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Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage —

Part 1: Calculation, reporting and communication

Développement durable dans les bâtiments et les ouvrages de génie civil — Métrique du carbone des bâtiments existants pendant la phase opérationnelle —

Partie 1: Calculs, rapports et communication

Reference number
ISO 16745-1:2017(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 59, *Buildings and civil engineering works*, Subcommittee SC 17, *Sustainability in buildings and civil engineering works*.

This first edition of ISO 16745-1, together with ISO 16745-2, cancels and replaces ISO 16745:2015, of which it constitutes a minor revision.

ISO 16745:2015, Clause 7 has been transferred to ISO 16745-2 to keep the requirements for the verification of the carbon metric declaration independent of the requirements for the carbon metric calculation, reporting and communication, as well as other minor editorial modifications.

A list of all parts in the ISO 16745 series can be found on the ISO website.

Introduction

Buildings contribute approximately one-third of global greenhouse gas (GHG) emissions. With its high share of emissions, the building and construction sector has the responsibility to take the global lead in implementing strategies to reduce GHG emissions. The building and construction sector has more potential and opportunity to deliver quick, deep, and cost-effective GHG mitigation than any other sectors. Carbon dioxide (CO_2) emissions contribute to global warming, which is one of the most recognized environmental impacts attributable to buildings.

In this context, measurement and reporting of GHG emissions from existing buildings are critical for enabling significant and cost-effective GHG mitigation. Currently, there has not been a globally agreed method established to measure, report, and verify potential reductions of GHG emissions from existing buildings in a consistent and comparable way. If such a method existed, it could be used as a universal tool for measurement and reporting of GHG emissions, providing the foundation for accurate performance baselines of buildings to be drawn, national targets to be set, and carbon trading to occur on a level playing field.

In principle, accurate and precise reporting can only be achieved if GHG emissions (and removals) from all life cycle stages of buildings are measured and/or quantified. However, not all countries in the world have sufficient capacity or resources to use and apply life cycle assessment (LCA) methodologies.

Respecting the need for collaboration on a global scale, the need exists for a metric that is usable not only in countries with sufficient number of experts and a precise database, but also in those countries where experts' services are limited and databases have considerable gaps. For instance, with the potential for global scale carbon trading within building-related sectors, a method that is consistently usable in both the well-developed and developing world is needed.

Operational energy use in buildings typically accounts for 70 % to 80 % of energy use over the building life cycle. Therefore, the operating stage of the building's life cycle is the focus of measurement and reporting of direct and indirect GHG emissions.

This document aims to set out a globally applicable common method of measuring and reporting of associated GHG emissions (and removals) attributable to existing buildings, by providing requirements for the determining and reporting of a carbon metric(s) of a building.

The carbon metric is a measure (a partial carbon footprint) that is based on energy use data and related building information for an existing building in operation. It provides information related to the calculation of GHG emissions and can be used as an environmental indicator. Using this approach, the metric and its protocol can be applied by all stakeholders in both developing and well-developed countries, where building energy consumption and other relevant data can be retrieved or collected, making it useful and globally transferable.

This document aims to be practical for many stakeholders (i.e. not only for the building profession), who are expected to use the carbon metric of a building as reference for decision making in their business activities, governmental policies, and as a baseline for benchmarking.

The simplicity of approach provides applicability at all scales, ranging from cities and building portfolios to individual buildings.

Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage —

Part 1: Calculation, reporting and communication

1 Scope

This document provides requirements for determining and reporting a carbon metric of an existing building, associated with the operation of the building. It sets out methods for the calculation, reporting and communication of a set of carbon metrics for GHG emissions arising from the measured energy use during the operation of an existing building, the measured user-related energy use, and other relevant GHG emissions and removals. These carbon metrics are separated into three measures designated CM1, CM2, and CM3 (see 5.1.1).

This document follows the principles set out in ISO 15392 and those described in Clause 4. Where deviations from the principles in ISO 15392 occur, or where more specific principles are stated, this document takes precedence.

The carbon metrics CM1 and CM2 are not quantified based on life cycle assessment (LCA) methodology. Carbon metric CM3 may include partial quantification based on the results of LCA.

This document does not include any method of modelling of the operational energy use of the building but follows the conventions provided by other International Standards, as given in relevant clauses.

