Decarbonising the Use-phase of Connected Devices

Assessment of Product Use-phase GHG Emissions from Electrical and Electronic Products - Part 1: Specification and Guidance

NOVEMBER 2024

Dissemination Level: Public

Revision: 3.4

Published: November 2024

Decarbonising the Use-Phase of Connected Devices (DUCD) is an initiative of companies which aims to harness the potential of connected devices to reduce use-phase GHG emissions.

The secretariat of the DUCD is led and funded by the leading organisations Amazon, Meta, Microsoft, Samsung, and Sky, working together with Carbon Trust and the selected Consultation Partners.

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1. Introduction

1.1. The Secretariat

The Decarbonising the Use-phase of Connected Devices (DUCD) secretariat is an industry collaboration formed to tackle the GHG emissions resulting from use-phase electricity consumption of internet-connected electrical and electronic products. Products that are connected to the internet have the ability to communicate information regarding their activity during their lifetime which enables calculation of their use-phase electricity consumption and resulting greenhouse gas (GHG) emissions based on data collected from devices in use. This can lead to considerable improvements in the accuracy of use-phase GHG emissions calculations over current estimation methods and enables annual GHG emissions reporting from products in use throughout their lifetime. Improved accuracy of GHG emissions calculations combined with annual reporting increases transparency of product impacts for stakeholders and allows organisations to demonstrate GHG emissions reductions for actions taken to improve energy efficiency.

The improved accuracy and annual GHG emissions reporting also creates the potential to enable novel approaches to reduce use-phase GHG emissions of products through actions to decarbonise electricity grids undertaken by organisations supplying the products. By accounting for the GHG emissions resulting from the use-phase of their products based on activity data and country of use, organisations could take proportional actions to decarbonise the electricity grids where use occurs and accelerate the transition to clean electricity grids.

The DUCD secretariat formed to develop a common approach to unlock these benefits and try to address the use-phase GHG emissions of connected devices where action is limited under current GHG emissions calculation and accounting methods.

1.2. Purpose of this Specification

The Assessment of Product Use-phase GHG Emissions from Electrical and Electronic Products - Part 1: Specification and Guidance provides requirements and guidance for organisations to calculate the GHG emissions resulting from the use of sold or leased electrical and electronic products through the use of data collected from devices in use by customers. The primary goal of this specification is to provide an approach to help organisations assess and report the GHG emissions impact resulting from the use of their electrical and electronic products throughout their lifetime and their efforts to reduce these emissions leading to more sustainable products for consumers. This document focuses solely on the use-phase of products which the secretariat identified as an area with considerable potential for improvements in GHG emissions accounting to support reduction efforts, as such, the guidance should be considered by organisations as one part of a wider strategy to address full life cycle emissions of the product. The outcome from the use of this specification is to report the total annual GHG emissions impact and reduction (where achieved) of *all devices in use* of the product being studied. The purpose is not to communicate the impact of a single device that a consumer would use, although the data collected could be analysed to usefully inform this type of study (typically called a product carbon footprint).

This specification provides an alternative approach to accounting and reporting of product use-phase emissions to current international standards, such as the Greenhouse Gas Protocol. It is both a specification and guidance document to provide context for the new methodology. The primary differentiators of this specification to existing current standards are reporting GHG emissions annually throughout the lifetime of the product and accounting for use-phase emissions using telemetry data from the devices that are in use in the reporting period. The latter is prevented by current standards that require reporting of full lifetime GHG emissions before product use has occurred. These differences in the approach are elaborated further in section 1.5. The objectives of this specification are:

- To support organisations accounting and reporting the use-phase GHG emissions from electrical and electronic products with the use of telemetry data from devices in use through a common approach and principles.
- To support organisations demonstrating product use-phase energy consumption and resulting GHG emissions reductions for actions taken to improve energy efficiency.
- To increase the transparency of the GHG emissions impact of electrical and electronic products through annual public reporting.

The DUCD secretariat intends for this specification to provide a foundation for annual reporting of product use-phase GHG emissions by organisations that may, in future, be used as the basis to report the total impact of all products sold or leased each year, and to establish novel approaches for organisations to contribute to decarbonising electricity grids and reduce the use-phase GHG emissions of their products.

1.3. Intended Audience and Benefits

The intended audience for this specification is electrical and electronic product manufacturers and organisations that sell electrical and electronic products, although third-party vendors will need to be able to collect the necessary data from devices. The benefits arising from this approach are:

- Improved accuracy in reported use-phase GHG emissions from electrical and electronic products.
- Transparency of product use-phase GHG emissions throughout the product lifetime.
- Incentivising organisations to minimise or reduce product energy consumption and resulting GHG emissions during the product lifetime.

1.4. Scope of the Specification

This specification has been created to account for the use-phase GHG emissions resulting from the consumption of electricity by an electrical or electronic product that is connected to the internet and sold or leased by an organisation. The GHG emissions considered are aligned with existing international standards and include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

The scope does not include other unconnected electrical and electronic products. Additionally, the scope of this specification document does not include the method for organisations to report total GHG emissions from the use of all sold or leased products at the corporate level (i.e scope 3 category 11 and 13), but this is the focus of future development by the DUCD Secretariat.

In the course of developing this specification, the DUCD secretariat began development of requirements and guidance for a novel approach for organisations to contribute to decarbonising electricity grids termed “renewable energy matching”. The development of this approach is incomplete and is therefore not included in the scope of this specification. The concept for renewable energy matching will be published in a separate document alongside this specification.

1.5. DUCD Product Use-phase Emissions Accounting Method

This specification is founded on the principle of collecting granular activity data relating to the use of a product during the time period that individual devices are in use. The granularity of the data allows the use-phase energy consumption and resulting GHG emissions to be calculated according to customer use during the product lifetime. As a result, the product use-phase GHG emissions can be regularly reported throughout the product lifetime (e.g. on an annual basis) based on the activity data from devices. This can be a significant improvement from the current accounting approaches that are based on forecasting the use-phase GHG emissions based on assumptions of product use.

Product carbon footprint accounting and reporting standards[1] do not require that use-phase GHG emissions are forecast, however, this is implicit as the result is not annually reported retrospectively for each year of product use but are a forward-looking prediction reported once and are typically calculated before a product is released. By adopting this specification’s *annual use-phase emissions accounting method*, product carbon footprints could update the use-phase emissions of the functional unit annually based upon activity data from devices in use.

Organisational carbon footprint accounting and reporting standards[2] require that GHG emissions of sold products are calculated based on the total *expected* lifetime emissions and reported once in the year in which the product is sold (*the lifetime use-phase emissions accounting method*). By adopting the annual use-phase emissions accounting method organisational carbon footprints could report GHG emissions from use of sold products annually for all products in use in the reporting year (i.e. including all historical sales that remain in use). This provides far greater accuracy on the actual use and lifetime of each device and avoids significant errors intrinsic to the lifetime use-phase emissions accounting method.

The improved accuracy resulting from the use of telemetry data and reporting GHG emissions annually compared to forecasting lifetime use-phase emissions is due to the improved calculation inputs and elimination of many assumptions as shown in Table 1.

[1] E.g. Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard

[2] E.g. Greenhouse Gas Protocol Corporate Value Chain Standard and ISO-14067:2018 Carbon footprint of products

Table 1: Comparison of lifetime and annual accounting methods

Calculation input	**Lifetime use-phase emissions accounting method**	**Annual use-phase emissions accounting method with telemetry data from devices in use**
Energy consumption from product use	One or a few energy profiles representing customer behaviours, making assumptions for usage frequency and intensity.	Energy consumption is calculated according to telemetry data on usage frequency and intensity collected from all devices or a sample of devices.
Number of devices in use	All products sold are assumed to be in use and generating GHG emissions, sometimes accounting for failure rates and obsolescence.	The number of devices in use is assessed at regular intervals to calculate emissions in relation to use.
Lifetime of devices	A product has an assumed lifetime. In some cases the assumed lifetime is an average lifetime of devices in use. The products may be assumed to reduce intensity of use throughout its lifetime.	Telemetry data on usage is collected throughout the lifetime of each device and GHG emissions are calculated for the full time that devices are in use.
GHG emissions calculation according to country of use	Assumptions on country of use calculates GHG emissions based on location of sales or anticipated sales.	Telemetry data on actual country of use calculates emissions according to where use occurred.
GHG emissions according to time period of use	Assumptions on future electricity grid emission factors or no consideration of future changes.	GHG emissions calculated according to actual emission factors relevant to the reporting period.

This approach increases the complexity of the GHG emissions calculation as it requires more data collection, a more complex energy model to compute the activity data, and annual reporting throughout the product lifetime. The approach can also include some estimation when data is not collected from all devices in use by consumers, although the extent of estimation is considerably reduced from current accounting approaches. For products that are internet-connected, the increased data collection and model complexity are unlikely to be a significant challenge as these products are already communicating other information for analysis and reporting. Non-internet connected products are not considered in the scope of this document, however, it is feasible to manage a ‘stock’ of products based on year of sale and an assumed lifetime. Application of the annual use-phase emissions accounting method to products that are not internet-connected are intended for a future scope of work. Whilst using either approach is reasonably straight-forward, the introduction and on-going accounting and reporting of connected and unconnected products simultaneously across all products of an organisation is complex and requires further guidance for organisations to be able to manage effectively.

1.6. Specification Overview

This specification is designed to be applicable to a broad range of electrical and electronic products and by any eligible organisation. To enable this the specification allows organisations to apply the most suitable approach to calculate the energy consumption[3] of each product for their strategy, maturity, and level of ambition. Therefore, this specification provides requirements on what the energy model shall achieve, and how it is constructed, but does not specify a single modelling approach. Similarly, it sets out requirements for how use-phase energy reductions should be assessed and demonstrated but does not specify how they should be achieved.

Sections 1 to 3 cover the introduction to the specification, definitions and acronyms used, and define eligible products, organisations, and the assessment boundary.

Section 4 defines requirements and provides guidance for organisations to quantify the product use-phase energy consumption and resulting GHG emissions of devices in active use.

Section 5 determines how organisations can demonstrate energy reductions resulting from their activities to improve the energy efficiency of the product and calculate the resultant GHG emissions reduction.

1.7. Product Scope

This specification includes any electrical or electronics product that has the ability to communicate information about the use-phase from devices for the purpose of calculating the electricity consumption (referred to as energy consumption throughout the document). The specification does not define applicable product categories as it is intended to be applied to the growing number of products that are gaining connectivity functionality. For example purposes only, this could apply to the following product categories:

- Mobile phones
- Tablets
- Smart watches
- E-readers
- Televisions
- Set-top boxes
- Laptop & desktop computers
- Household / office appliances (e.g fridges, washing machines)
- Ancillary computer hardware (e.g. printers, scanners)
- Network communication devices (e.g. routers)
- IoT products (e.g. security cameras, doorbells)

[3] The scope of the specification is limited to electricity consumption, but it is more generally referred to as energy consumption throughout.

1.8. Specification Principles

This specification is aimed at improving the accuracy of energy use calculations of the use-phase of connected devices beyond the current status quo. The specification does not prescribe how measurements should be conducted but puts in place a structure to review and report measurement methods and ensure reasonable accuracy, consistency, transparency, and conservativeness of approach. Assessment of the use-phase energy consumption from a population of connected devices is likely to require some estimation and / or extrapolation and should be considered as an estimation and not a measured value while still improving the accuracy of the assessment compared to current approaches.

The cross-cutting principles used throughout the specification are as follows:

1) **Accuracy**: The measurement method should have greater accuracy than standard methods of calculating use-phase energy consumption with estimated lifetimes and usage profiles. As such, telemetry data collected from the connected devices in use shall be included in the measurement method and uncertainties should be reduced as far as practicable.

