFP_A < CFP_B), \text{ where } \mu_A > \mu_B \end{cases}$$

It is important to note that there is often correlation among life cycle activities across a product of interest and a baseline, particularly for downstream activities such as the grid mixes associated with use phase.

In assessing the difference between the uncertain impact of a product of interest and a baseline, therefore, consider correlation (i.e. the degree to which two or more variables are related in some fashion) to avoid statistical bias. To that end, the analysis should likely be conducted simultaneously for both the product and baseline such that for each Monte Carlo run the same sample sets are used for the correlated activities and parameters.

Another form of resolution metric which is often reported is referred to as the comparison indicator (β), which is defined as the probability that the ratio between the product of interest and the baseline is less than one, that is

$$\beta = P\left(\frac{CFP_B}{CFP_A} < 1\right)$$

where

β is the comparison indicator;

P is the probability;

CFP_B is the CFP for the product of interest;

CFP_A is the CFP for some baseline comparison product.

This enables characterization of the likelihood that the baseline has lower impact than the product of interest.

A decision regarding the sufficiency of the analysis can then be made when β is greater than a prescribed threshold. This threshold is a decision parameter that controls the level of risk that a decision-maker is willing to take and should be set by the decision-maker for a given context. If the metric of interest does not indicate that there is high statistical confidence in the comparison result (i.e. there is high risk that a conclusion drawn on this result will be directionally incorrect), the analyst has the option either to declare the products not differentiable or to attempt to collect additional more precise data to improve the resolution of the analysis.

An example of a hypothetical benchmark could be use of the same data distribution for a product of interest displaced by a difference threshold established in the goals of the study. This difference threshold distance could be defined as a percentage of the magnitude of the mean, i.e. shifting the mean of A (μA) by 10 %. The reason for this sort of a benchmark would be if data for another product were not available. Another example could be a product analysis for a larger or smaller screen size in the case of a laptop.

An example of the above calculations for a hypothetical comparison is shown in Table 1.

Table 1 – Depiction of how streamlined CFP fits into comprehensive CFP

Monte Carlo trial	Footprint of product of interest (CFP_B)	Footprint of alternative product (CFP_A)	Is $CFP_B < CFP_A$?	Is $CFP_A < CFP_B$?	Ratio CFP_B/CFP_A
1	73	71	–	Y	1,02
2	77	131	Y	–	0,59
3	90	92	Y	–	0,99
4	92	122	Y	–	0,76
5	98	74	–	Y	1,32
6	103	122	Y	–	0,85
7	81	90	Y	–	0,90
8	96	105	Y	–	0,91
9	104	87	–	Y	1,19
10	100	154	Y	–	0,65
	91 Average CFP_B (μ_B)	105 Average CFP_A (μ_A)	0,7 Distinction rate (DR)	0,3 False signal rate (FS)	0,70 Comparison indicator (β)

4.2.3 Principles of CFP from IEC TR 62725

4.2.3.1 Life cycle thinking (LCT)

In the development of methodology to quantify the greenhouse gas emissions throughout an electrical and electronic (EE) product's life cycle, take all stages of the life cycle of a product into consideration.

4.2.3.2 Relevance

Select and use data, methods, criteria and assumptions that are appropriate to the assessment of greenhouse gas emissions and removals from the goal and scope definition being studied.

4.2.3.3 Completeness

Include all greenhouse gas emissions and removals that provide a significant contribution to the assessment of greenhouse gas emissions and removals arising from the goal and scope definition being studied.

4.2.3.4 Consistency

Apply assumptions, methods and data in the same way throughout the greenhouse gas emissions for an EE product's life cycle to arrive at conclusions in accordance with the goal and scope definition.

4.2.3.5 Accuracy

Reduce bias and uncertainties as far as is appropriate to the goal of the study.

4.2.3.6 Transparency

Address and document all relevant issues in an open, comprehensive and understandable presentation of information. Fully disclose any relevant assumptions and limitations and make appropriate references to the methodologies and data sources used. Clearly explain any estimates and avoid bias so that the greenhouse gas emissions throughout an EE product's life cycle study report faithfully represent what it purports to represent.

4.2.4 Uncertainty

4.2.4.1 General

There is an extensive literature characterizing sources and types of uncertainty in life cycle assessment and methods for analysing the impact of uncertainty on life cycle impact assessment. A good summary of this literature can be found in a review article by Lloyd and Reis. Existing literature and footprinting standards have discussed terminology for types of uncertainty for both life cycle inventories (LCI) and life cycle impact assessment (LCIA) methods including parameter, scenario, and model uncertainty. Although LCI and LCIA have the same types of uncertainty, the sources of and methods for evaluating uncertainty will likely be different.

- Parameter uncertainty refers to the uncertainty in observed or measured values, and provides a measure of how close the data and calculated emissions are to the real data and emissions. For LCI and LCIA this applies to the input data used in the inventory or impact assessment method, respectively.
- Scenario uncertainty refers to the variation of results depending on methodological choices (e.g. CFP modelling principles, allocation procedures), and represents the choices that are made when conducting an LCA. These choices are made in order to manage the scope of the analysis and because of the inherent variation in conditions under which products and processes operate (e.g. different locations or types of user).
- Model uncertainty refers to insufficient knowledge of the studied system (e.g. emissions from the supply chain for transportation), leading to omission of data or incorrect assumptions; it results in uncertainty in the mathematical relationships used to develop LCIs and LCIAs.

There are several significant sources of uncertainty related to computers and monitors. Though not subjected to uncertainty analysis in most LCA studies, there are significant variations in the bill of materials and parts for IT products.

While disassembly of a particular machine reveals the materials and parts for that model, the purpose of most LCA studies is to understand a type of product (e.g. a laptop computer) rather than a particular model (e.g. a Dell[1] Latitude E5450). Without information on how materials and parts vary among models, it is difficult to judge how to generalize results from a sample model to a product class.