This document is not an assessment method for evaluating the overall environmental performance of a building or a building-rating tool and does not include value-based interpretation of the carbon metric(s) through weightings or benchmarking.

This document deals with the application of the carbon metric(s) for an existing building, either residential or commercial, or a building complex. It does not include provisions for regional and/or national building stock.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6707-1:2004, *Buildings and civil engineering works — Vocabulary — Part 1: General terms*

ISO 12655, *Energy performance of buildings — Presentation of measured energy use of buildings*

ISO 14050, *Environmental management — Vocabulary*

ISO 15392, *Sustainability in building construction — General principles*

ISO/TR 16344:2012, *Energy performance of buildings — Common terms, definitions and symbols for the overall energy performance rating and certification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6707-1, ISO 12655, ISO 14050, ISO 15392, ISO/TR 16344 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
building service
service provided by *technical building systems* (3.19) and by appliances to provide acceptable indoor environment conditions, domestic hot water, illumination levels, and other services related to the use of the building

Note 1 to entry: For the purposes of this document, the following terms are used as per their definitions in the following reference documents: *appliances* (ISO 6707-1:2004, 5.4.7) and *building* (ISO 6707-1:2004, 3.1.3).

[SOURCE: ISO 52000-1:2017, 3.3.3, modified – Note 1 to entry has been added.]

3.2
carbon intensity
carbon metric (3.3) expressed in relation to a specific reference unit related to the function of the building

Note 1 to entry: For the purposes of this document, the following terms are used as per their definitions in the following reference documents: *function* (ISO 15686-10:2010, 3.10) and *building* (ISO 6707-1:2004, 3.1.3).

Note 2 to entry: Examples of reference units may include per unit area, per person, per kilobyte, per unit output, and per GDP.

3.3
carbon metric
sum of annual greenhouse gas emissions and removals, expressed as CO_2 equivalents, associated with the use stage of a building

Note 1 to entry: For the purposes of this document, the following terms are used as per their definitions in the following reference documents: *greenhouse gas emissions* (ISO 14064-1:2006, 2.5), *removals* (ISO 14064-1:2006, 2.6), *CO_2 equivalents* (ISO 14064-1:2006, 2.19) and *building* (ISO 6707-1:2004, 3.1.3).

3.4
cooling
removal of latent and/or sensible heat

[SOURCE: ISO 16818:2008, 3.47]

3.5
delivered energy
energy (3.6), expressed per *energy carrier* (3.7), supplied to the *technical building systems* (3.19) through the *system boundary* (3.18), to satisfy the uses taken into account [heating, *cooling* (3.4), *ventilation* (3.20), domestic hot water, lighting, appliances, etc.], or to produce electricity

Note 1 to entry: For the purposes of this document, the term *appliances* is used as per its definition in ISO 6707-1:2004, 5.4.7.

Note 2 to entry: Delivered energy can be calculated for defined energy uses or it can be measured.

[SOURCE: ISO/TR 16344:2012, 2.1.33, modified – Note 1 related to active solar and wind energy systems has been deleted.]

3.6
energy
capacity for doing work; having several forms that may be transformed from one to another, such as thermal (heat), mechanical (work), electrical, or chemical

[SOURCE: ISO 16818:2008, 3.74]

3.7
energy carrier
substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes

Note 1 to entry: For the purposes of this document, the term *heat* is used as per its definition in ISO 16818:2008, 3.117.

Note 2 to entry: The energy content of *fuels* (3.10) is given by their *gross calorific value* (ISO/TR 16344:2012, 2.1.78).

[SOURCE: ISO/TR 16344:2012, 2.1.46]

3.8
energy source
source from which useful *energy* (3.6) can be extracted or recovered either directly or by means of a conversion or transformation process

EXAMPLE Oil or gas fields, coal mines, sun, wind, the ground (geothermal energy), the ocean (wave energy, ocean thermal energy), forests, etc.

[SOURCE: ISO 52000-1:2017, 3.4.15]

3.9
exported energy
energy (3.6), expressed per *energy carrier* (3.7), delivered by the *technical building systems* (3.19) through the *system boundary* (3.18) and used outside the system boundary

Note 1 to entry: It can be specified by generation types [e.g. combined heat and power (CHP), photovoltaic (PV)] in order to apply different weighting factors.