2) **Consistency**: The chosen measurement method, assumptions, and data should be applied consistently for all devices of the same product to allow reproducible and comparable results over time. Manufacturers should aim to be consistent in their measurement approach across different products where practicable.

3) **Transparency**: The measurement method, assumptions and data sources should be recorded with a clear audit trail available to a third-party assurance provider on request. Organisations should publicly disclose relevant assumptions, boundaries, and other information necessary to faithfully represent the reported values.

4) **Conservative**: Assumptions and estimations shall adopt a conservative approach to ensure that any uncertainty included within the calculation does not result in an under-estimation of GHG impact. This principle shall be applied in conjunction with adherence to accuracy.

5) **Universality and inclusion**: The specification is intended to be universally applied to any product meeting the eligibility requirements including all industries and product categories (see section 3).

6) **Privacy:** The use of telemetry data for the purpose of calculating device energy consumption and resulting GHG emissions requires the organisation to use customer-owned / operated device data and potentially share information with assurance bodies. Customer data may need to be anonymised before use in energy consumption and emissions calculations. Organisations and assurance bodies shall undertake to meet all applicable national and international regulations concerning the sharing and use of customer data and commit to taking care and consideration as necessary above legal requirements.

2. Definitions and Abbreviations

Definitions in this specification

Active device, all devices (sold or leased) that remain in use in the reporting period. The accounting and reporting of product use-phase GHG emissions are not limited to only those products sold or leased in the reporting year. i.e. Active devices include all devices in use from the current year's manufacturing and the residual from previous years that are in their 2nd, 3rd, nth year of use.

Attributable product, a product that is sold with the product, e.g. a non-integrated power adaptor

Carbon dioxide equivalent (CO_2e), CO_2e shows the combined GHG impact of all applicable greenhouse gases if all the GHG emissions derived from CO2, by using GWPs for conversion.

Device, the individual product unit sold or leased to the customer, therefore, the product and product variants include all of the individual device units sold by the reporting organisation

Electrical and electronic products, electric equipment intended for everyday use including consumer electronics and electrical appliances products. Please see section 3.1 for a list of example products.

Energy consumption factor, any characteristic that when varied can affect the energy consumption of the product, for example, time-in use would affect the energy consumption of all products.

Energy model, see "Use-phase energy model"

Geographic region, a defined geographic boundary referred to in the document for the calculation of GHG emissions resulting from electricity use for the specified region. Typically, individual countries are distinct geographic regions for electricity use (e.g. United Kingdom), however, a country may have multiple electricity grids or may provide regional location-based emission factors for more granular GHG emissions calculations.

Greenhouse gases (GHGs), gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds.

Model evaluation, the task of assessing whether a chosen model is appropriate or not.

Product, the goods that are sold or leased to the customer. A product has a defined function or set of functions, and it may be sold in a number of different variants including a variety of hardware and software configurations.

Product family, a product family is a group of related goods produced by the same company under the same brand. The product family supplies an array of products that are similar but meet slightly different needs or tastes.

Product variant, variations of the product in form and function that are available to consumers who can select from multiple configurations or options. For the purpose of this specification the product variants of interest are only those that result in a different energy consumption.

Reference data, includes any data used in the energy model that is not collected from the device in use (i.e. not telemetry data). This may include data obtained from lab testing or from secondary data sources.

Reporting organisation, any entity, public or private, such as a business, corporation, government agency non-profit organisations, institution, local authority, etc. that wishes to use this document – referred to as the "organisation"

Reporting period, the time period for which the assessment is carried out.

Telemetry data, includes data collected on devices and data transmitted from devices that is remotely collected. The data collected will be used in the energy consumption modelling (either on the device or remotely) and will include data relating to the activity of the device and its location of use. It may also include other information about the device necessary for the energy modelling, e.g. product version. (Note that the data collected by the devices may be processed on the device before transmission, both the collected data and transmitted data is considered as telemetry data).

Use-phase energy model, a mathematical representation of the product, used to simulate its energy consumption – referred to as the "energy model".

Verification, an assurance process for evaluating a statement of historical data and information to determine if the statement is materially correct.

Abbreviations in this specification

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DUCD	Decarbonising the use-phase of connected devices
EU	European Union
GHG	Greenhouse gas
GWP	Greenhouse warming potential
GW	Gigawatt
GWh	Gigawatt-hour
kW	Kilowatt
kWh	Kilowatt-hour
MW	Megawatt
MWh	Megawatt-hour
USA	United States of America

3. Eligibility & Boundary Definition

3.1. Eligible Products

- Electrical and electronic products that are:
  - Powered only by electricity
  - Have the ability to communicate information about the use-phase from devices for the purpose of calculating the electricity consumption

Note: It is recommended that this specification is applied to products where the use-phase emissions represent a significant share of the product's full life cycle emissions.

3.2. Eligible Organisations

- For an organisation to be eligible to apply this specification, they will need to:
  - Be a manufacturer / retailer of the product
  - Have access to sufficient device data necessary for energy consumption measurement

3.3. Assessment Boundary

3.3.1. Product boundary

Box 1: Products, product variants, and reported GHG emissions
Products are often available to consumers in multiple configurations or selectable options, for example in different sizes or different capabilities. These are termed *product variants* and the use of a different variant by a consumer would result in a different energy consumption. Assessment of multiple product variants is allowed under this specification, but the variants must be similar enough to be considered the same product. Product variant examples:

(a) An air conditioning product may be available in different sizes and cooling capacities

(b) A laptop computer product may be configurable with different screen sizes, memory, graphics cards, etc.

As the assessment relates to all devices in use of the product, and hence all devices of all product variants, the reported GHG emissions are the total impact of the product in the reporting period and geographical boundary.

WARNING: Reporting of this total value should be clearly communicated as the total emissions of all uses of all variants of this product in the reporting time period in the geographical boundary. A per product value should not be simply calculated as an average due to the potential for very diverse product variants. Communications to consumers (about specific product variants in specific geographic areas) requires data specific to the product variant.

- The specification shall be applied to a single product, to qualify as a single product:
  - All product variants shall have an equivalent function or set of functions
  - All product variants shall be under an equivalent level of control by the organisation. For example, a branded variant and a retailer's own brand variant cannot be combined.
  - All product variants shall have the same customer use-case, i.e. an AC unit in a residential building application is a different product to an AC unit in an industrial or vehicle application.
  - Product variants should have the same product name and model name, and have the same energy model.
- Organisations shall define the studied product and any product variants included in the assessment.
  - Where there are product variants that are not internet connected and are therefore out of scope, these shall be clearly reported as out of scope as not included in the use-phase emissions and or any reductions.
- The organisation shall ensure transparency to the consumer about the specific product and variants included and any excluded variants.

Note: The definition of the product and product variants are included in this section and further requirements necessary to define how product variants can be grouped are addressed in section 4.4.2.

- The product use-phase GHG emissions assessment shall include:
  - All devices in use within the reporting period (termed *active devices**).
  - Attributable products: GHG emissions resulting from energy consumption of products that are sold with the product, e.g. a non-integrated power adaptor.
- The product use-phase GHG emissions assessment shall not include:
  - Non-attributable products: GHG emissions resulting from energy consumption of products that are used in tandem with the product but are not sold with the product, e.g. a separate display screen.

Box 2: Active devices (*)
Active devices include all devices sold or leased to consumers that remain in use in the reporting period. The accounting and reporting of product use-phase GHG emissions are not limited to only those products sold or leased in the reporting year. i.e. Active devices includes all devices in use from the current year's manufacturing and the residual from previous years that are in their 2^{nd}, 3^{rd}, n^{th} year of use.

3.3.2. GHG emissions boundary

- GHG emissions shall include greenhouse gas emissions from carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) converted to CO_2 equivalent GHG emissions (CO_2e), using a 100-year global warming potential (GWP).

- The boundary of the assessment shall use a full life-cycle emissions factor for electricity, i.e. including both:
  - Direct use-phase electricity GHG emissions: GHG emissions resulting from the electricity consumption of the product or other attributable products during use as a result of electricity generation.
  - Upstream GHG emissions associated with use-phase electricity consumption: GHG emissions resulting from upstream activities relating to the provision of use-phase electricity consumed by the product and attributable products including extraction, production, transportation of fuels consumed in the generation of electricity, and transmission and distribution losses.
- The boundary of the assessment shall not include,
  - Indirect GHG emissions: GHG emissions resulting from additional activities, such as maintenance or cleaning, required for the product to function throughout its lifetime.
  - Infrastructure or Supporting Services: GHG emissions resulting from energy consumption necessary for the connectivity network infrastructure or support services, e.g. data hosting services.

3.3.3. Geographical boundary

- The geographical boundary for the assessment shall be defined by the reporting organisation.
  - Note: Geographical boundaries should be kept consistent across reporting periods to support comparisons in annual reporting.
- The minimum boundary shall be the product use in one country, but organisations can select multiple countries, a region, multiple regions, or globally.
- If a region or multiple regions are selected, the region shall be defined. If a known region name is used, for example the EU, all countries within the region shall be included. All devices within the geographical boundary shall be included in the assessment.

3.3.4. Reporting period

- Organisations shall report the calculated product use-phase GHG emissions and energy reduction activities on an annual basis resulting in a maximum reporting period of one year.
- Organisations typically have a defined annual reporting period, such as a calendar year or a financial year. Where a product's use starts or ends during an annual reporting period the organisation shall only report the time period where use occurred and, as such, may report less than the full annual period in these circumstances.

Note: while the reporting period is one year, organisations are required to collect and analyse data across the full time period (section 0). As such continuous / regular collection throughout the reporting period is likely necessary for monitoring and internal reporting.

4. Product Use-Phase Energy Consumption & GHG Emissions Calculation

This section describes the methodology for calculating the product use-phase energy consumption and resulting GHG emissions using data collected from devices during use.

4.1. Units of Analysis

The chosen metrics to measure energy consumption and report GHG emissions allows for consistency and comparisons across different products and provide a meaningful measure for reductions. All units used are metric international system of units (SI units).

Energy Consumption

Energy consumption shall be measured in watt-hours (Wh). The reporting organisation can select the appropriate scale for reporting, e.g. kWh, GWh, MWh, etc. Energy consumption is the calculated output, but power consumption is regularly discussed in the specification as it is independent of time in use.

Power Consumption

Power consumption shall be measured in watts (W). The reporting organisation can select the appropriate scale for reporting, e.g. kW, GW, MW, etc. This metric is used throughout the specification to measure and compare energy performance of the product independent of time.

GHG emissions

GHG emissions shall be measured in CO_2-equivalent (CO_2e), aligning to the Greenhouse Gas Protocol. The reporting organisation can select the appropriate scale for reporting, e.g. kgCO_2e, tonnes CO_2e, Megatonnes CO_2e, etc.

4.2. Energy Modelling Guidance

4.2.1. Energy modelling process

Modelling a product's energy consumption based on data relating to the activity of devices in use involves:

(1) Data collection: Collection of telemetry data on devices and reference data necessary for the energy model.

(2) Energy modelling: Computation of the data in an energy model to calculate energy consumption per device and energy consumption of attributable products.

(3) Total product energy consumption: Calculation of total product energy consumption which is achieved by either aggregation of energy consumption from all devices or extrapolation of calculated energy consumptions from a sample of devices to full number of active devices.

The energy modelling process for a product based on these three steps is shown in Figure 1 below.