Other sources of data variability and uncertainty include variability in suppliers for various components over different time scales, uncertainty in secondary data for components, and uncertainty in overhead of production (e.g. waste management). One critical source of variation stems from geographical variability in production facility energy efficiency and electricity grid mix, and variability in delivery distances and supply chain freight movement.

In addition to model variations among brands within a given year, computer and monitor products evolve significantly over time. Thus trends in the bill of materials, parts and manufacturing burden can significantly affect the product carbon footprint. This critical source of uncertainty stems from the rapid change in processes through advancement and innovation.

Detailed modelling is recommended around all of these aspects of uncertainty – each quantity and impact has an associated uncertainty which allows the user to get total product uncertainty. For example, there is uncertainty on quantity information (including bill of materials, process, user profile) and type (e.g. mode of transport, type of steel). Where empirical data exist, distributions can be fitted accordingly. Having enough data to fit a distribution can be quite rare. Therefore, other approaches are necessary to make this effort manageable.

[1] Dell is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

One framework proposed in the academic literature to accommodate limited data, including cases where only one data point is available, is to estimate uncertainty through a secondary data quality indicator method. Where multiple data are available, simple distributions can be used to model uncertainty (e.g. uniform distribution in the case where two points are available, triangular distribution where a central tendency can be estimated). Data quality indicator (DQI)-type approaches are useful because they only require a single data point for a unit process or elementary flow of a unit process. An example of a DQI approach is found in the pedigree matrix published for the *ecoinvent*[2] life cycle inventory database. Data points are evaluated along metrics of reliability, completeness, as well as temporal and geographic representativeness. Lack of data for electronics makes it difficult to ascertain empirical underlying uncertainty distributions in most of the unit processes and inventories used.

4.2.4.2 Examples of application of uncertainty analysis

Example 1: CFP is assessed in two different studies for two laptop products made by a manufacturer, products A and B. The calculated difference in the CFP between A and B is 25 %. The estimated uncertainty of the analysis is 50 %. In this case it is not possible to judge if A or B is a better product with respect to CFP, although the result value indicates a clear difference.

Example 2: CFP is assessed for two desktop computer products that use different architectures and materials (new product vs. business-as-usual scenario). The estimated uncertainty of the CFP analysis is 50 % in this case as well, but the calculated improvement in the CFP when applying the new architecture and materials is a factor of ten. In this case it can be concluded that the new product clearly has the best performance even though the uncertainty associated with the analysis impacts the absolute value of the CFP.

The above examples illustrate that both uncertainty analysis and sensitivity analysis (distinction rate) are important tools to understand the results of a study and what conclusions can be made.

5 Approaches to streamlined CFP

5.1 General

While there are different approaches to streamlining a CFP, the two most common approaches include:

- simplifying the data collection process, or
- reducing the number of data inputs required to do the CFP calculation.

Some streamlined methods use one or the other of these simplification processes; others use both.

5.2 Streamlining of data collection

5.2.1 General

Data collection involves obtaining underlying data for the analysis. There are several types of data that can be used in a CFP analysis: primary, primary aggregated, and secondary. Primary data are typically the most difficult to obtain; secondary typically the simplest.

- Primary data are expected to be fully representative of the particular product being analysed. Primary data are often thought to be the best representation of that specific item, and are often the most resource-intensive approach to data collection. For an industry

[2] Ecoinvent is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

such as the ICT industry, in which single components can be sourced from multiple suppliers each with multiple facilities and multiple downstream suppliers, primary data for every item are impossible to collect.

- Primary aggregated data are representative of a class of products or processes as opposed to an individual product or process. Primary aggregated data can be less resource intensive to obtain than product-specific primary data and are often more consistently up-to-date than secondary data. In this process, data on a product type, not a specific product, (i.e. data collected on integrated circuits (ICs) used in computer products rather than data collected on a particular IC) are obtained from suppliers and/or industry associations and then aggregated to obtain an “average” CFP value.
- Secondary data are not specific to the studied product as a substitute for product-specific primary data. Secondary data are not necessarily less accurate than primary data, although less representative of the specific process or product being evaluated. Typically, secondary data, particularly when sourced from commercially-available databases, are much less resource-intensive to collect, and thus represent a widely-used approach to streamlining CFPs.

5.2.2 Approaches to streamlining data collection

Streamlined methodologies use two main approaches to simplifying data collection for assemblies/components/processes:

- secondary data available in industry databases; and/or
- primary industry data that have been aggregated.

This often means that more work is done upfront to collect and analyse data, but results in a reduced burden for the user of the methodology. As with the data input reduction process, an initial CFP is often done to understand the largest impacts and thus where to focus additional data collection efforts.

5.3 Streamlining of data inputs

5.3.1 General

Reducing the number of data inputs is the second aspect by which CFPs are often streamlined. While a comprehensive CFP attempts to characterize all inputs and outputs to a process/product, etc., streamlined CFPs often apply rules to reduce the number of items to track. This reduction in inputs can be achieved through various cut-off rules and/or parameterization, both of which exclude certain items that have less effect on the overall impact.

5.3.2 Approaches to streamlining data inputs (processing)

Streamlined methodologies use a similar approach in which product environmental impacts are calculated using fewer direct inputs by users. Two main approaches to streamlining data input include:

- using algorithms that automatically relate attributes of a product (display size, printed wiring board dimension, energy use, etc.) to a product carbon footprint value; and
- using standard impact data for common components.

Often, a preliminary comprehensive CFP is performed in order to understand the life cycle processes with the greatest impacts so that these can be further evaluated and included in the streamlined calculation.