[SOURCE: ISO/TR 16344:2012, 2.1.72, modified – Note 2 has been deleted.]

3.10
fuel
material that can be used to produce heat or generate power by combustion

Note 1 to entry: For the purposes of this document, the term *heat* is used as per its definition in ISO 16818:2008, 3.117.

[SOURCE: ISO/TR 16344:2012, 2.1.74]

3.11
functional equivalent
quantified functional requirements and/or technical requirements for a building or part thereof for use as a reference basis for comparison

Note 1 to entry: For the purposes of this document, the term *building* is used as per its definition in ISO 6707-1:2004, 3.1.3.

[SOURCE: ISO 21931-1:2010, 3.7, modified – a reference to part of a building has been added.]

3.12
greenhouse gas emission coefficient
coefficient that describes the amount of a specific greenhouse gas that is released from doing a certain activity, such as burning one tonne of *fuel* (3.10) in a furnace

Note 1 to entry: For the purposes of this document, the term *greenhouse gas* is used as per its definition in ISO 14064-1:2006, 2.1.

Note 2 to entry: In general, GHG emission coefficients from specific *energy consumption* (ISO 50001:2011, 3.7) are quantified based on *GHG emission factors* (ISO 14064-1:2006, 2.7) for use of the *energy* (3.6).

Note 3 to entry: Greenhouse gas emission coefficients can differ by year.

3.13
greenhouse gas reservoir
physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG removed from the atmosphere by a *greenhouse gas sink* (3.14) or a GHG captured from a *greenhouse gas source* (3.15)

Note 1 to entry: For the purposes of this document, the term *GHG* is used as per its definition in ISO 14064-1:2006, 2.1.

Note 2 to entry: The total mass of carbon contained in a GHG reservoir at a specified point in time could be referred to as the carbon stock of the reservoir.

Note 3 to entry: A GHG reservoir can transfer greenhouse gases to another GHG reservoir.

Note 4 to entry: The collection of a GHG from a GHG source before it enters the atmosphere and storage of the collected GHG in a GHG reservoir could be referred to as GHG capture and storage.

[SOURCE: ISO 14064-1:2006, 2.4]

3.14
greenhouse gas sink
physical unit or process that removes a GHG from the atmosphere

Note 1 to entry: For the purposes of this document, the term *GHG* is used as per its definition in ISO 14064-1:2006, 2.1.

[SOURCE: ISO 14064-1:2006, 2.3]

3.15
greenhouse gas source
physical unit or process that releases a GHG into the atmosphere

Note 1 to entry: For the purposes of this document, the term *GHG* is used as per its definition in ISO 14064-1:2006, 2.1.

[SOURCE: ISO 14064-1:2006, 2.2]

3.16
gross floor area
sum of the floor areas of the conditioned spaces within the building, including basements, mezzanine and intermediate floor tiers, and penthouses, of headroom height 2,2 m or as specified in national or regional codes and standards

Note 1 to entry: For the purposes of this document, the following terms are used as per their definitions in the following documents: *conditioned spaces* (ISO 16818:2008, 3.38) and *building* (ISO 6707-1:2004, 3.1.3).

Note 2 to entry: It is measured from the exterior faces of exterior walls or from the centreline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

[SOURCE: ISO/TR 16344:2012, 2.1.79]

3.17
renewable energy
energy (3.6) from an *energy source* (3.8) that is not depleted by extraction

[SOURCE: ISO/TR 16344:2012, 2.1.123, modified – specific reference to energy source has been added and the examples and explanatory note have been removed.]

3.18
system boundary
boundary that includes within it all areas associated with a building (both inside and outside the building) where *energy* (3.6) is consumed or produced

Note 1 to entry: For the purposes of this document, the term *building* is used as per its definition in ISO 6707-1:2004, 3.1.3.

Note 2 to entry: Inside the system boundary, the system losses are taken into account explicitly, while outside the system boundary, they are taken into account in the conversion factor.

[SOURCE: ISO/TR 16344:2012, 2.1.142]

3.19
technical building system
technical equipment for heating, *cooling* (3.4), *ventilation* (3.20), humidification, dehumidification, domestic hot water, lighting, building automation and control and electricity production

Note 1 to entry: A technical building system can refer to one or several *building services* (3.1) [e.g. heating, heating and domestic hot water, and indoor transportation (e.g. escalator, elevator)].