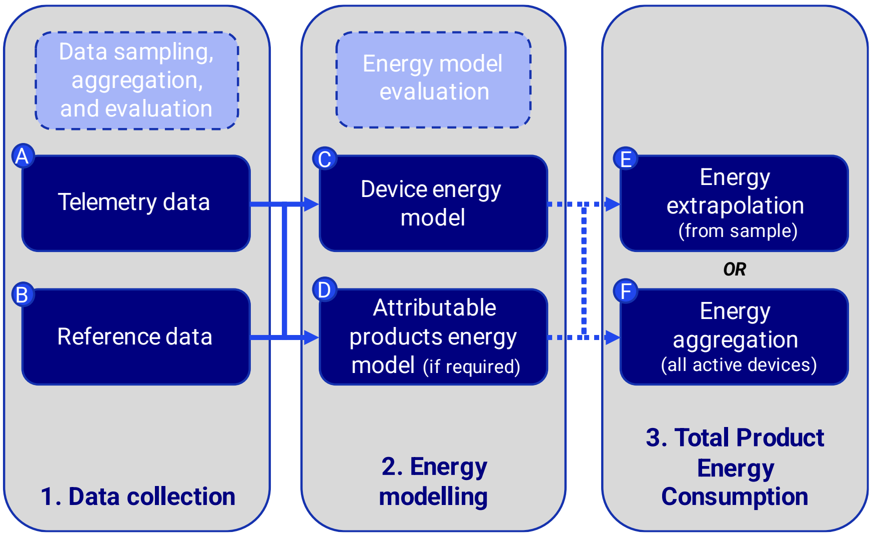


Figure 1: Energy modelling process to calculate the total product energy consumption

Figure 2 below shows computation of the device energy model (C) centrally once the telemetry data has been collected from devices (A) and transmitted to a central database for the remainder of the energy modelling process outlined above.

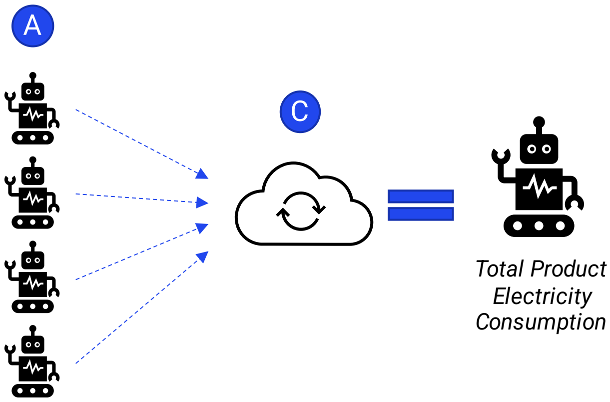


Figure 2: Energy model computation centrally

However, it should also be noted that computation of the device energy model (C) can also take place on the individual devices, as shown on Figure 3 below, where the calculated device energy consumption is then transmitted to a central database for the remainder of the energy modelling process above.

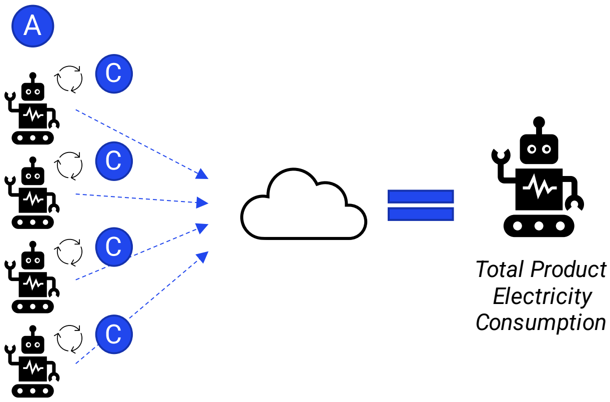


Figure 3: Energy model computation on the device

(1) Data collection consists of:

- Telemetry data collection from devices (section 4.3.1)
  - Telemetry data includes all data transmitted from devices and remotely collected. This data will be used in the energy consumption modelling and will include data relating to the activity of the device and its location of use. It may also include information about the device necessary for the energy modelling, e.g. product version.
- Reference data collection (section 4.3.4)
  - Reference data includes any data used in the energy model that is not collected from the device in use (i.e. not telemetry data). This may include data obtained from lab testing or from secondary data sources.
  - Lab test data is collected via testing of the product in a lab environment. This data may be used by the energy model for the calculation of the product energy consumption and/or for evaluating the correlation of the energy model against tested performance.
- Use of data sampling (section 4.3.2) and aggregation (section 4.3.3) to minimise data collection, transfer, processing, and storage may be suitable or necessary for some organisations.
  - Data sampling may be used by organisations to limit data collection from a sample of active devices which can later be extrapolated to the total number of active devices.
  - Data aggregation defines requirements for consolidating data to ensure the data quality is maintained.
- Data quality and uncertainty evaluation (section 4.3.4).

(2) Energy modelling consists of:

- Energy consumption calculation for active devices of the product (section 4.4.1).
  - The product energy consumption is the total energy consumption of all devices of a product that are in use, these are termed active devices.
- How product variants can be grouped in the energy model if desired (section 4.4.2).
- How the energy model can be evaluated to assess its accuracy at representing the real-world product energy consumption (section 4.4.3).
- Energy consumption calculation for attributable products (section 4.4.4).

(3) Total product energy consumption calculation consists of:

- Calculating the total use-phase energy consumption of the product (section 4.4.5).
  - The total use-phase product energy consumption is the total energy consumption from all active devices and attributable products.
  - The energy consumption from all active devices can be calculated by
    - aggregation of the calculated energy consumption of all individual active devices which necessitates data collection from all active devices, or,
    - extrapolation, where organisations choose to only collect data from a sample of active devices and extrapolate the energy consumption of the sample to the total number of active devices.

4.2.2. Characteristics that affect product energy consumption

The energy consumption of products is driven by three general characteristics: the product specification, the usage of the product, and the external environment of its use. While the energy consumption of a specific product is driven by a unique set of energy consumption factors, these factors will be associated with one of these three characteristics. Therefore, all product energy consumption models need to address each characteristic to a greater or lesser extent.

Product specification

Product specifications can include a hardware specification and a software specification. Products often have multiple configurations of hardware and software available to the consumer which can result in *product variants* with different energy consumptions. For example, a television may be available in different sizes, each is a different product variant that has a different power consumption according to its size. The energy model will need to be able to represent all of the different product variants of the product. Therefore, the energy modelling should consider how each possible configuration of the hardware and software can affect the energy consumption of each device.

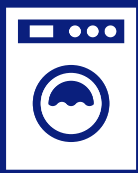
Device use

The usage conditions of each active device by a consumer will affect its total energy consumption which can be considered in terms of frequency and intensity of use (see example on the right for further explanation). Therefore, the product energy model needs to consider both the usage frequency and the usage intensity of each device.

Usage frequency is typically considered by collecting telemetry data of time in use, frequency of use, or by collecting other telemetry data over time to generate a time series dataset. The frequency of use of a product often changes over its lifetime, for example, a new television used in the living room may be moved to a bedroom in the house when it is older reducing its frequency of use. Therefore, this is an essential input into the energy model.

Likewise, the usage intensity of the device is an essential input into the energy model. The same product in use by different users can have significantly different energy consumptions due to the operations each user decides to carry out. Therefore, energy modelling of usage intensity has to consider the operations available to users and the functionality of the product. For example, certain products have sleep/low-power mode(s) to reduce the power consumption in these modes relative to when in use. Some products even have multiple levels of sleep/low-power mode to further reduce power consumption. The impact of these modes or similar functionalities will vary

Box 3: Device use intensity



A simple washing machine with only one wash cycle has a single usage intensity, however, if one device was operated twice as often as another device the energy consumption would be doubled.

The energy consumption of a washing machine with multiple selectable wash cycles of different usage intensities can therefore be affected by the number of times the washing machine is operated (frequency) and the wash cycle selected (intensity).

between products and need to be adequately accounted for in the energy model.

The usage intensity of the device should be assessed by considering the types of the operations and functionality of the product. Some products have discrete pre-determined operations that result in one or several specific usage intensities, such as programmes on a washing machine. These are pre-determined operations that each have specific power consumptions with little variability when repeated. In these cases the usage intensity may be more easily determined by collecting telemetry data on the selected operation (e.g. the washing cycle) which defines the power consumption or total energy consumption during the operation.

The usage intensity of other products with highly variable operations can be more complex to assess. Highly variable operations can be selected by users, for example while using a mobile phone, users can select to use multiple third-party applications, use network communication, or configure performance settings such as screen brightness. There are a number of different operations and configurable settings available to users and therefore the usage intensity of the product can vary significantly for each device. High usage intensity will increase the power consumption of the device and therefore the energy model needs to be able to adequately represent the variable power consumption when the device undertakes operations of different intensities.

Detailed guidance of approaches that can be adopted by the energy model to account for variation in product use is provided in the following sections.

External environment

The energy consumption of some products will be affected by the external environment, for example the energy consumption of an AC unit is affected by the ambient temperature. The effect of the external environment can be considered in the energy model either as a model input by collecting data on the environmental factor as telemetry data or by building in assumptions of the external environment in the energy model. For example, a product energy consumption that is affected by temperature could model different energy consumptions according to the average ambient temperature by region and time of year where each device is in use. The different energy consumptions by ambient temperature would be established via analysis or lab testing.

Including the effect of the external environment on energy consumption as a model input is likely to result in greater accuracy but will increase the complexity of the energy model, therefore, the significance of the impact from the external environment should be considered when deciding on an approach.

4.2.3. Energy modelling parameters

Telemetry data from active devices will be collected and used as input parameters for the energy model. Collecting telemetry data relating to the activity of devices in use is fundamental to this specification for calculating product energy consumption and therefore its use-phase GHG emissions. Therefore, organisations will need to ensure that the relevant systems are in place to collect, process, store and manage telemetry data collected from devices and ensure compliance to national and international data privacy, collection, and processing regulations.

Organisations will need to identify the most suitable type of telemetry data relating to the activity of devices to be collected in conjunction with their selection of the energy modelling approach and additionally consider other data that may be necessary to be collected (such as information about the device, location of use, etc.). Organisations are likely to have different telemetry data available to them so the selection of suitable data will be largely based on what data is accessible. The basic principle adopted is that any telemetry data used to calculate a product's use-phase energy consumption and GHG emissions will be more accurate than assumptions of device energy consumption extrapolated over a lifetime. Further guidance on the types of telemetry data that could be used is provided in the energy modelling approaches section via the examples discussed and also in data collection section.

As referred to above, the selection of suitable telemetry data for the energy model will likely be unique to the product being modelled, and therefore there is a large variety in the parameters that could be used in the energy model. The parameters that provide information about the product use and external environment that have an effect on the device energy consumption can be direct or indirect parameters. Direct and indirect parameters describe the type of relationship the parameter has with the power consumption of the device. Other telemetry data may also be necessary to collect, such as information on the product specification, or device location during use.

Direct parameter

A parameter that has a direct relationship with the power / energy consumption so that in the event of variable power consumption (induced by product use or external factors) the measured parameter will directly reflect all variations. Direct parameters have established mathematical relationships with power / energy consumption.

Examples

Current and Voltage	A device measures current and voltage used to power a component. ***Power = current x voltage.*** If product use or external factors change causing an increased demand on the component the current to the component increases. Therefore, the parameters of current and voltage directly represent the power consumption of the component.
Fan / pump speed	A device measures the fan / pump speed over time. The component has defined power consumptions for different speeds provided by the manufacturer. As the component speed is adjusted the variable power consumption can be accounted for.

Direct parameters are relevant when calculating energy consumption of each component within a product. The direct relationship is between the parameter and the component, the parameter does not necessarily have a direct relationship to the total device energy consumption as this can be affected by the other components and interactions between components. The device energy consumption is then the sum of all of the component energy consumptions.

Indirect parameter

A parameter where a relationship with power consumption can be determined within certain conditions, but the relationship is an estimation, and it is often based on correlation. These parameters do not accurately represent the variable power consumption of the device and as such are not accurate under all operating conditions. However, the error can be reduced by careful consideration of the measured parameters, aligning the energy model to the specific usages of the product, or advanced modelling practices. Indirect parameters are often used to calculate the total device energy consumption rather than calculating individual component energy consumptions.