For the algorithm approach, data are collected from LCA databases and/or directly from suppliers, aggregated, and then used to develop algorithms embedded within a methodology. This allows users to simply enter information on a product into an assessment tool; the tool then uses the embedded allocations to estimate a carbon footprint value for each component and process. These are then summed up in order to obtain a total product carbon footprint.

The common component approach has embedded within the methodology, environmental impacts of common assemblies, components and/or processes for ICT products. These can be product specific or can be based on average product data. Someone calculating the CFP of multiple products could use the same "product-type" data, selecting a process or component and its associated carbon footprint, instead of having to collect product-specific data. These values are likewise added together to get a total CFP.

6 Comparative study on existing CFP methodologies

6.1 Examples of current worldwide streamlined CFP methodologies

6.1.1 General

Summarized results of a comparative study on existing relevant, worldwide streamlined CFP methodologies are described in 6.1.2 to 6.1.6. More detailed information on these methodologies can be found in Annex A. Each of these methodologies involves some level of streamlined data collection or data inputs.

6.1.2 Product attribute to impact algorithm (PAIA)[3]

This is a streamlined carbon footprinting approach that maps product attributes to their environmental impact through the use of algorithms. Unlike most methodologies, PAIA includes uncertainty in the results. PAIA currently covers notebooks, desktops and monitors; tablets and all-in-ones are in development.

6.1.3 iNEMI eco-impact evaluator[4]

This is a streamlined "building block" approach to assessing the environmental impact of ICT products. The environmental impacts of assets/sub-assemblies for ICT products are embedded within the methodology; these are summed up to give the entire product environmental footprint. The iNEMI eco-impact methodology includes other environmental impacts besides carbon.

6.1.4 Orange Telecom environmental methodology[5]

This is a streamlined methodology that measures the environmental performance of mobile phones. Output impacts include a carbon footprint of a product (manufacture, transport, use, etc.), energy efficiency, resource preservation and recyclability. This methodology is similar to PAIA in that product attributes are mapped to their environmental impact.

6.1.5 Japan CFP method

This is a product-specific methodology which requires the user to assess the entire environmental footprint of a product. Primary data less than 12 months old have to be used and greater than 95 % of the impact has to be included. However, it also requires approaches that use algorithms that automatically relate attributes of a product to an environmental impact. This allows users to simplify data collection and/or reduce the number of data inputs while still allowing the necessary goals of the CFP to be achieved.

3 PAIA is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

4 The iNEMI eco-impact evaluator is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

5 The Orange Telecom environmental methodology is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of this product.

6.1.6 China CFP method

This is a CFP methodology being developed by industry, consulting and academia with funding from regulatory agencies. This methodology, which is product-specific and based on a full CFP, is still in the research phase. Current focus is on the assessment of supply chain data collection. This method has the potential to become a streamlined methodology depending on research results.

7 CFP product category rules

7.1 General

Clause 7 defines comprehensive product rules for notebooks, desktops and monitors. Detailed rules for other audio, video and multimedia products can be added in future revisions of IEC TR 62921.

Clause 7 covers the following product category (PCR) topics:

- goal;
- scope (including uncertainty and allocation);
- functional unit;
- life cycle stages (production, distribution, use and end of life).

For each topic, this Technical Report recommends current "state-of-the-art" data and processes that users can employ in order to determine the streamlined CFP of notebooks, desktops and monitors. The input recommendations outlined in Clause 7 are the current best methods for calculating streamlined CFPs. Other methods can be used to do the calculations.

State-of-the-art data and processes are best practice processes and data recommendations for determining the CFP of computer products as viewed and researched by the industry for the development of this Technical Report (refer to Clause 6). Because these are state-of-the-art, they can recommend different methods for performing calculations (e.g. using area- or mass-based emission factors). These are based on the current best known estimations for each specific subassembly. The state-of-the-art recommendations described in Clause 7 could change over time, as the industry gets better at collecting and analysing data and product information.

Clause 7 also includes guidelines if a user wants to include additional input data (e.g. 7.8.2, 7.9.2).

7.2 Goal

The objective of a CFP is primarily to build knowledge regarding the environmental performance of a product. Although this Technical Report gives detailed guidance for estimating greenhouse gas emissions for computer and monitor products, it is important to understand what it can be used for and what not.

This Technical Report can be used to:

- provide supporting data for identification of a life cycle stage, subassembly or process that have significant greenhouse gas emissions (hot spot);
- prioritize reduction efforts across the product life cycle;
- create a basis for quantifying and reporting CFP performance over time, etc.

At this time, only products within a company should be compared using information in Clause 7. However, it is a step towards being able to eventually compare all similar products.

7.3 Scope

7.3.1 In scope

Notebooks, desktops and monitors, including their packaging.

NOTE Other audio, video and multimedia products (e-readers, phones, thin clients, workstations, tablets, storage equipment, etc.) can be added during a future revision of IEC TR 62921.

7.3.2 Out of scope

Accessories/peripherals (keyboard, mouse, docking station, camera, speakers, external hard disk drives (HDD), etc.) and consumables (e.g. batteries) as well as manuals/CDs.

Any other audio, video and multimedia product.

7.4 Use of primary, primary aggregated and secondary data

7.4.1 General

This Technical Report recommends using primary or aggregated primary data for liquid crystal displays (LCDs), printed wiring boards (PWBs), and integrated circuits (ICs). It also recommends using secondary data for all other data needs.

7.4.2 Allocation methods

IEC TR 62725 recommends avoiding allocation, but if done use the following methods (in order of preference):

- subdivide according to distinct processes;
- subdivide according to physical relationships (mass, energy, etc.) tied to product's functional unit;
- subdivide according to economic value;
- subdivide according to a combination of the rules listed above.

Suggestions on how to perform allocations of overall facility carbon data for LCDs, PWBs, and ICs can be found in the paper titled "Product Carbon Footprinting Allocation Project Results" located on the EICC website.