Note 2 to entry: A technical building system is composed of different sub-systems.

Note 3 to entry: Electricity production can include *cogeneration* (ISO 52000-1:2017, 3.3.5), wind power and photovoltaic (PV) systems.

[SOURCE: ISO 52000-1:2017, 3.3.13, modified – indoor transportation has been added to Note 1 to entry.]

3.20
ventilation
process of supplying or removing air by natural means or mechanical means to or from a space for the purpose of controlling air contaminant levels, humidity, odours, or temperature within the space

[SOURCE: ISO 16818:2008, 3.242]

4 Principles

4.1 General

The application of the following principles is fundamental to ensuring that GHG-related information presented through the carbon metric represents a true and fair measure. These principles provide the basis for the application of the requirements in this document by the organization or individual determining the carbon metric.

4.2 Completeness

Include all relevant GHG emissions and removals (see 5.1) that provide a significant contribution to the carbon metric.

4.3 Consistency

Apply assumptions, methods, and data in the same way throughout the carbon metric determination to arrive at conclusions in accordance with the needs of the intended user and intended use (see 5.1).

4.4 Relevance

Select the GHG sources, GHG sinks, GHG reservoirs, data, and methodologies appropriate to the needs of the intended user and the intended use (see 5.3.4).

4.5 Coherence

Select methodologies, standards, and guidance documents already recognized and adopted for energy measurement and consumption to enhance comparability between common carbon metrics (see 5.3.2)

4.6 Accuracy

Ensure that the carbon metric quantification and communication are accurate, verifiable, relevant, and not misleading and that bias is avoided and uncertainties are minimised (see 5.3.4).

4.7 Transparency

Address and document all relevant issues in an open, comprehensive, and understandable presentation of information.

Disclose any relevant assumptions and make appropriate references to the methodologies and data sources used. Clearly explain any estimates and avoid bias so that the carbon metric faithfully represents what it purports to represent.

Ensure that the carbon metric communication is available to the intended audience and its intended meaning is presented in a way that is clear, meaningful, and understandable. Include information on the functional equivalent, data assumptions, calculation methods, and other characteristics to make the limitations in the comparisons of carbon metrics transparent and clear to the target group (see Clause 6).

4.8 Avoidance of double counting

Avoid counting of greenhouse gas emissions and removals that have already been allocated within other carbon metrics (see 5.3).

NOTE This list of principles has been adapted based on the principles described in ISO/TS 14067:2013, Clause 5.

5 Protocol of measuring the carbon metric of a building in the use stage

5.1 System boundary

5.1.1 Types of carbon metrics of a building

A carbon metric shall be measured by quantifying the direct and indirect GHG emissions and removals associated with a building in use.

The three types of carbon metrics of a building are defined as follows:

a) Carbon metric 1 (CM1) is the sum of annual GHG emissions, expressed as CO_2 equivalents, from building-related energy use (see 5.3.4.1);

b) Carbon metric 2 (CM2) is the sum of annual GHG emissions, expressed as CO_2 equivalents, from building- and user-related energy use (see 5.3.4.2);

c) Carbon metric 3 (CM3) is the sum of annual GHG emissions and removals, expressed as CO_2 equivalents, from building- and user-related energy use, plus other building-related sources of GHG emissions and removals.

5.1.2 System boundary for the carbon metrics of a building

5.1.2.1 System boundary for the carbon metrics CM1 and CM2

The system boundary for the CM1 and CM2 of a building is shown in Figure 1. It consists of the equipment to operate the building fulfilling the demand as energy end use and the technical building system(s) to deliver, convert, and generate energy for the energy end use.

CM1 and CM2 of a building are determined based on the following:

a) delivered energy for the building and for other energy use within the building's site (curtilage);

NOTE 1 Delivered energy includes energy provided by the local or national utility supplier and any remotely generated energy [e.g. from photovoltaic (PV), wind power, or combined heat and power (CHP), etc.] that is directly connected to the building.

b) total on-site energy generated and used in the building and for other energy use within the building's site (curtilage).

NOTE 2 Examples of sources of on-site energy generation can be solar power [photovoltaic (PV) panel], wind turbine power, biomass fuel, combined heat and power (CHP), fuel cell, and others.