Examples

Energy state	A device measures the residency time in different energy states of the device (e.g. standby, low use, high use) and calculates the energy consumption based on a specified average power consumption for each state. As the average power consumption for the energy state is static it does not represent variable power consumption that can be induced by the user or the external environment. However, if the specified power consumption for each energy state can be closely aligned to specific operating conditions it can be reasonably accurate.
CPU utilisation (%)	A device measures the CPU utilisation over time to calculate energy consumption of a product. While the CPU utilisation accurately represents the power consumption of the CPU it does not account for the other components. Therefore, while there is significant correlation with the device energy consumption and variable power consumption it is not necessarily accurate. The energy model can consider multiple parameters to improve its accuracy.

Summary

Both types of parameters can be used to calculate device energy consumption. Using direct parameters is typically preferable as it can result in higher accuracy of measurements[4]. However, this approach may not always be suitable as it can be more resource intensive and therefore more costly. Using indirect parameters can be more accessible for organisations and may be easiest to apply to devices already in circulation. It is likely that many organisations will use a combination of both direct and indirect parameters.

4.2.4. Energy modelling approaches

Modelling a product's energy consumption can adopt many different approaches. Selection of the most suitable approach will be determined by several factors including the type of telemetry data available, the product's energy consumption characteristics (e.g. static or highly variable), factors that affect the product energy consumption, and the data collection, processing, and modelling capabilities of the organisation. Consequently, the energy modelling approach selected is likely to be unique to the organisation and may also vary according to the product.

This guidance section includes some typical approaches used for energy modelling and considers their strengths and weaknesses which is intended to support organisations in the selection and appraisal of their own modelling approach. These examples are also used for illustration of concepts throughout the guidance.

The typical approaches include example telemetry data, explanation of reference data needed, a review of the strengths and weaknesses of the approach, and commentary on the suitability of the approach for different products. It is the intent of this specification to allow organisations the flexibility to select and develop their own energy modelling approach due to their different telemetry data availabilities and capabilities, as such, these approaches are to offer guidance and are not mandated for use. The examples presented are:

[4] It is noted that direct parameters will not always results in more accurate measurement.

a. A regression model with different parameters based on hardware activity
b. An energy state model based on measurement of time in each energy state
c. Measurement of component energy consumptions model

Energy modelling approach example	
(a) A regression model with different parameters based on hardware activity	
Description:	The product energy model is determined via a regression model based on multiple direct/indirect parameters of hardware activity
Telemetry data:	The energy model can utilise any direct/indirect parameter relating to hardware activity that has a significant effect on energy consumption and that can be measured. For example: • CPU utilisation (%) • Disk transfer rate (MB/s) • WiFi throughput (Kbps) • Screen brightness (%) This data is collected as a time series over the reporting period from each device so that the total energy consumption can be calculated. In addition, other information is also necessary to be collected: • Device model (hardware specification) • Software version • Location of use Note: In this example that location of use is also collected as a time series only for the GHG emissions calculation and not in the energy model, however, in products that are affected by external environment factors it may be an input to the energy model.
Reference data:	Data will need to be collected via lab testing on all of the hardware activity direct/indirect parameters under specified representative test scenarios to establish both a model training dataset and a model testing dataset to evaluate the model. Each possible configuration of the hardware and software (product variant) must have a relevant training and testing dataset. This necessitates collecting training and testing datasets data for each product variant, or by grouping several similar variants to use the training and testing datasets collected for one variant.
Energy modelling	The energy model calculates the energy consumption of each device using the defined data inputs (e.g. CPU %, disk MB/s, WiFi Kbps, Brightness %) applied to the energy relationship specified for the device model over the time period. Where there are multiple product variants the energy model contains multiple energy relationships, where each relationship is defined from regression testing.
Strengths and weaknesses of approach:	• The energy model can be constructed to measure telemetry data of key parameters that are closely related to energy consumption of the product. While these parameters individually do not directly represent the product

	energy consumption, the combination of multiple parameters together can be an accurate method of estimating energy consumption. • The accuracy of the energy model is highly dependent on the reference data collected to train the regression model. The lab test scenarios used to collect the training dataset need to adequately represent the usage of the product by users. • The energy model only accounts for energy consumption factors that are identified and measured and is therefore susceptible to significant factors not being identified and considered in the model, resulting in inaccuracy.
Energy model considerations:	• A regression model requires a sufficient amount of high-quality data to create the training dataset which may be resource intensive to collect. • The number of different lab test scenarios necessary to establish a suitable training dataset will depend on the different usage intensities of the product. The testing should consider how the product is likely to be used in all scenarios and consider a full range of usage intensities from low to high. • Energy model evaluation is essential for a regression model as it is necessary to ensure the model is robust and performs well on unseen test data.
Suitability of approach:	This modelling approach is suitable for most product categories but is particularly suited to more complex products consisting of multiple hardware components affecting energy consumption, or products with a diverse range of usage profiles and intensities.

Energy modelling approach example	
(b) An energy state model based on measurement of time in each energy state	
Description:	The product energy model is determined by establishing different energy states for the product and defining an average power consumption in each energy state. Telemetry data is collected from the indirect parameters of time spent in each energy state to calculate the total energy consumption.
Telemetry data:	This energy model approach requires telemetry data for: • Energy state (#) • Time in energy state (s) In addition, other information is also necessary to be collected: • Device model (hardware specification) • Software version • Location of use Note that location of use is also collected as a time series, however, it is used for the GHG emissions calculation and not in the energy model.
Reference data:	The average power consumption of each energy state needs to be defined by lab testing to be used by the model to calculate total energy consumption. Lab testing measures the power consumption of the product under specified representative

	test scenarios for each energy state to establish a suitable average power consumption for each. An average power consumption for each energy state must be defined for each possible configuration of the hardware and software (product variant). This necessitates collecting lab test data for all product variants, or by grouping several similar variants to use the average power consumptions defined for one variant.
Energy modelling	The energy model calculates the energy consumption of each device by totalling the energy consumed in each energy state. The total of each energy state is calculated from the average power consumption of each energy state for the specified product variant and the total time in each energy state over the time period. The product variant is defined by the device model and software version of each device (in some cases there may only be one product with no variants). This calculates the total energy consumption for the product / specified product variant over the time period.
Strengths and weaknesses of approach:	• The energy model can be relatively simply constructed based upon lab test reference data without complex analysis or modelling. • The accuracy of the energy model is wholly dependent on the average power consumption defined for each energy state, therefore, the energy states should have low variability of power consumption within each state. • By using average power consumption, the energy model is less accurate when representing products that have continuously variable power consumption or those products that do not have discrete energy states / usage intensities. • Modelling a large number of product variants can require a significant amount of lab testing to define average power consumptions for each energy state of each variant. Alternatively, if grouping of product variants is used to reduce the necessary lab testing, the variants should have similar energy consumptions under the specified test scenarios.
Energy model considerations:	• The energy states must be selected appropriately to consider the different usage intensities of the product and ensure that the average power consumption is a reasonable representation of actual power consumption. • Increasing the number of energy states can increase the accuracy of the model and reduce variability between the calculated average power consumption and actual power consumption. • The power consumption dataset for each energy state needs to be collected from test scenarios that accurately represent the usage and usage intensity of the product by consumers in each state. • Induced power consumption that can occur from activities selected by users (e.g. running 3rd party software, using connectivity, etc.) or due to configurable or adaptive settings (e.g. screen brightness) should be considered in the model. This will require the average power consumption testing of the energy states to include all activities that can induce power consumption.

	• Energy model evaluation is essential for an energy state model as it is necessary to ensure the model is robust and to understand the uncertainty of the model against actual energy consumption.
Suitability of approach:	This modelling approach is particularly suitable for products that operate in very defined states (e.g. on/off/standby) and have very consistent power consumptions in each of the states.

Energy modelling approach example	
(c) Measurement of component energy consumptions	
Description:	The product energy model is determined by totalling the energy consumptions estimated/calculated for each individual component. The energy consumption of each component can be estimated/calculated from either indirect or direct parameters.
Telemetry data:	The energy model can utilise any parameter that has a significant effect on energy consumption that can be measured. Direct parameters are preferred as they can accurately calculate energy consumption whereas indirect parameters can only estimate the energy consumption. For example, a product consisting of 10 energy consuming components may have 2 components that demand 95% of the power. The energy model could be constructed as: • Component 1 – Fan: Fan speed (Direct parameter) • Component 2 – Heating element: Current and voltage (Direct parameters) • Components 3-10 – Electronic controls, circuit boards, etc.: Time in use (Indirect parameter to estimate energy consumptions) This data is collected as a time series over the reporting period from each device so that the total energy consumption can be calculated. In addition other information is also necessary to be collected: • Device model (hardware specification) • Software version • Location of use Note that location of use is also collected as a time series, however, it is used for the GHG emissions calculation and not in the energy model.
Reference data:	• The energy consumption relationship with fan speed is likely provided by the component manufacturer or could established via lab testing. • No reference data is needed to calculate the energy consumption of the heating element as P=IV. • The average power consumption of each of the remaining components while in use needs to be defined by lab testing to be used by the model to calculate total energy consumption. The device model data defines the average power consumption used to calculate energy consumption from time in use for each device model.

Energy modelling	The energy model calculates the energy consumption of each device by totalling the energy consumptions calculated for each component. Some estimation may be included to account for systemic losses that consumes energy between the components. In this example, the energy consumption of the fan is calculated from the fan speed over the time period using the fan's energy consumption relationship which is determined by the device model. The heating element energy consumption is calculated from the power consumption over the time period (P=IV). The remaining components energy consumption is calculated by applying the average power consumption for the specified product variant for the recorded total time in use. The product variant is defined by the device model and software version of each device (in some cases there may only be one product with no variants).
Strengths and weaknesses of approach:	• The energy model can have a high accuracy when direct parameters are used to calculate energy consumptions from the highest energy consuming components. • As the energy model assess each component individually the effort can be significantly increased for products with many components. • Using indirect parameters to estimate component energy consumptions does not consider the system effects of interaction between the components which can be significant. • When only some component energy consumptions are considered by the energy model, estimation is required to calculate the total energy consumption. • The principles for accuracy and reliability apply to all modelling approaches, including component level modelling. Component level modelling can, for some components, introduce errors and decrease the reliability of the model which should be considered when selecting a modelling approach.
Energy model considerations:	• The highest energy consuming components should use direct parameters where possible. If this is not possible, other modelling methods may be more suitable. • Where indirect parameters are used in the energy model the estimation approach could replicate the approaches in examples (a) a regression model or (b) an energy state model. • Energy model evaluation can be minimised where direct parameters are used for significant components as it can result in little or no estimation. • Estimation may be necessary to calculate total energy consumption to account for losses between the components.
Suitability of approach:	This modelling approach is particularly suitable for products that have a few components that constitute a significant majority of the products power demand and that are suitable for direct measurement of the energy consumption. The approach is less suited to products with a large number of energy consuming components as the computational resource to collect the necessary quantities of data can be significant.

4.2.5. Modelling variable power consumption

Device users can often select various tasks or operations to be performed by the device, such as running 3rd party software on a laptop or by selecting a quick freeze function on a refrigerator. The energy model needs to account for the effect of variable usage intensity inducing changes to the power consumption of each device. This guidance includes two methods that can be used to model variable power consumption of a device:

- Collecting telemetry data of parameters either directly or closely related to energy consumption of the product so that any variation in usage intensity is assessed through collected data.
- Defining discrete operational states of the product representing different usage intensities and collecting telemetry data on the operational state of each device.