7.5 Relevant emission factors and databases

When feasible, the most current and applicable emission factors should be used. A list of relevant databases of emission factors for the IT industry can be found in Annex C.

7.6 Functional unit

7.6.1 General

Full life cycle of a notebook or a desktop or monitor with its designated life time.

7.6.2 Life cycle stages included

The following life cycle stages are included:

- product manufacturing (including raw materials extraction, production of components and subassemblies, and final product assembly);
- distribution;
- product use;
- end of life (EoL).

7.6.3 Life cycle stages excluded

Life cycle stages that are excluded from this PCR include maintenance, refurbishment, and second use.

7.7 Production

7.7.1 General

Production covers all stages from raw material extraction to the product leaving the final assembly site. It therefore includes raw material extraction, manufacturing of components and subassemblies including final product packaging, and assembly into the finished product. The items mentioned below should be included in the calculation. To go beyond state-of-the-art, additional components and processes should be included in the CFP.

7.7.2 State-of-the-art calculation recommendations

7.7.2.1 General

The state-of-the-art method for calculating carbon emissions from manufacturing processes for notebooks, desktops and monitors requires summing up all of the subassembly and process impacts associated with that product's production stage.

7.7.2.2 Recommended input data for calculation

The carbon footprints of the component/process listed below are summed to obtain the total production carbon footprint:

- raw material extraction (included in the manufacturing of each subassembly);
- chassis manufacturing;
- populated printed wiring board (PWB) manufacturing (excluding integrated circuits);
- integrated circuit (IC) manufacturing;
- display manufacturing;
- data storage device manufacturing (hard disk drive or solid state drives);
- optical disk drive (ODD) manufacturing;
- power supply manufacturing (PSU, internal or external);
- battery manufacturing;
- final assembly;
- final packaging manufacturing.

NOTE If a product does not include a particular component, it can be excluded in the calculation (e.g. display manufacturing can be excluded for desktops).

7.7.2.3 Additional considerations for input data

Other major components/processes can be included in the calculation.

7.8 Chassis

7.8.1 State-of-the-art calculation recommendations

7.8.1.1 General

State-of-the-art recommendations for this calculation assume that the summed carbon footprints of all major chassis materials are equal to the total product chassis impact. Major chassis materials should include steel, aluminium, magnesium, thermoplastic and copper. For notebooks, the keyboard and touchpad should be included in the chassis.

7.8.1.2 Recommended input data for calculation

The carbon footprints of the component/process listed below are summed to obtain the total chassis carbon footprint:

- mass of main chassis materials, including scrap (main chassis materials include steel, aluminium, magnesium, thermoplastic, carbon fibre and copper);
- emission factor of each chassis material.

7.8.2 Additional considerations for input data

To move beyond state-of-the-art with chassis materials, additional input data to consider include the following:

- specific emission factors for chassis material which include details on
  – material production approach, including the actual material production process used,
  – energy sources used at that material production facility (e.g. fuel source, electricity grid mix),
  – material losses at the material production facility,
  – scrap in raw material production, including disposal of scrap;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of chassis parts.

7.9 Populated printed wiring board (PWB) (excluding integrated circuits)

7.9.1 State-of-the-art calculation recommendations

7.9.1.1 General

State-of-the-art recommendations for this calculation assume that the summed carbon footprints of all significant PWBs are equal to the total product PWB impact. Area should be used for calculating the impact of printed wiring board.

This calculation excludes both printed wiring boards associated with a subassembly, as well as integrated circuits. Printed wiring boards that are associated with a subassembly are included in that subassembly's calculation. Integrated circuits are not included due to their large impact and unique method for calculating their impact (see 7.10).

7.9.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the PWB carbon footprint:

- area of motherboard;
- areas of all other printed wiring boards not associated with a subassembly;
- number of layers;
- emission factor of motherboard/printed wiring board.

PWBs smaller than 1 cm^2 or those that are associated with a subassembly are excluded.

7.9.2 Additional considerations for input data

To move beyond state-of-the-art with the PWB, both for this PWB and for all subassemblies in which PWBs are used, additional input data to consider include the following:

- number of sides used on the PWB;
- scrap in PWB production;
- number of components on the PWB, including
  - integrated circuits not included elsewhere,
  - capacitors,
  - resistors,
  - connectors, including information on contact materials and contact coating materials,
  - heat sinks,
  - other electronic components;
- manufacturing methods used to produce PWB;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of PWB parts.

7.10 Integrated circuits (ICs)

7.10.1 State-of-the-art calculation recommendations

7.10.1.1 General

State-of-the-art recommendations for this calculation assume that area is the best method for calculating the impact of integrated circuits. This calculation includes all integrated circuits that are not associated with a subassembly. ICs that are associated with a subassembly are included in that subassembly's calculation.

7.10.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the IC carbon footprint:

- area of all integrated circuits;
- emission factor for integrated circuit manufacturing.

ICs associated with a subassembly are excluded.

7.10.2 Additional considerations for input data

To move beyond state-of-the-art with ICs, both with these ICs and with all subassemblies in which ICs are used, additional input data to consider include the following:

- number of dies in an IC package;
- package size;
- mask layers (reflects complexity of IC manufacturing);
- feature size on dies;
- wire material type;
- IC type;

- manufacturing methods used to produce ICs;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of IC.

7.11 Display

7.11.1 State-of-the-art calculation recommendations

7.11.1.1 General

State-of-the-art recommendations for this calculation assume that area is the best method for calculating the impact of displays.

7.11.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the display carbon footprint:

- area of display;
- type of backlight technology;
- screen resolution;
- emission factor for display manufacturing (dependent on backlight technology, screen resolution, PFC abatement);
- total mass of the populated display PWB, including ICs;
- emission factor of a populated PWB, including ICs;
- fugitive emissions during manufacturing, including fluorinated greenhouse gases .