The system boundary shall include all the energy-consuming and -generating systems that are within the building's site (curtilage) and that support the operation of the building.

All building-related energy end use (as indicated in the pale grey boxes in Figure 1) shall be taken into account for the carbon metric (CM1), even when energy for these building services is separately measured through sub-metering.

Lighting (including plug-in lighting necessary for the basic function of the building) and controls (including systems for daylight control) shall be included in the CM1 (see 5.3.4.1).

User-related energy use (as indicated in the dotted box in Figure 1) shall be included in the CM2, including energy for supplementary lighting installed by building users (see 5.3.4.2).

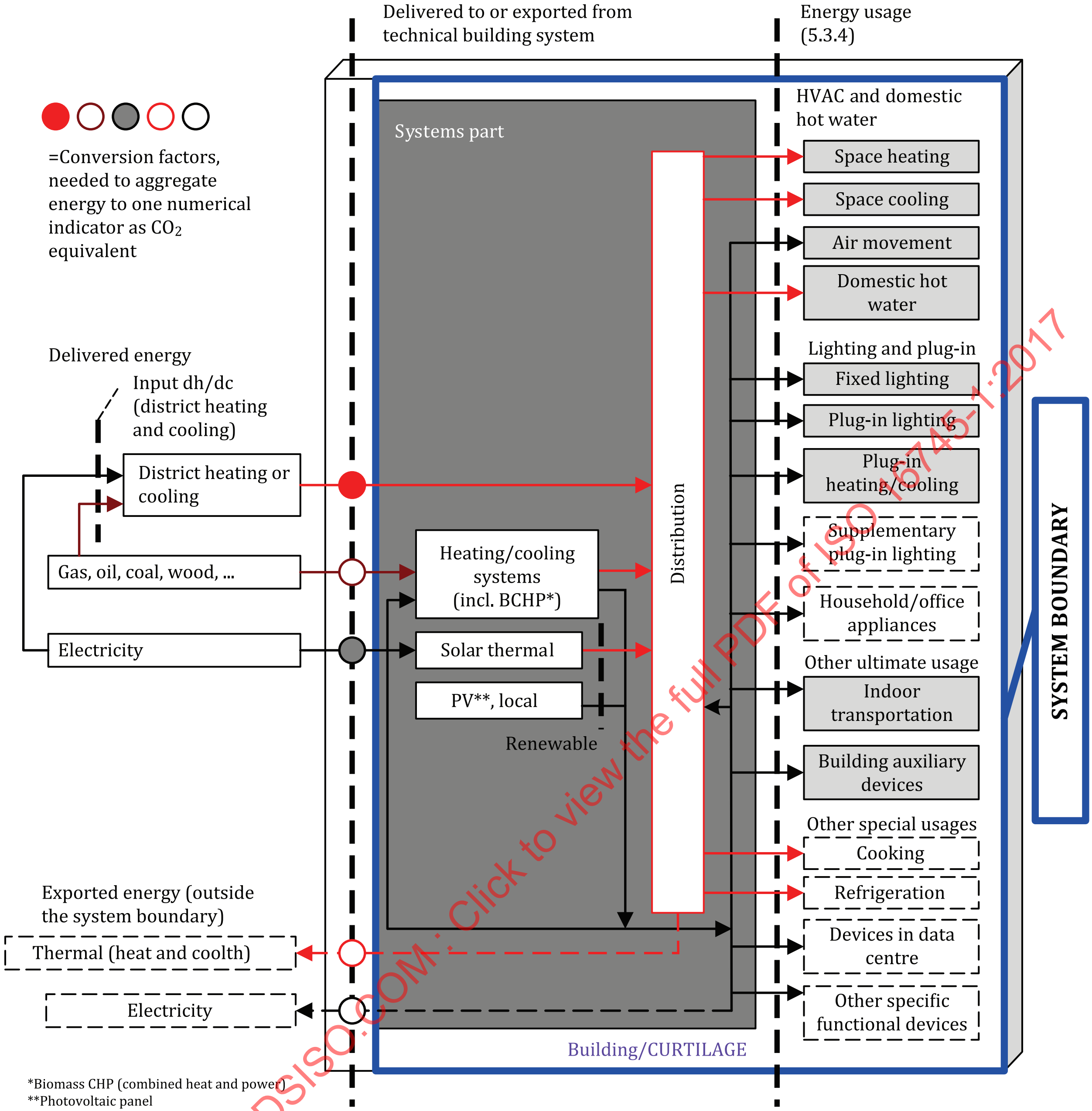

Figure 1 — Boundary and energy flows — Main energy flows within and crossing the boundaries for energy use of a building

It is NOT necessary to separately measure the amount of energy generated, converted, or consumed within the system boundary by each individual system, piece of equipment, or machine.