Collecting telemetry data either directly or closely related to energy consumption of the product is illustrated in example approaches (a) A regression model with different parameters based on hardware activity and (c) Measurement of component energy consumptions model. In both of these approaches the calculated total energy consumption can account for variable power consumption if the approach is implemented correctly.

The regression model will be more accurate in accounting for variable power consumption of each device if

- the hardware parameters measured have been correctly selected as those that have a significant impact on energy consumption, and
- the model has been trained sufficiently on a dataset representing the full spectrum of possible usage intensities.

The component energy consumptions model will be more accurate in accounting for variable power consumption if

- the component energy consumptions calculated have been correctly selected as those that typically form the significant majority (e.g. 95%) of the product energy consumption, and
- the component energy consumptions that form the significant majority of product energy consumption are calculated using direct parameters.

Defining discrete operational states of the product representing different usage intensities is illustrated by example (b) An energy state model based on measurement of time in each energy state. This approach requires

- the energy states selected adequately represent the full range of usage intensities of the product,
- the actual power consumption range of each energy state is small and can be reasonably represented by a single average power consumption, and
- the average power determined for each energy state to consider the impact of configurable or adaptable settings on power consumption.

To ensure the energy states selected represent the full range of the product usage intensities the states should include a maximum and a minimum energy state, where each represents the maximum and minimum power consumptions possible for the product. The number of energy states required between the maximum and minimum energy states will be defined by the possible modes of operation between these states. Where specific operations are known to significantly affect power consumption, e.g. streaming, the energy states selected should ensure that the operation is accounted for. To define suitable energy states different modes of operation should be identified, for example:

TV Set top box

Energy state
Standby
Low-power mode
Digital / Streaming

Endpoint device

Energy state
Standby
Low-power mode
Music streaming
Voice assistant
Internet search
Other applications

Washing machine

Energy state
Cycle 1
Cycle 2
Cycle 3
Cycle 4

The average power consumption for each energy state needs consideration configurable or adaptive settings, such as, screen brightness. Where a setting such as screen brightness affects multiple energy states, it may be possible to assume a variance of x% determined through lab testing. Any estimations should aim to minimise the error as far as practical and should define a conservative upper bound power consumption for each energy state.

4.2.6. Modelling multiple product variants

Multiple product variants can drive complexity in the energy model and increase the resources required to collect, process, and store data and compute the energy model. As demonstrated by the example modelling approaches, a high number of product variants can increase the amount of lab testing required to collect reference data and can result in a complex energy model to be able to assess each variant. Some product variants may be similar to another variant, or a variant may be so few in number that individually assessing these product variants will not result in a significant improvement in accuracy of the model. Therefore, organisations may choose to group product variants together where appropriate to reduce the resource necessary to construct and compute the energy model.

This is termed *product variant grouping* and refers to several product variants with different energy/power consumptions being modelled by one specific variant. Organisations will need to demonstrate that the grouped product variants have similar energy/power consumptions and thus are fairly represented by a single variant.

It may be suitable to apply product variant grouping when there are very few devices of a particular variant. For example, the product variants may be determined by different hardware configurations of CPU, GPU, screen size, disk size, and operating system. If a particular variant has a unique disk size and doesn't have a sufficient number of active devices, this variant could be grouped with other product variants for a similar disk size with a sufficient number of active devices in the group.

Note, product variant grouping is optional and may not be necessary to be applied. There may be no product variants of the product or the energy modelling approach doesn't require variant grouping.

4.3. Data Collection

Reminder: *Active devices* are devices that are in use during the reporting period

4.3.1. Telemetry data

Data privacy

- Organisations shall adhere to the data privacy principle (section 1.8) at all times.
- Organisations shall adhere to all national and international regulations related to data privacy.

Coverage of the reporting period

- Data shall be collected from active devices for the full duration of the selected reporting period, extrapolation shall not be used to extend temporal coverage over the reporting period (i.e. data cannot be extrapolated from 6 months to represent 12 months).

Parameters for device energy consumption and GHG emissions calculation

- Telemetry data related to the energy / power consumption of the product shall be collected from devices to be used in the energy consumption model and be able to assess:
  - Device usage frequency (e.g. time in use / frequency of use / other parameters collected as a time series)
  - Device usage intensity (e.g. direct/indirect parameters relating to energy consumption of the device)
- Telemetry data shall be collected on the product specification (hardware and software configuration).
- Telemetry data shall be collected on the number of active devices throughout the reporting period (termed *number of active devices*).
  - Active devices should include all devices in use by customers and are not limited to the number devices from which the organisation can receive telemetry data.
  - Active devices should include the number of devices that are in use and not transmitting data, for example, where users have selected not to share their data, or the device isn't enabled with the necessary telemetry to record and transmit usage data.
  - Where it is not possible for the organisation to record the number of devices not transmitting data but estimated to still be active, organisations may only calculate and report energy consumption and GHG emissions for connected devices (although it is recommended to include for all) and, in addition the organisation:
    - Shall include a clear statement alongside all communications that the reported totals only represent devices where they are receiving data and does not include devices where data has not been shared.
    - Should report the percentage of total devices from which data is received as a proportion of total estimated number of active devices (from those ever sold).

    - Shall explain how these GHG emissions are accounted for and reported elsewhere by the organisation.
  - The number of active devices will vary throughout the reporting period and shall be assessed at a minimum on a monthly basis. For example:
    - A daily total logging the number of devices in use each day
    - A daily / weekly / monthly average of active devices
- Telemetry data shall be collected on the geographic regions where the active devices are in use to accurately calculate the resulting GHG emissions using a geographically relevant emission factor. Where individual devices are able to be used in multiple geographic regions throughout the reporting period the organisation should record data per geographic region where use occurred.

4.3.2. Telemetry data sampling

Box 4: Data sampling

The energy consumption for the product is the total energy consumption of active devices across all product variants. It may not be possible or practical for organisations to collect data from all active devices due to the high volume of data that would need to be stored and processed. In this case, data sampling may be used, and the energy consumption of the sample extrapolated to the total number of active devices.

Data sampling shall not be used within the data collected per device, i.e. data samples from one device, as this would contravene requirement 4.3.1 Coverage of the reporting period.

Where data sampling is used:

- Data shall be collected on the number of devices from which telemetry data is collected (termed *number of sampled devices*)
  - The number of sampled devices may vary throughout the reporting period and should be monitored at a minimum on a monthly basis and on the same monitoring frequency as the number of active devices.
- The sampling rate shall be calculated by the equation below and on the same frequency as monitoring of the number of sampled and active devices.

$$Sampling\ rate = \frac{Number\ of\ sampled\ devices}{Number\ of\ active\ devices}$$

- The minimum sampling rate is dependent on the number of active devices:

Table 2: Minimum sampling rates

Number of Active Devices	Minimum Sample Size	Minimum Sampling Rate
10	10	100%
100	80	80%
1,000	278	28%
10,000	371	4%

50,000	383	1%
100,000	384	0.4%
1,000,000	385	0.04%

- Where product variant grouping is used, each product variant group shall have a data sample and the minimum sampling rate above applies to each product variant group.
- The sample should be random and representative of the total number of active devices of the product or product variant group.
- Where possible, telemetry data of the geographic region where use occurs should be collected from all active devices (i.e. no data sampling) as the total number of active devices per geographic region is required to allow extrapolation of the data sample to the total number of active devices per geographic region.
  - Where this is not possible, telemetry data shall be collected for geographic regions where a significant number of devices are in use.
- Data sampling shall not be used when collecting data on the number of active devices throughout the reporting period. This shall be collected from all active devices according to the requirements in section 4.3.2.

4.3.3. Telemetry data aggregation

Box 5: Data aggregation
To minimise data transfer and storage from the device to the data platform, it may be necessary to aggregate data on the device for the time period when data is collected. For example, a device collecting time spent in each energy state may report a daily or weekly total instead of reporting a continuous time series of data. Similarly, this may be suitable for products that calculate the energy consumption on the device.
Note: Organisations may choose not to aggregated data or to aggregate data at a more granular level to provide insights into product redesign to reduce energy consumption.

Where data aggregation is used:

- Aggregation shall only consider sum totals and not employ averaging or other kinds of transformation that could skew the data.
- Aggregation across the reporting period can have a maximum aggregation per month, i.e. data shall be collected at a minimum of a monthly basis and not quarterly or larger aggregation periods.
- Where aggregation occurs across multiple devices, data shall be aggregated separately for:
  - any product variant groupings applied, and
  - each geographic region where use has occurred.

4.3.4. Reference data

Box 6: Reference data
Reference data is necessary to calculate the product energy consumption from the telemetry data collected from devices. As shown in the examples in 4.2.4, reference data may be obtained from lab testing or may be alternative sources, such as proxy data provided from a suitable substitute product or from research.

Where lab test data is used its collection shall meet the following requirements:

- Standardised test scenario(s) for the lab test shall be used which shall be described in the energy model documentation.
- The test scenario(s) shall simulate representative conditions for the product use and external environmental factors that have an impact on device energy consumption.
    - This is highly significant where average power consumptions are being defined via lab testing for specified energy states. The test scenario(s) used shall accurately represent the defined energy state and shall account for induced power consumption from product use or the external environment possible in the specified state.
    - Similarly, where a regression model is used the training dataset shall be generated from test scenario(s) representing a full range of usage intensities of the product from low to high to account for induced power consumption from product use or the external environment. Several different test scenarios are likely to be required to adequately represent all likely usage scenarios and intensities.
- The lab testing scenario(s) and test conditions shall be documented and justified as representative of product use and external environment factors that have an impact on device energy consumption.
- The number of devices tested should be statistically significant to ensure reliability of the test results.
- Lab test data can be collected by the organisation or a third-party (e.g. a component manufacturer).

Where alternative sources are used its collection shall meet the following requirements:

- Alternative sources acting as a proxy for the product, such as lab test data from similar products or similar product research, shall be justified to show that it is suitable proxy for the product.
- Alternative sources shall not introduce significant uncertainty or error into the energy model
    - Organisations shall define and report their selected measure of significance, and introduced uncertainty or error, where alternative sources are used.
- Alternative sources or proxy data shall not be used to estimate the total product energy / power consumption (for example, using industry average power consumption for a device while recording time in use).

4.3.5. Data quality and uncertainty

- Organisations shall assess the quality and the uncertainty of the data used in the calculation.
  - A quantitative or qualitative assessment shall be carried out to assess the robustness of the data being received from the device. Existing guidance from product footprinting standards (e.g. Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard) for assessing data quality and uncertainty should be used.

4.4. Energy Modelling Requirements

Box 6: Energy modelling guidance

Section 4.2 Energy Modelling Guidance provides information and context to support these requirements, please review / refer to this section throughout.

Reminder: The product energy consumption is the total energy consumption of all active devices and attributable products. Data sampling may be used to calculate the energy consumption from a limited number of active devices and the total energy consumption of the sample must be extrapolated to total number of active devices.

The device energy model may be carried out by each device or in an external energy model once the measured data has been collected from devices.