NOTE Impacts from fugitive emissions during manufacturing are appreciable due to fluorinated greenhouse gas emissions.

7.11.2 Additional considerations for input data

To move beyond state-of-the-art with displays, additional input data to consider include the following:

- manufacturing methods used to produce displays;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of displays.

7.12 Data storage device

7.12.1 State-of-the-art calculation recommendations

7.12.1.1 General

State-of-the-art recommendations for this calculation assume that mass is the best method for calculating the impact of a data storage device.

NOTE Data storage devices can be hard disk drives or solid state drives or other data storage devices.

7.12.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the data storage device carbon footprint:

- mass of the data storage device;
- emission factor of data storage device manufacturing;
- total mass of the data storage device populated PWB, including ICs;
- emission factor of populated PWB, including ICs.

7.12.2 Additional considerations for input data

To move beyond state-of-the-art with data storage device, additional input data to consider include the following:

- type of storage [hard disk drive (HDD) or solid state drive (SSD)]. In the case of an SSD, the input data relevant to ICs are critical and the mass-based approach of the state-of-the-art method should not be used;
- number of dies in an IC package;
- yield of data storage device.

7.13 Optical disk drive (ODD)

7.13.1 State-of-the-art calculation recommendations

7.13.1.1 General

State-of-the-art recommendations for this calculation assume that mass is the best method for calculating the impact of an optical drive.

7.13.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the optical drive carbon footprint:

- mass of the optical disk drive;
- emission factor for optical disk drive manufacturing;
- total mass of the populated PWB, including ICs;
- emission factor of populated PWB, including ICs.

7.13.2 Additional considerations for input data

To move beyond state-of-the-art with ODD, additional input data to consider include the following:

- manufacturing methods used to produce ODD;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of ODDs.

7.14 Power supply unit (PSU, internal or external)

7.14.1 State-of-the-art calculation recommendations

7.14.1.1 General

State-of-the-art recommendations for this calculation assume that mass is the best method for calculating the impact of a power supply unit.

7.14.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the power supply unit carbon footprint:

- mass of the power supply unit;
- emission factor of power supply unit manufacturing;
- total mass of the power supply unit populated PWB, including ICs;
- emission factor of populated PWB, including ICs.

7.14.2 Additional considerations for input data

To move beyond state-of-the-art with PSU, additional input data to consider include the following:

- cords included with PSU;
- manufacturing methods used to produce PSU;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of PSUs.

7.15 Battery

7.15.1 State-of-the-art calculation recommendations

7.15.1.1 General

State-of-the-art recommendations for this calculation assume that mass is the best method for calculating the impact of a battery.

7.15.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the battery carbon footprint:

- mass of the battery;
- emission factor of battery manufacturing;
- total mass of populated PWB, including ICs;
- emission factor of populated PWB, including ICs.

7.15.2 Additional considerations for input data

To move beyond state-of-the-art with the battery, additional input data to consider include the following:

- battery chemistry;

- material composition of battery (e.g. cathode, anode, electrolyte, separator, passive components);
- manufacturing methods used to produce battery;
- energy sources for manufacturing;
- steam use in manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of batteries.

7.16 Final assembly

7.16.1 State-of-the-art calculation recommendations

7.16.1.1 General

State-of-the-art recommendations for this calculation assume that the largest impact is due to the electricity used in assembling the product.

7.16.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the final assembly carbon footprint:

- total electricity used to perform final assembly and testing of product;
- emission factor of grid electricity in final assembly country.

The impact due to transport of a subassembly to final assembly should only be taken into account in the case of air transport.

7.16.2 Additional considerations for input data

To move beyond state-of-the-art with final assembly, additional input data to consider include the following:

- additional materials and process chemicals used in final assembly;
- scrap in final assembly, including disposal of scrap;
- transport distances of components from production to final assembly;
- transport modes of components from production to final assembly.

7.17 Final product packaging

7.17.1 State-of-the-art calculation recommendations

7.17.1.1 General

State-of-the-art recommendations for this calculation assume that mass is the best method for calculating the impact of final product packaging.

7.17.1.2 Recommended input data for calculation

The data listed below should be included in the carbon footprint calculation to obtain the final product packaging carbon footprint.

- mass of cardboard/paper packaging;
- emission factor of cardboard/paper packaging;

- mass of plastic/polystyrene packaging;
- emission factor of plastic/polystyrene packaging.

7.17.2 Additional considerations for input data

To move beyond state-of-the-art with packaging, additional input data to consider include the following:

- mass of all packaging components, including non-cardboard and non-polystyrene packaging (e.g. other natural fibres, other polymers);
- mass of all packaging components, including overboxes/shipping boxes, instruction manuals, etc.;
- emission factors for each specific packaging material, including specific emission factors for recycled materials as compared to virgin materials;
- manufacturing methods used to produce packaging;
- energy sources for manufacturing;
- additional materials and process chemicals used in manufacturing;
- additional emissions generated during manufacturing;
- scrap in manufacturing, including disposal of scrap;
- yield of packaging.

7.18 Distribution

7.18.1 State-of-the-art calculation recommendations

7.18.1.1 General

State-of-the-art recommendations for this calculation assume that final product distribution covers the following transportation processes:

- distribution of products from final assembly to a central hub within the region where the product is being used;
- transport from the regional hub to the country where the product is being used.

7.18.1.2 Recommended input data for calculation

The data listed below should be included in the calculation to obtain the carbon footprint from final product distribution:

- mass of final product and its packaging;
- transport distances from final assembly to regional hub;
- transport distances from regional hub to country where product is used;
- transport modes for each transport route;
- emission factors of different modes of transport (air, ship, ground, etc.).

7.18.2 Additional considerations for input data

To move beyond state-of-the-art with distribution, additional input data to consider include the following:

- increasing the number of countries considered, thus increasing the specificity of the calculations.