Exported energy is outside the system boundary but may be reported as additional information where appropriate (see 6.2.2).

Figures 2, 3, and 4 show examples of the system boundary for CM1.

EXAMPLE 1 Only the energy carrier for the delivered energy and energy generated by the PV panels and used within the system boundary are required to be measured for CM1.

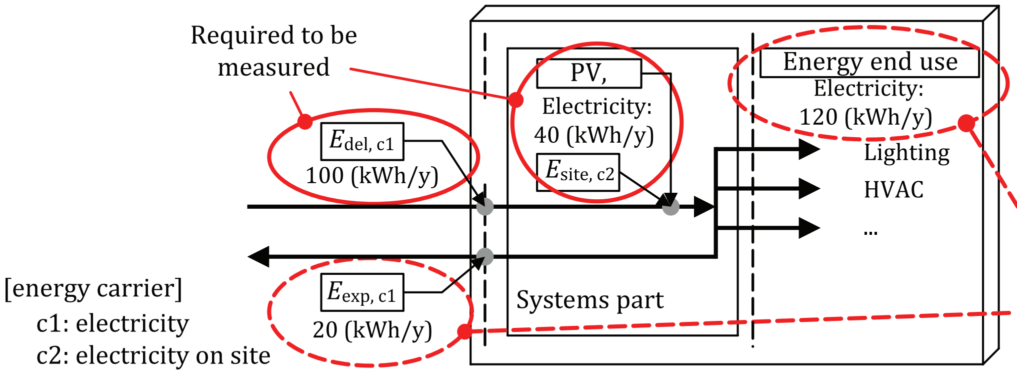

Figure 2 — Examples of energy flow measuring by energy carriers (Ex.1)

EXAMPLE 2 Only the energy carriers for the delivered energy are required to be measured when a co-generation system is installed and used within the system boundary for CM1.

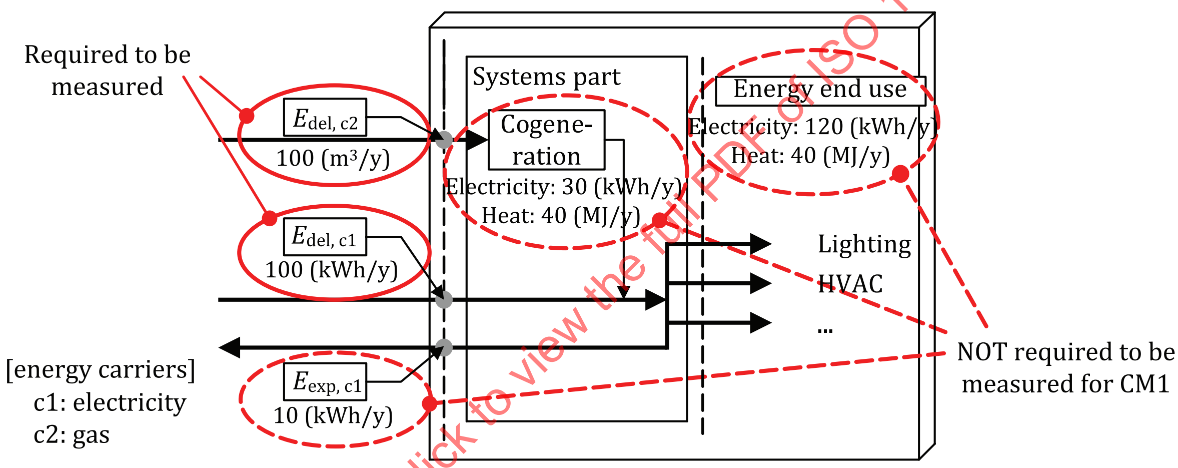

Figure 3 — Examples of energy flow measuring by energy carriers (Ex.2)

EXAMPLE 3 The energy carrier for the delivered energy and biomass fuel (wood, waste, etc.) harvested within the system boundary are measured when biomass cogeneration system is installed and used within the system boundary for CM1.