4.4.1. Device energy model

- Organisations shall identify a suitable energy modelling approach to calculate device energy consumptions considering the guidance provided in section 4.2.
- To establish a device energy modelling approach organisations shall:

1. Identify all factors that affect product energy consumption
2. Define how the energy model will assess or control for each factor
3. Construct the energy model

Step 1: Identify energy consumption factors

- The device energy modelling method needs to identify the energy consumption factors that can significantly affect the energy consumption of the product. The energy consumption of each product will be affected by different factors and organisations shall identify all factors that can affect the energy consumption of the product.
- Once identified, all energy consumption factors of the product (including all product variants where applicable) shall be documented including descriptions of how these factors relate to the three characteristics that affect energy consumption (product specification, product use, and external environment)

Step 2: Define how the energy model will assess or control for each factor

- All identified energy consumption factors shall be reviewed and all factors deemed to significantly affect energy consumption of the product shall be represented in the energy model by telemetry data or reference data.
- Organisations shall define and report their selected measure of significance and means of assessment.
- Factors identified to affect energy consumption of the product that are excluded from the energy model on the basis of significance shall be reported and the significance assessment documented.
- Telemetry data shall be used in the energy model to assess energy consumption factors associated with product use, the energy model shall be able to account for device usage frequency and device usage intensity, therefore, the telemetry data shall include direct parameters, indirect parameters, or both (section 4.2 should be referred to during its selection).
    - All telemetry data used in the energy model shall be documented including what energy consumption factors the data assesses and how it will be used in the energy model.
    - There is a preference for direct parameters over indirect parameters as direct parameters typically measure energy consumption of the product more accurately. Where it is not possible to use direct parameters, the organisation shall select indirect parameters that should be the most correlated to energy consumption that they can feasibly measure and minimise error between the calculated and actual energy consumption of the product.
- All reference data used in the energy model shall be documented including a description of:
    - What energy consumption factors the reference data assesses
    - How the reference data is used in the energy model
    - How it is obtained (e.g. lab testing, from research, or other alternative sources)

Step 3: Construct the device energy model

- The device energy model shall represent the energy consumption of a device or multiple devices using the selected telemetry and reference data. (It is not required to represent the energy consumption of all active devices as extrapolation can be applied later)
- The energy model approach (e.g. a regression model) shall be documented and describe the method used to compute the device energy consumption from the telemetry data and reference data inputs, including any assumptions used supported by justifications as necessary. The methodology shall describe how all of the identified use-phase energy consumption factors have been addressed by the energy model.
- The energy model approach documentation shall demonstrate how the device energy model accounts for all factors that can significantly affect the energy consumption of the product, it shall include reference to:
    - **Product specification** – Where a product is available in multiple product variants (configurations resulting in different specifications of devices – see section 4.2.2) the energy model shall be able to represent the energy consumption of all variants.

    - The different product variants represented by the model shall be documented including a description of how the energy model accounts for all different configurations of hardware and software.
    - Where product variants are grouped (see section 4.4.2) the modelling method for each group shall be documented.

- **Product use** - The model shall be able to represent the energy consumption according to the usage frequency and usage intensity of the product. It is not acceptable to model energy consumption of the product based on idle power consumption.
    - The energy model shall be able to account for the effect of different operational modes and/or variable tasks inducing power consumption. Induced power consumption can occur from activities selected by users (e.g. running third party software, using connectivity, etc.).
    - If any configurable or adaptable settings can significantly impact energy consumption, then these shall be accounted for in the model. If telemetry data cannot be collected from devices of the settings configuration, then any assumptions of their settings in the energy model shall be documented.
    - Organisations shall document the potential different modes of operation of the product including descriptions of the possible usage intensities in each mode and variable tasks that can induce power consumption. The documentation shall specify how each mode and any induced power consumption is assessed in the energy model.
    - If any modes of operation or tasks that can induce changes in the device power consumption are not accounted for in the energy model, the expected variance in energy consumption and its significance to the device energy consumption shall be assessed and reported.
- **External environment –** The model shall be able to represent the product energy consumption in the environment where it is being used. If external environment factors have been identified to significantly affect the energy consumption of the product these effects shall be included in the energy model.
    - The method to assess any significant external environment factors in the energy model shall be documented.
    - If telemetry data cannot be collected from devices of the external environment, then organisations should collect or identify suitable reference data to assess the effect of the external environment factor and document any assumptions used in the energy model.
    - Where environment factors are not accounted for in the energy model with either telemetry data or reference data, the expected variance in energy consumption and its significance to the device energy consumption shall be assessed and reported.

4.4.2. Product variant grouping

Where product variant grouping is applied (see guidance in section 4.2.6) the following requirements shall be met:

- Product variant groups are defined by the average power consumption of the product variants determined from their operation under a pre-defined standard test scenario.
  - Estimation of average power consumption of each variant shall be modelled or defined from lab testing using a standard test scenario that is consistently applied for all product variants assessed.
  - The standard test scenario for the modelling or lab test shall be described in the energy model documentation and shall include a justification of its representativeness of typical use of the product.
  - Lab testing and / or energy modelling to validate the grouping is not required for all variants in the group but should be carried out for the highest, the second highest, and the lowest energy consuming variants of the group, based on prior energy consumption estimation.
- Product variants should be grouped when the variance of average power consumption is within a 5%-10% range, where 5% is best practice.
  - If product variants are grouped with variance higher than 10%, then justification shall be provided for why the grouping is necessary.
  - Grouping of variants larger than 10% variance is only acceptable where a significant number of variant groups would create excessive workload to individually model and manage.
- The energy consumption calculation for the product variant group shall use the highest average power consuming variant of the group.
  - Using the highest average power consuming variant incentivises organisations to group variants accurately to minimise total device energy consumption but allows grouping to practically manage resources.
  - A reasonable balance shall be determined between the number of groups and accuracy of the calculation. Too many groups will generate excessive workload, data processing and storage, however, too few groups may result in inaccurate energy consumption calculations.

4.4.3. Energy model evaluation

Box 7: Energy model evaluation
Energy model evaluation is an assessment of the energy model’s ability to represent the product energy consumption by considering the difference between actual data collected from devices tested in representative use scenarios and the model’s predictions.

Model evaluation is necessary for all models, but the level of evaluation necessary is linked to the complexity of the energy model. The number and type of parameters used in an energy model is indicative of its complexity and models of higher complexity are likely to require more evaluation effort to simpler models.

Evaluation shall meet the following requirements:

- The device energy consumption output from the energy model shall be compared to the device energy consumption measured via lab testing when the model and lab testing are simulating the same test scenario(s) representing product use by customers. It may be necessary to use multiple test scenarios to simulate a full range of conditions representative of customer use.
- The test scenario(s) shall simulate conditions for the factors identified to affect energy consumption that are representative of a full range of expected customer use. They shall include variable tasks, modes of operation, and settings that can be selected the user or are adaptive which can induce a change in power consumption.
- The test scenario(s) applied to the energy model and lab testing shall be documented in the energy model documentation including:
    - The test procedures and test conditions describing the different operations and usage intensities over a defined time period.
    - Justification of the test scenarios representativeness of customer use considering all factors identified to affect energy consumption of the product.
- Organisations shall carry out a statistical evaluation to compare the energy consumptions predicted by the energy model output with the lab test results from the test scenario(s) and report their conclusions or a third-party's conclusions on the accuracy, error, or uncertainty of the model.
- Where multiple product variants exist the energy model evaluation should be repeated for a sample of the product variants that have the most significance to the total product energy consumption (i.e. considering number of variants sold).

4.4.4. Attributable products energy model

- The energy consumption from attributable products (defined in section 3.3.1), such as power adaptors, shall be included in the total product energy consumption.
- The calculation approach shall be suitable to the attributable product and the materiality when compared to the energy consumption of the device.
- Calculating energy consumption of attributable products can be achieved by:
    - Applying a fixed loss percentage increase to the total energy consumption of the product
    - Calculating the attributable product energy consumption as an additional base load
    - Another approach specified by the organisation
- Where the total energy consumption of the attributable product is significant and shows considerable variability, this may require detailed energy modelling based on lab testing.

Box 8: Determining a suitable approach for modelling energy consumption of a power adaptor

Power adaptors show higher losses under low device power consumption, therefore, applying a fixed loss approach would be suitable for products that have small variations in power consumption. For products with highly variable power consumption the power adaptor energy consumption could be estimated by considering a suitable average power consumption (e.g. the power rating stated by the manufacturer) and applying this as a constant additional base load.

4.4.5. Product use-phase energy consumption

- The product use-phase energy consumption shall be calculated from the total energy consumption of all active devices and any attributable products occurring within the selected time boundary.
- The product use-phase energy consumption shall be calculated separately for each geographic region where device use has occurred (to allow for GHG emissions calculation by geographic region).
- Where telemetry data is collected for all active devices and the device energy model computes the energy consumption for all active devices, the total product use-phase energy consumption is the sum of all the active device energy consumptions and the attributable products.

$$Product\ use\ phase\ energy\ consumption_{Mkt} = \sum active\ device\ energy\ consumption_{Mkt} + \sum attributable\ product\ energy\ consumption_{Mkt}$$

- Where data sampling has been used (refer to section 4.3.2) to collect telemetry data from a sample of active devices, the total product use-phase energy consumption is the energy consumption of the sample extrapolated to the total number of active devices and the energy consumption of attributable products.
    - Extrapolation shall be achieved by calculating an average energy consumption per device from the sampled data and multiplying this by the total number of active devices.
    - Where product variant groups are used, then extrapolation shall be done for each group individually.

$$Product\ use\ phase\ energy\ consumption_{Mkt} = \left(\frac{sampled\ device\ energy\ consumption_{Mkt}}{number\ of\ sampled\ devices_{Mkt}}\right)\ x\ number\ of\ active\ devices_{Mkt} + \sum attributable\ product\ energy\ consumption_{Mkt}$$

4.5. GHG Emissions Calculation

The GHG emissions calculation shall meet the following requirements:

- The product use-phase GHG emissions for the reporting period shall be calculated from the calculated total product use-phase energy consumption including the product and the attributable products (where applicable) by applying relevant emission factors to convert the energy consumption (Wh) into CO_2 equivalent (CO_2e).

- GHG emissions shall be calculated for each device according to the location-based electricity emission factor relevant to the geographic region where device energy consumption is known to have occurred. As per the Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard, "*companies should select electricity emission factors that are geographically specific to the electricity sources used in the product inventory*".
    - In case a device energy consumption occurs in multiple geographic regions throughout the reporting period the organisation should calculate the GHG emissions according to each geographic region where consumption occurred, however, calculation according to the primary geographic region of use is acceptable where multiple geographic region calculations are not feasible.
- Location-based electricity emission factors are the electricity grid emission factors for a specified geographic region published by a national or international body such as those published by governments or the International Energy Agency.
    - Electricity grid emission factors for a specified geographic region are typically a single annual emission factor for the whole region. Where more granular grid emission factors are available/become available, such as hourly location-specific emission factors, organisations are encouraged to develop their modelling approach for their use to improve accuracy of the GHG emissions calculation.
    - Where the reporting period spans multiple time periods of electricity grid emission factors (e.g. the reporting period spans across two years of annual grid emission factors) the GHG emissions shall be calculated according to all relevant time period emissions factors.
- Electricity emission factors shall account for GHG emissions arising across the full life cycle of the electricity supply system including emissions resulting from generation, transmission and distribution losses, and well-to-tank activities (such as extraction, refining, transport, etc.). This may require the use of several emission factors.
- Electricity generation only (direct) GHG emissions shall be calculated with electricity emission factors in compliance with the location-based method emission factor hierarchy as specified in the Greenhouse Gas Protocol Scope 2 Guidance.

5. Demonstrating Energy Reductions

5.1. Introduction

Reducing energy consumption is currently the only mechanism that organisations can use to reduce the use-phase GHG emissions impact of their products (a future alternative is to reduce the emissions intensity of electricity grids). By collecting telemetry data from devices in use organisations can go beyond accounting and reporting of use-phase GHG emissions from their products throughout their lifetime and demonstrate the emissions reductions that occur as a result of energy efficiency initiatives they have implemented.

The energy efficiency of the product is one factor of many that determine the total product use-phase GHG emissions reported each year including, the length of time consumers are using the product each year (usage frequency), how they are using the product each year (usage intensity), the countries of use and their electricity grid emission intensities (CO_2e/kWh), and external environment factors that affect its energy consumption. Each of these factors can change year-on-year, therefore, the total use-phase GHG emissions reported is not a suitable indicator of improvements to the energy efficiency of the product. As a result this section is concerned with changes in the energy consumption of the product, to remove the variability of electricity grid emission intensities, and requires demonstration of the energy reduction in a lab test and from devices in use to control the effects of the different factors.