7.19 Use

7.19.1 State-of-the-art calculation recommendations

7.19.1.1 General

State-of-the-art recommendations for this calculation assume that product energy consumption during its service life should consider:

- use profile consisting of time spent in different operating modes, based on the actual or estimated usage patterns;
- power consumption corresponding to the different modes.

7.19.1.2 Recommended input data for calculation

The data listed below should be included in the calculation to obtain the carbon footprint from product use:

- power consumed in different operating modes to calculate a typical energy consumption (TEC) according to the ENERGY STAR® Version 6.1 computer specification[6];
- lifetime of the product;
- emission factor of electricity grid in country or region of use.

7.19.2 Additional considerations for input data

The most accurate use stage assessment will seek to represent actual usage patterns, and utilize greenhouse gas emissions associated with the national grid where the use stage occurs. IEC 62623 gives a standardized testing protocol for the measurement of computer power consumption.

The determination of the use profile, i.e. the duty cycle scenario (time spent in on/active, idle, sleep and off modes) and the assumed product lifetime can be based on:

- a manufacturer's own use phase studies and service life information;
- published industry use phase studies and service life information;
- published national or industry guidelines that specify guidance for development of scenarios and product lifetime for the use stage for the product being assessed;
- technology changes that impact the power consumed during the use phase – for example, proxy network connectivity or connected standby technologies can be assessed and appropriate modifications made to use phase assessment guidelines.

7.20 End of life (EoL)

7.20.1 State-of-the-art calculation recommendations

7.20.1.1 General

State-of-the-art recommendations for this calculation assume that EoL covers transport of the product to the recycling facility, the impacts by recycling the product and impacts by landfilling of those materials that cannot be recycled. Any material credits for recycled/recovered materials are not included at EoL. Credits are included in product manufacturing via the use of recycled material.

6 ENERGY STAR Version 6.0 computer specification is the trade name of a product supplied by ENERGY STAR. This information is given for the convenience of users of this standard and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

7.20.1.2 Recommended input data for calculation

The data listed below should be included in the calculation to obtain the carbon footprint due to product final disposal.

- estimated transport distance to recycling/final disposal facilities;
- recycling percentage of the product and packaging mass;
- disposal of materials that cannot be recycled;
- emission factors for material disposal (for recycled/recovered product and packaging materials, for materials that cannot be recycled, etc.).

7.20.2 Additional considerations for input data

Take into account recyclability rate determined by following IEC TR 62635.

8 Documentation

8.1 General

See IEC TR 62725 for guidance on documentation of CFP studies.

8.2 CFP database

Once an IEC standard is published, it can be 3 to 5 years before a maintenance or update cycle begins. In the environmental field, where regulations, state-of-the-art processes and industry technology advances are evolving rapidly, this maintenance schedule is insufficient to keep pace with global requirements. In response to the challenge, IEC has developed a "database" process that enables technical committees to maintain relevant information on a more frequent basis (e.g. 1 to 3 updates per year).

The procedures for establishing and maintaining an IEC standard in database format are outlined in Annex SL of the IEC Supplement to the ISO/IEC Directives. Typically, a database will be established in conjunction with an IEC standard and a Validation Team (VT) is established to maintain the database. The standard will contain the business process rules or requirements, which are expected to remain constant over a long time frame (3 to 5 years), while the database will contain information, calculations or data that require more frequent updates (e.g. 1 to 3 updates per year).

The specific information contained in the standard versus the database is left to discretion of the TC that is developing the standard and is based on the specific needs of the standard being supported. For example, IEC TC 111 Horizontal Environmental Committee has piloted this database concept with IEC 62474, where the standard contains the business requirements for product content reporting and electronic data exchange rules, while the database contains the declarable substance list, which is updated approximately once or twice per year depending on the changes in global regulations.

A database process cannot be set up for a Technical Report such as this document. However, a standard should be pursued for streamlined carbon footprint methodologies, with an accompanying IEC database. This would be very useful in maintaining the relevance of streamlined CFP methodologies due to their rapidly evolving state-of-the-art processes and data, as well as expanding product category rules.

9 Communication and verification

See IEC TR 62725 for guidance on communication and verification of CFP studies.

Annex A
(informative)

Results of a comparative study on existing relevant streamlined product carbon footprinting methodologies

Table A.1 gives the results of a comparative study on existing relevant streamlined product carbon footprinting methodologies.

Table A.1 – Comparison of "streamlined" product carbon footprinting methodologies