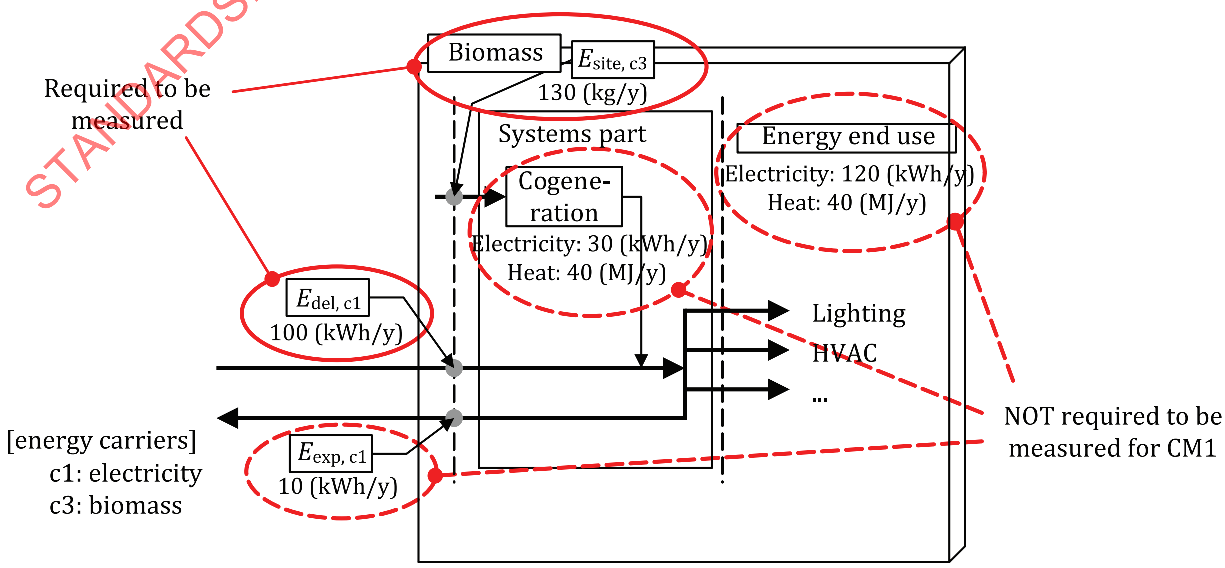

Figure 4 — Examples of energy flow measuring by energy carriers (Ex.3)

5.1.2.2 System boundary for the carbon metric CM3

The system boundary for the carbon metric CM3 shall include all the elements within the system boundary for CM2 plus other processes and activities (including upstream and downstream processes), causing GHG emissions and removals associated with the use stage of the building and other systems within the building's site (curtilage). These shall include, where significant, maintenance, including cleaning, repair, replacement and refurbishment, water use, waste treatment and disposal, and emissions of refrigerant from building air cooling systems.

5.2 Carbon metric and carbon intensity

The carbon metric is a measure of total GHG emissions attributed to the use of a building in operation, over a one year period. For more detailed analysis or comparison, the carbon metric may be denoted relative to a specific measure of carbon intensity, e.g. per unit area, per person, per kilobyte, per unit output, and/or per GDP.

5.3 Calculation of GHG emissions

5.3.1 GHG emissions associated with energy use of a building

The emitted mass of GHG, expressed as kg CO_2 equivalent per kg emission, shall be calculated from the delivered energy for each energy carrier plus the on-site energy, if any, produced without using delivered energy and used in the building and/or for other energy use within the building's site, multiplied by the respective GHG emission coefficient, as given in Formula (1):

$$m \cdot \mathrm{co}_{2\mathrm{eqv}} = \sum\left(\left(E_{\mathrm{del,ci}} \times K_{\mathrm{del,ci}}\right) + \left(E_{\mathrm{site,ci}} \times K_{\mathrm{site,ci}}\right)\right) \tag{1}$$

where

$E_{\mathrm{del,ci}}$ is the delivered energy for energy carrier del,ci;

$E_{\mathrm{site,ci}}$ is the energy produced onsite for the energy carrier site,ci;

$K_{\mathrm{del,ci}}$ is the GHG emission coefficient for delivered energy carrier del,ci (see 5.3.5);

$K_{\mathrm{site,ci}}$ is the GHG emission coefficient for on-site energy carrier site,ci.