This section of the specification defines how organisations can demonstrate energy reductions of the product and how to estimate the resulting GHG emissions reduction. The intent is to encourage organisations to take action to reduce the energy consumption of their products through a robust mechanism for assessment and communication, ensuring transparency to consumers of any actions taken and the resulting GHG emissions reductions. This specification does not specify how energy reductions should be achieved.

5.2. Demonstration Approach

Energy reductions are assessed by comparison of the energy consumption of the product against a baseline that has been determined to represent the product without the energy saving feature(s). Demonstration of an energy reduction is achieved in two-steps. Demonstration of the energy reduction in a controlled environment and demonstration of the energy reduction in telemetry data collected from devices in use.

Demonstration of the energy reduction in a controlled environment allows for the effect of the energy reduction action(s) to be isolated and establish that the action(s) result in an energy reduction while other factors that affect energy consumption, such as product use and the external environment, are controlled. Lab testing is used to compare the energy consumption of the product against a baseline product under defined test scenarios.

Demonstration of the energy reduction in telemetry data collected from devices in use is then necessary to ensure that the energy reduction demonstrated in the controlled environment test is reflected in the actual use of the product. The energy reduction can be confirmed from devices in use by demonstrating that a reduced average power consumption expected for the product is achieved while the product is in use. The expected average power consumption in use for the product is defined during the controlled environment testing as a range of the best-case (minimum) to worst-case (maximum) average power consumption expected for the product. The actual average power consumption in use is calculated from the telemetry data collected from devices in use and compared to the expected range. Despite the variability of energy consumption of each device due to different product use and external environment factors that will be experienced by devices in operation, the in use *average* power consumption of the product calculated from active devices should be within the minimum and maximum limits.

5.3. Pre-requisite Requirements

To qualify as an energy reduction the reporting organisation shall demonstrate that the product meets applicable current energy efficiency standards.

5.3.1. Product energy efficiency

- The product shall conform with the most current version of existing energy efficiency standards applicable when the device was sold/leased and where standards exist for the product type. Examples of such standards are:
  - Energy Star (USA)
  - EU Energy Labelling Regulation (EU)
  - Energy Management System (EnMS) (Korea)

5.3.2. Maximum allowed power consumption per product type

- The product shall meet the maximum allowed power consumption for the product type where one is available as detailed in: Energy efficient products (europa.eu).

5.4. Energy Reductions Assessment

5.4.1. Actions taken to reduce the energy consumption of the product

- The organisation shall have taken action(s) which (cumulatively) achieve(s) reductions in use-phase energy consumption of the product.
- The action(s) taken shall be documented including detailed descriptions of the functional changes made, how the new functionality results in energy consumption reductions, the operational conditions necessary for the reduction to occur, and any conditions that can prevent the reduction from occurring.
- Standard practice energy saving functionalities shall be included in the product and cannot be claimed as energy reduction actions undertaken by the organisation.
  - Examples of this functionality could include a power off mode, low power mode, or network standby mode, and each organisation may use different terminologies to refer to them.
  - Actions taken to improve on a standard energy saving functionality should be considered as eligible, for example, if the energy reductions from low power mode were increased by

improving the speed at which the mode is activated, this should be considered as new functionality.

- What constitutes standard practice energy saving functionality will vary across different product types, will change over time, is subjective, and will require application of conservative judgement.
  - As an underlying principle, the functionality should not be considered by others in the relevant industry as standard for the product type in question.
  - Due to the breadth of products eligible for this specification, organisations should consider what functionality is standard for their product type and apply the conservative principle when assessing this criterion, i.e. assume functionality is standard in case of doubt.

5.4.2. Baseline selection

Box 9: Baseline selection
Selecting a baseline that is representative of the product without the energy saving feature(s) is essential and this specification allows for two different types of baselines, a comparator product, and a hypothetical baseline. This is in recognition that a comparator product may not always be available.

- An energy reduction claim may be awarded for achieved reductions based on comparison with the following baselines:

  (A) **Comparator product:** Reductions demonstrated against a qualifying comparable product (e.g. an earlier generation of the product or a similar product that has been replaced).

    - The product shall be readily substitutable for the comparator product and fulfil or exceed the functionality of the comparator product.
    - The product and comparator product shall not be concurrent versions that offer a different user experience (e.g. concurrent versions of a product with different screen sizes cannot be compared).
    - The comparator product does not need to be discontinued, although this may be used as justification of the comparator product as a previous version.

  (B) **Hypothetical baseline:** Reductions demonstrated against a calculated baseline of the same product configured without a specified energy saving feature.

    - The product shall be new without previous generations or versions that could be used as a comparator product (in these cases baseline A shall be used).
      - The product can be classified as new if previous generations or versions were not connected devices and could not communicate information about their use-phase activity.
      - A product can be classified as new for up to five years from introduction (after this time organisations are expected to have made further improvements to the product in which case baseline A is applicable).

- The baseline selected shall be documented and justified:
  - Comparator products shall be clearly described, the functionality compared to the product, and its ability for substitution explained. The comparator product technical specification should be publicly available.
  - Hypothetical baselines shall be clearly described including details of the functional difference(s) that are represented by the baseline and justified how these align to the functional changes introduced in the product (section 5.4.1).
- An average power consumption obtained from similar devices available on the market cannot be used as a baseline.

5.4.3. Reference unit

- A reference unit shall be defined to enable comparison between the product and the baseline energy consumptions.
- The reference unit shall be defined per device considering either:
  - Average power consumption (W) per device, or
  - Total energy consumption (Wh) per device

Note: Requirements for the test scenarios in Section 5.4.4 define how measurements of the reference unit are to be carried out for the product and the baseline.

5.4.4. Comparison in a controlled environment

- Lab testing shall be carried out to demonstrate the energy reduction that is achieved as result of functional changes made by a comparison between the product and the baseline.
- The testing shall compare the change in the reference unit between the product and the baseline under the same test conditions as shown in the example in Figure 4, under three test scenarios: a representative use-case, a best-case, and worst-case.

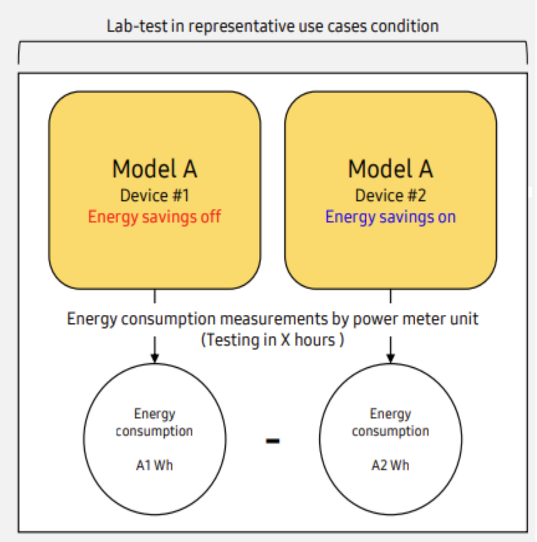


Figure 4: Controlled environment comparison testing using a hypothetical baseline

- Where a hypothetical baseline is used, the approach used to prepare a device for lab testing representing the hypothetical baseline shall be documented including details of how the energy saving functionality has been removed / turned off / etc.
- Testing shall be carried out on the final products as will be sold to consumers.
- The number of devices tested should be statistically significant to ensure reliability of the test results.
- Where product variants have been grouped, testing shall be carried out for each product variant group and consider the 'product' as the average product variant of the product variant group. The average product variant can either be:
  - A calculated average from test results of the highest and lowest power consuming variants of the product variant group. Or,
  - A single product variant that is representative of the average of the group, this shall be justified by supporting evidence.
- Test scenarios apply to the product or each product variant group (where used) and shall be designed to demonstrate:
  - The energy reduction between the product and the baseline with other energy consumption factors controlled as a representative use-case.
  - The energy reduction between the product and the baseline with other energy consumption factors representing best-case test conditions (i.e. the lowest energy consuming scenario).
  - The energy reduction between the product and the baseline with other energy consumption factors representing worst-case test conditions (i.e. the highest energy consuming scenario).
- The test scenarios shall use test conditions for the identified energy consumption factors that are representative of expected customer use in each scenario.
  - Test conditions for each test scenario shall be the same for the product and baseline tests.
  - Test conditions shall control for all identified energy consumption factors (section 4.4.1) that are not modified by the energy reduction action(s). Multiple tests may be requried to satisfy different energy consumption factors (e.g. if a product is affected by ambient temperature, multiple tests may be required at different temperatures).
  - Test conditions for the representative use case should define the controlled energy consumption factors to demonstrate the energy consumption a typical user would experience.
  - Test conditions for best- and worst-case scenarios should define the controlled energy consumption factors to demonstrate the maximum and minimum energy consumptions that users would reasonably experience that are representative of a full range of users. The usage shall include variable tasks, modes of operation, and settings that can be selected the user or are adaptive which can induce a change in power consumption.
  - Test conditions for the controlled energy consumption factors should be defined by primary data collected from the product (preferable) or similar products (also preferable), or by research.

- The test scenarios and their conditions shall be documented including the test procedures, an explanation of how the test conditions for each scenario is representative of customer use.
- For an energy reduction to be demonstrated the test results shall show:
    - A reduction in the reference unit between the product and the baseline in the representative use case scenario.
    - No significant increase in reference unit between the product and the baseline in the best- and worst-case test scenarios.
    - Or, where product variants have been grouped:
        - A reduction in the reference unit between the product and the baseline in the representative use case scenario for all product variant groups or a reduction in the reference unit when considering all product variant groups together as a weighted average according to their proportion of active devices.
        - No significant increase in reference unit between the product and the baseline in the best- and worst-case test scenarios for all product variant groups or no significant increase in the reference unit when considering all product variant groups together as a weighted average according to their proportion of active devices.

5.4.5. Confirming energy reductions occur in use

- The average power consumption of the product in use shall be assessed to demonstrate that a reduced average power consumption for the product is achieved when compared to an expected power consumption range defined from the controlled environment testing.
- Where product variants have been grouped the average power consumption of the product in use and the expected average power consumption range shall be defined for each product variant group considering the highest power consuming variant as identified in section 4.4.2.
- The expected average power consumption range for the product or product variant group is defined by,
    - Minimum: The average power consumption of the product calculated from the best-case test scenario from controlled environment testing.
    - Maximum: The average power consumption of the product calculated from worst-case test scenario from controlled environment testing.
- The actual average power consumption in use for the product or product variant group shall be calculated from the telemetry data collected from active devices by
    - Calculating the average power consumption of each active device by assessing the total energy consumption of the device relative to its total time in use occurring within the time boundary (i.e. total energy consumption / total time in use).
    - Calculating the weighted average power consumption for all active devices according to their time in use.

- The telemetry data should be collected for the full time period. For example, confirming an energy reduction after one-year requires 12 months of consecutive primary data.
    - Where an energy saving feature has been introduced during a reporting period, the actual average power consumption shall be calculated using telemetry data during the time period when the feature was in place. For products with seasonally affected energy/power consumptions, organisations shall be able to justify that the data period represents typical usage of the product.
- For an energy reduction to be demonstrated the actual average power consumption of the product in use shall be in-between the minimum and maximum expected average power consumption limits defined.
    - Where product variants have been grouped, the actual average power consumption of the product in use shall be in-between the minimum and maximum expected average power consumption limits defined for each group.

5.5. GHG Emissions Reduction Estimation

Box 10: Optional GHG emissions reduction estimation

A calculation of the energy reduction of the product may be performed to estimate the resulting GHG emissions reduction from the action(s) taken. This step is optional as organisations may choose to demonstrate that an energy reduction has occurred via section 5.4 but not attempt to estimate the resulting GHG emissions reduction.