Criteria	Streamlined methodologies				
	iNEMI eco-impact evaluator	**Orange**	**PAIA**	**Japan PCF**	**China PCF**
Modelling topics					
Modelling approach	The approach follows the ISO 14040 methodology. Uses simplified techniques and algorithms for estimating GHG emissions. The following LCA stages are evaluated in the ICT estimator: – Manufacturing / Assembly of ICT Products – Transport, Distribution and Installation of ICT Products – Use and Servicing of ICT Products – End-of-Life Treatment of ICT Products The following steps define the basic principles in the simplified ICT LCA estimator: – Since the tool is product specific, the goal and scope are pre-defined. Define the functional unit and system boundaries. Set the base flow for the functional unit, e.g. one ICT product/asset that operates over a given lifetime. – Break down the ICT product/asset into a structure that describes how the different parts fit together, and identify the component list based on the pre-defined factors in the tool. – Group the component list according to common ICT component categories. – Obtain LCIA parameter information for key components defined (e.g. for printed wiring boards: board size, laminate layers, surface finish type, etc.). – Determine the transportation distances from the ICT product / asset assembly location to the warehousing / distribution (logistics) centre, and then from the logistics centre to the customer's / end-user's point of usage. – Determine the energy consumption during the "use phase" of the ICT product / asset over its intended or design service life. – Determine the probable distribution of end-of-life treatment methods; use the total approximate material declaration for the ICT product / asset as the input for such treatment. – Calculate the eco-environmental impacts per the estimator tool. – Evaluate the estimator tool results and perform a sensitivity analysis on the results to confirm its validity.	Looks at raw materials, manufacturing, distribution, use and end of life of a mobile/smart phone. Focus on PWB (area, # layers), ICs (are of silicon), display (area), battery (mass), charger (mass), housing (mass/materials). Transport taken into account if by air for upstream (PWB, battery, etc.) and for downstream (until warehouse). Output (PCF) is calculated in "black box", possibly with ADEME/Ecoinvent LCA data and primary data collected by Orange at their suppliers' premises.	The overall methodology has been developed for monitors, desktops, laptops and televisions and will be developed for all-in-ones and tablet/slates (mobile compute devices). Life cycle stages included: materials, manufacturing, transportation, use and end-of-life. For each product the method begins by developing a high level assessment of "industry average" product assembled from existing data on global warming potential for that product. The bill of materials is essentially an average of products within that category (15" laptops, for example). Uncertainty is quantified as explained below and then statistical trials are run to determine where more precise data are needed. Data quality and primary data are explained below. Based on the statistical analyses run in the uncertainty analysis data are refined, where possible. Then equations that map characteristics of the product to environmental impact are developed for the most relevant attributes and activities that contribute to impact.	The entire life cycle of the product is included: – raw materials – manufacturing – logistics – use phase – disposal/recycling) Object: main body, peripherals, package.	Raw materials, Parts/components manufacture, Logistics (raw materials to parts/components, parts/ components to brand companies), Assembly, Logistics from assembly site to customer, Use phase, Recycling. The research phase focuses on the entire product life-cycle; intent is to require primary data for the different phases. Streamlined methodology and criteria will be developed according to the research.

Criteria	Streamlined methodologies				
	iNEMI eco-impact evaluator	**Orange**	**PAIA**	**Japan PCF**	**China PCF**
Unit of analysis	The LCA estimator tool will evaluate a product unit consisting of individual hardware equipment or an asset level. The product unit will be attributed to a functional unit as defined by the product manufacturer. The functional unit will be defined to have a specified capacity or deliver a certain type of functionality or service over a given period. – Cradle-to-grave.	Make and receive calls for a total of 5,5 h of communication per month for 2 years.	The product of interest (laptop, desktop, monitor, etc.) for its first lifetime, where the lifetime in years is part of the assumptions described in the methodology.	Functional unit. Sales unit.	Road test being done on a desktop product with mouse/keyboard/ packaging, without monitor. Use phase: 5 years. For different product categories, the owners need to define the functional units separately.
Use phase modelling	No set values defined; left up to the evaluator. Location where product is being used – global or by region. Power consumption – per typical product configuration and feature set. Function of how the product is used (e.g. active, idle / sleep modes, etc.). Include power to cool equipment internally and externally – transfer heat, control humidity levels, and cool the surrounding equipment location / environment, e.g. CRAC unit within CO / server facility / apportionment of energy needed to maintain typical temperature / humidity requirements. Power usage per annum – this can be an average daily power usage based on a typical pattern of usage that includes sleep modes and other power saving features. Product operating life (e.g. typical operating life or design life). Servicing – eco-impact associated with servicing of ICT product (significant for network equipment; may be insignificant for personal ICT products).	(Geared towards mobile / smart phones) Communication time: 5,5 h per month. Average lifetime of the product: 2 years. After each charge, it is assumed that the charger is left plugged in for 5 h with the mobile connected and fully charged, and 5 h with the mobile disconnected. Step 1: Calculation of the number of charges per month, based on the use scenario and the autonomy of the mobile. Step 2: Calculation of the energy consumed during charge, and by the charger when the charge is completed. Step 3: Conversion into CO_2 emissions with the country's energy mix.	There are several elements, including power, duty cycle, location, and lifetime. Duty cycle: For desktop and laptop, Energy Star version 5 or 6 depending on region of interest. For monitor, on and off power only. Power: Numbers are entered or default based on Energy Star data. The location of the grid can be specified and lifetime specified or default assumed based on literature.	Common rule is used. Japanese electrical products industry defines a common rule for quantifying via the Voluntary Action Plan.	Energy Star 5.2.
Cut-off rules	Several cut-off criteria are used in LCA practice to decide which inputs are to be included in the assessment, such as mass, energy and environmental significance. For all three of these criteria, total cumulated flows of less than 5 % of the benchmark flow can be excluded [FR STD: BP X30-323].	None. Based on previous LCA by ADEME, most significant aspects are identified.	None, assessment should include all of the life cycle inventory, but the level of specificity in data depends on the goal of the study.	Cut off ≤ 5 % of the mass of the reference flow as defined in Sections 2.2.2 and 2.2.3 (http://www.cfp-japan.jp/english/rules/pdf/ C-09-03.pdf) of the Japan Environmental Management Association for Industry.	Following PAS 2050 criteria in the road test. This has not yet been defined in China PCF methodology but will be discussed in the future development.

Criteria	Streamlined methodologies				
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Allocation	A co-product is defined as "any of two or more products coming from the same unit process or product system" [ISO 14044:2006]. The allocation of environmental impacts between products and co-products shall be performed according to one of the following procedures, listed in order of priority: 1) Subdivide according to distinct processes; 2) Subdivide according to physical relationships (mass, energy, etc.) tied to the product's functional units; 3) Subdivide by extending the system's boundaries to include the co-products function when it is possible to assess some impacts that have been avoided by producing the co-product. 4) Subdivide according to economic value; 5) Subdivide according to a combination of the rules listed above.	No co- or sub-product.	Very dependent on the component. Allocation is avoided where possible and then done primarily by physical unit such as printed wiring board area, input sheet of glass, units, etc. Transportation calculated by mass allocation. End-of-life processing allocated to the product – no credit for recycling.	Discretionally.	1) Try to avoid allocation. 2) Physical allocation, such as by amount. 3) Other allocation methods according to different status.