- Organisations may select the approach for estimating the GHG emissions reduction resulting from the energy reduction demonstrated for the product. The selected approach will depend on several factors including the telemetry data available for energy modelling of the product and the functional change(s) resulting in the energy reduction.
- Organisations shall define and document the estimation method used including any assumptions used, and justifications for how it accurately represents the action(s) described in section 5.4.1:
    - How the approach accurately represents the changes introduced in the product to result in the energy reduction.
    - How the operational conditions necessary for the reduction to occur are identified from the telemetry data and applied in the estimation method,
    - How any conditions that can prevent the reduction from occurring have been considered in the estimation method.
- The GHG emissions reduction estimate shall,
    - Calculate the total energy reduction for each geographic region where device use occurred in the reporting period.
    - Calculate the GHG emissions using the relevant full life cycle emission factor for the electricity grid following guidance in section 4.5.

- The GHG emissions reductions for the product may be estimated from the energy reduction per device demonstrated in the representative use-case test scenario assessed in the controlled environment testing by:
    - Calculating the average power consumption reduction per device between the product and the baseline using the representative use case scenario for the product or (where applicable) for all product variants together as a weighted average according to their proportion of active devices.
    - Calculating the energy consumption reduction for all active devices per geographic region by multiplying the average power consumption reduction per device by the average time in use of devices per geographic region. (Note: organisations should consider whether average power consumption per device across all geographic regions is suitable for the product being assessed, or if power consumption varies too much to just use one figure, the estimate may need to be more granular.)
    - Calculating the GHG emissions reduction estimate for each geographic region by using the relevant emission factor for the electricity grid.
- Alternatively, the GHG emissions reduction may be estimated from a comparison of the actual energy consumption of each device with a predicted energy consumption of the baseline. The typical steps for this approach are:
    - Calculate the actual energy consumption of each device (sections 4.3 and 4.4)
    - Calculate the predicted energy consumption of the baseline for the specific usage profile of each device
        - Calculation of the predicted energy consumption of the baseline for the specific usage profile of each device requires mathematical modelling to determine a relationship between the product and the reference product.
        - The relationship shall consider the different product specifications, product use and external environmental factors, therefore, it requires primary data of these factors to be collected from the product in use, or previous versions of the product, or similar products.
    - Calculate the energy reduction between the device and expected energy consumption of the baseline for each device.
    - Aggregate expected energy reductions of devices for each product or product variant group in each geographic region.
    - Extrapolate expected energy reductions for each product or product variant group to full population of active devices in each geographic region (if data sampling used).
    - Calculate GHG emissions reduction for each product or product variant group according to the relevant full life cycle emission factors for the electricity grid in each geographic region
- Organisations shall carry out a statistical evaluation of the accuracy of the GHG emissions reduction estimate and report their conclusions or a third-party's conclusions on the accuracy, error, or uncertainty of the estimate.

- As an example, an organisation estimating the GHG emissions reduction using a predicted energy consumption of the baseline may use lab-testing to evaluate the accuracy of the energy reductions calculated as shown in Figure 5.

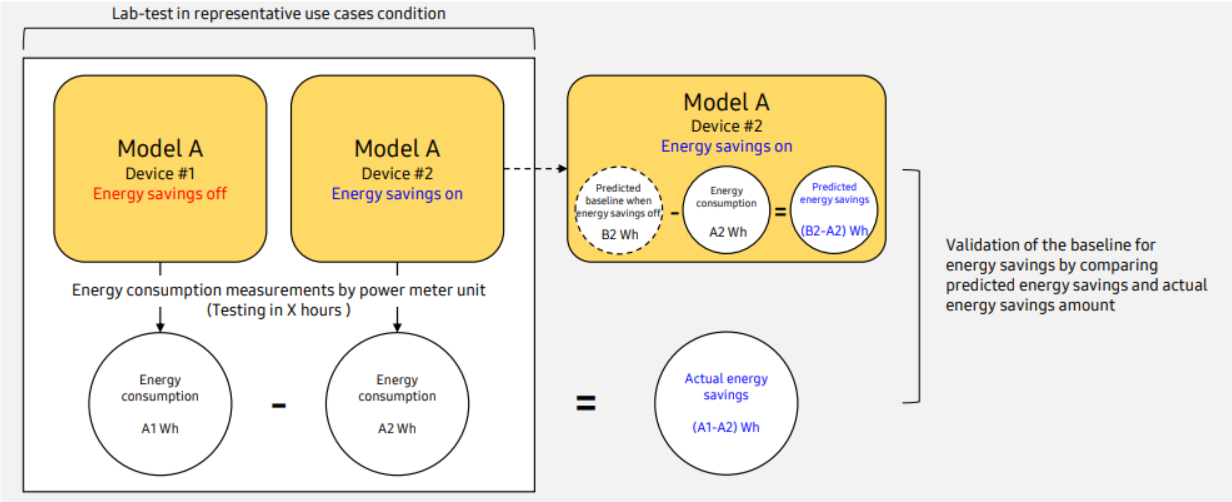


Figure 5: Approach for validating the predicted energy consumption of the reference product

6. External Reporting and Public Communication

The specification enables reporting of the total use-phase GHG emissions impact and reduction (where achieved) of all devices in use of the product being studied within the defined reporting period and geographical boundary. The GHG emissions impact or reduction represents the total emissions in that year from all active devices ever sold or leased.

Products are often available to consumers in multiple configurations or selectable options, termed product variants, and the use of a different variant by a consumer would result in a different energy consumption. The total product use-phase GHG emissions can possibly include multiple different product variants and use in multiple different countries. Therefore, reporting of this total value should be clearly communicated as the total GHG emissions of all uses of all variants of this product within the reporting time period and geographical boundary. A per product value should not be simply calculated as an average across the number of active devices to communicate the impact of a single device to the consumer due to the potential for very diverse product variants. The data collected and produced during the assessment could be used for consumer-level communications of a single device, however, this would require the reported outcome to be specific to a particular product variant in a specific geographic area. This is not in the scope of reporting from this specification but could be achieved with careful consideration of the consumers engagement with the product.

6.1. External Reporting of the Product Use-Phase Emissions and Energy Consumption Assessment

Organisations looking to report the outcome of the assessment undertaken in 4. Product Use-Phase Energy Consumption & GHG Emissions Calculation should publicly disclose:

- The total energy consumption of the product and attributable products (where applicable) during the reporting period
- The total use-phase GHG emissions of the product and attributable products (where applicable) during the reporting period
- Use-phase GHG emissions of the product and attributable products (where applicable) by country, group of countries, or region
- The product definition and all included product variants.
    - Where it is not possible for the organisation to record the number of devices that are not transmitting data (i.e. there is an unknown quantity of active devices not included in the assessment), the organisation shall report as supporting information the percentage of total devices known to be / have ever been active as a proportion of total devices sold and explain how these GHG emissions are accounted for and reported elsewhere by the organisation.
- The geographic boundary of the assessment
- Description of the measurement method used, including the characteristics used to measure energy consumption

- The results of an assessment of the product life cycle GHG emissions or a "product carbon footprint", reported as global warming potential for a 100-year time horizon (GWP-100) in units of CO_2 equivalents

6.2. External Reporting of the Product Use-Phase Emissions and Energy Reductions Assessment

Note: External reporting of a reduction should only occur if all reporting requirements in section 6.1 have been met.

Organisations looking to report the outcome of the assessment undertaken in 5. Demonstrating Energy Reductions should consider the significance of the calculated reduction compared to the uncertainty in the assessment and adopt a conservative approach to any communications. Organisations wishing to make communications about a product should publicly disclose:

Either

- A statement that a GHG emissions reduction has been achieved without communicating a specific reduction value.

Or,

- A quantitative GHG emissions reduction reported as the total GHG emissions reduction from all active devices.

And,

- The energy reduction action(s) taken.
- A description of the baseline, its relationship to the product, and justification for its use as a baseline.
- All product variants included in the reported energy reduction.
- An explanation of the supporting evidence for the reduction claim.

6.3. Public Communication of Outcomes and Reduction Claims

Any public communications of environmental benefits of products shall consider regulations and best-practice in all regions relevant to the reported benefit. Particularly relevant for reporting environmental benefits only of the product use-phase is the proposed EU Green Claims Directive[5], which requires that the assessment used to substantiate claims needs to consider the full life cycle of the product to avoid omissions in claims and ensure the benefit claimed does not result in a significant increase of other environmental aspects. This would require the reporting organisation to further assess all other aspects of the product life cycle before making a claim.

[5] At time of writing the directive is proposed: Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on substantiation and communication of explicit environmental claims (Green Claims Directive)

It is recommended that organisations seek third-party assurance of the reported outcome from the assessment and any reduction claims they wish to make. The supporting document *"Assessment of Product Use-phase GHG Emissions from Electrical and Electronic Products - Part 2: Conformity Assessment"* provides assurance requirements for the assessment of conformity of products to the requirements contained in this document.

The purpose of third-party assurance is to allow organisations to communicate if:

- The use-phase GHG emissions of their product have been calculated accurately and in accordance with *Part 1: Specification and Guidance* using activity data collected from devices in use during the reporting period.
- That the product has achieved energy reductions when compared to a baseline and (where applicable) that the resulting GHG emissions reduction estimate has been verified in accordance with *Part 1: Specification and Guidance*.

6.3.1. Structure of Public Communications

Public communications shall be structured as follows:

- 'Product claim' – see section below for an example claim, including a link to a webpage with supporting information about the claim
- 'Supporting information' – information that shall be provided on a webpage and can be used in the sustainability report
- 'Disclaimer' – this is text which does not need to be published, but organisations should consider the guidance provided and shall ensure any published claims align to all relevant regulations.

6.3.2. Product claims

- Product claims shall be reviewed and agreed by both the organisation and assurance provider.
- Examples of suitable claims relating to the product use-phase energy consumption and emissions assessment may be:

The 'YYYY'/[reporting period] energy consumption and GHG emissions of the use phase of the [product]/this product have been verified by the [assurance provider] according to the DUCD Part 1: Specification and Guidance. Learn more at …[web link]

Or

The use-phase GHG emissions of the [product]/this product for the period [reporting period] have been verified by [assurance provider] according to the DUCD Part 1: Specification and Guidance. Learn more at …[web link]

- An example of a suitable claim relating to the product use-phase energy consumption and emissions reductions may be:

The total energy consumption and GHG emissions of the use phase of all active devices of this product has reduced since 'YYYY-1' in regions 'RRRR' calculated according to the DUCD Part 1: Specification and Guidance.

The use-phase emissions represent Z% of the total product carbon footprint for X product(s).

Learn more at …[web link]

6.3.3. Supporting information

- In addition to the product claims, supporting information shall be provided to include the full public disclosure as defined in sections 6.1 and 6.2
- The supporting information shall be provided as a link to a supplementary webpage.
- The supporting information may also provide further details to this claim. Examples are:

The total energy consumption and GHG emissions of all active devices of the [product]/this product in the period YYYY-1 to YYYY in regions 'RRRR' have been verified as XXX kWh resulting in XXX tCO2e.

The verified total energy consumption and GHG emissions reductions demonstrate the energy reductions from [energy saving feature], in the period YYYY-1 to YYYY from all active devices. Users of [PRODUCT] using [energy saving feature] saved a total of XXX tCO2e in regions 'RRRR'.

6.3.4. Disclaimer

The following disclaimer does not need to be published, but organisations shall consider the guidance provided and shall ensure any claims align to relevant regulations.

Any communication relating only to the product use-phase (energy consumption or emissions) shall include a reference to the full product carbon footprint and be supported by publication of the full product carbon footprint. This is recommended to be included for all claims to align with EU and UK regulation and as industry best practice.

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Published in the UK: 2024