Criteria	Streamlined methodologies				
	iNEMI eco-impact evaluator	Orange	PAIA	Japan PCF	China PCF
Uncertainty	Uncertainty in eco-impact assessment comes from two sources: technical uncertainty and natural variability. Technical uncertainty is created by limited data quality, ineffective sampling, wrong assumptions, incomplete modelling and other flaws in the assessment calculation itself. Natural variability can be accounted for in the definition of the LCA estimator methodology framework as an average, or representative figure, so it does not need to be quantified. Because the nature of this estimator methodology involves estimates and judgment, there will be some degree of uncertainty associated with it. A recommended approach for calculating uncertainty is to perform a Monte Carlo analysis of the algorithms created within the estimator tool.	Not included.	First of all, uncertainty is modelled around both the quantity and type/impact aspects of the analysis. Quantity includes amount of materials, amount of transportation, power, etc. Type includes the specificity of the material (non-ferrous versus aluminium), mode of transport (road versus air), location (China versus Asia), etc. and impact data refer to the impact associated with the type. Uncertainty is represented quantitatively where sufficient information exists, or quantitative accounting of qualitative uncertainty is made based on data quality indicators. Uncertainty is typically log normally or uniformly distributed, occasionally other distributions are modelled where enough data exist. This uncertainty information is used to prioritize where more data should be collected.	Database of basic unit quality is not defined.	Should evaluate the data sources, completeness and accuracy of the information.

Criteria	Streamlined methodologies				
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Comparability	Products cannot be compared based on this tool.	Not defined in the methodology. Each user can define its own way of using the indicators, raw value, staged rating, absolute or relative.	The metric that this method has emphasized for determining whether or not the data are of sufficient quality to enable comparison is the "false signal rate" or the number of times that a product whose mean is higher than another product actually appears lower in impact for each individual statistical trial. The more narrow the distribution (or certain the result), the lower this number becomes. Another important element of this is the difference in the means of the two products. So while comparison is not recommended, metrics for evaluating whether comparison is possible has been the emphasis.	There is no rule for comparing products.	Not included. Since the life cycle analysis and scope/boundary could be defined differently, it doesn't support comparison.
Data topics					
Data quality	Current data are from public or private databases so not high quality data.		Data quality is evaluated on metrics of: sample size, age of data and data source. Data quality is noted for all relevant data but prioritization is made on data that are of lowest quality but are of greatest importance to the overall analysis.	Primary data – Ideally want to use data less than 12 months old; however collection of all data is very difficult. Secondary data – use a common database.	Focusing on the time-related coverage, geographical specificity, technology coverage and data accuracy. On-site audit is required in the road test; the auditor would check the data quality on site.

Criteria	Streamlined methodologies				
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General steps for collecting data	Data from public and non-public databases was used to develop the algorithms embedded in the tool through regression analysis. For basic components (like capacitors, resistors, ICs) whose data exists in an LCI database, LCIA is performed and is allocated based on the associated scale factor (weight, area, package type, etc.) For modules, data were extracted from complete LCAs of modules (like a hard drive) and allocated by product features (i.e. size, weight, etc. of the components).	Primary data needed on "critical few", e.g. mass of housing, size of PWB.	1) For tool development: high level assessment from existing data gathered from public sources, commercially available datasets, and market information. Then primary data collection for relevant high impact components. 2) For use of tool: gather information on product attributes, for example screen size, resolution, PWB area, chassis materials percentages.	Use common database for secondary data.	1) Define product scope. 2) Collect primary data. 3) Perform initial calculation to help define the key parts/phases. 4) Obtain better data for the key parts/phases. 5) Secondary data where primary activity data have not been obtained.

Criteria	Streamlined methodologies				
	iNEMI eco-impact evaluator	**Orange**	**PAIA**	**Japan PCF**	**China PCF**
Definition of primary and secondary data	Secondary data – provided from public and private sources.	Primary data: Quantized value from a direct measurement or calculation from direct measurements of an activity or process life cycle of the product. This value, when multiplied by an emission factor or characterization, to calculate an indicator of impact category. Secondary data – Quantized value of an activity or process life cycle of the product obtained from sources other than direct measurement or calculation from direct measurements. The fact that data are secondary does not mean they do not remain influential. Example for the use phase: Primary data: autonomy in standby and in communication, time and energy for a charge from 0 % to 100 %, power consumed by the charger in no-load condition, and with load charged at 100 %. Secondary data: g CO_2e/kWh (EdF)	Primary data: Site-average or site-specific data from direct measurement or calculation from direct measurement if from several facilities, with 18 months, representative of technology used in product, including uncertainty is considered primary data. Secondary data: arising from relevant sources, but maybe industry association, published, LCA databases, government sources, etc.		Primary data: collected directly from the supply chain, including tier one/two/three suppliers. The data is directly collected from the active unit processes. Secondary data: data arising from competent sources, such as LCA database, industry association, national government, official, United Nations publications.
Transparency		Some "black box" calculation formulae are disclosed.			
Data	Algorithms are very transparent – uses physical characteristics of the product.	Input data need to be primary, supplied by manufacturer. LCA data in "black box", possibly ADEME or Ecoinvent data.	Aggregated component and materials means and standard deviations are transparent. Broken down by regions in most cases.	It should be shown if data are primary or secondary.	The input is more likely the primary data. For the road test, data come from China CLCD, NDRC, Ecoinvent database.
Methodology	Very transparent.	Black box.	Explained throughout Excel tool and in separate word documents.	All PCR information should be disclosed.	Black box.