Where the sum of energy produced on-site is estimated to be less than 2 % of the total energy, $E_{\mathrm{site,ci}}$ should be ignored.

NOTE Energy produced on site does not include co-generation by delivered energy sources.

5.3.2 Measurement of energy carrier

Where the energy carrier(s) provides energy to support the operation of the building and/or other on-site facilities, measurement of the energy carrier shall take account of all the sources delivered to and generated within the system boundary including

— electricity,

— fuels (e.g. gas, oil, wood, and other biomass waste), and

— imported coolth/steam/heat.

Data for nominal delivered energy is available from the following sources:

a) utility provider reports and contracts;

b) electricity bills;

c) invoices for fuel deliveries;

d) gas bills;

e) meter readings (estimated from invoices, if meter readings are not available);

f) pipeline measurements;

g) energy management software.

The sum of these data shall include all of the energy usage described in 5.3.4.

Data for the on-site generated energy shall be based on the following:

a) meter readings;

b) measured amount of biomass consumed (kg).

NOTE Further information for the method of measuring and calculation of energy in the use stage of a building is available from ISO 12655, ISO 16343, and ISO 16346.

5.3.3 Exported energy

Exported energy, i.e. energy produced on-site, but not used for the building or other on-site facilities, is not included in the carbon metric but can be reported as additional information.

Where exported energy is reported as additional information, the GHG emissions from the exported energy shall be calculated from the amount of energy generated, multiplied by the respective GHG emission coefficient, as shown in Formula (2):

$$m \cdot \mathrm{co}_{2\mathrm{eqv}} = \sum \left(E_{\mathrm{exp,ci}} \times K_{\mathrm{exp,ci}} \right) \quad (2)$$

where

$E_{\mathrm{exp,ci}}$ is the exported energy for energy carrier exp,ci;

$K_{\mathrm{exp,ci}}$ is the GHG emission coefficient for exported energy carrier exp,ci.

NOTE Annex D presents examples of allocation rules that can be used for combined heat power.

5.3.4 Energy usage

5.3.4.1 Building-related energy use

For CM1, building-related energy use shall be determined as follows (see Annex B for the classification):

a) Energy for HVAC and domestic hot water:

    1) energy for space heating;

    2) energy for space cooling;

    3) energy for air movement;

    4) energy for domestic hot water.

b) Energy for fixed lighting;

c) Energy for plug-in equipment for basic building services:

    1) plug-in lighting;

2) plug-in heating;

3) plug-in cooling.

d) Energy for other usage:

1) energy for indoor transportation;

2) energy for building auxiliary devices.

For purposes of determining the carbon metric, all building-related energy use shall be included, even for building services not typically sub-metered or separately measured.

5.3.4.2 User-related energy use

For CM2, user-related energy use is determined as follows (see Annex B for the classification):

a) energy for lighting and plug-in equipment:

1) energy for supplementary lighting installed by building users;

2) energy for household/office appliances.

b) energy for other special usages:

1) energy for cooking;

2) energy for refrigeration (cooling and storage);

3) energy for devices in data centres;

4) energy for other specific functional devices.

5.3.5 GHG emission coefficients

5.3.5.1 General

The greenhouse gas emissions from energy consumption are quantified by using GHG emission coefficients. GHG emission coefficients characterize the amount of a specific GHG that is released from doing a certain activity, such as burning one tonne of fuel in a furnace.

The GHG emission coefficient(s) used is based on the type of delivered energy carrier or exported energy carrier.

For the purpose of this document, the following information shall be stated regarding the type of GHG emission coefficient used to determine carbon metric:

— sources of information (e.g. national, international);

— greenhouse gases included in CO_2 equivalent (e.g. following Kyoto protocol, Montreal protocol, or other protocols);

— included elements in supply chain (e.g. on-site or on-site plus upstream processes);

— time frame of impacts on environment (100 years);

— year of reference of emission coefficient data.

The choice of the source of the GHG emission coefficient used for calculating a carbon metric shall be appropriate for the intended use of the carbon metric.

GHG emission coefficients shall be obtained from, in the following order of priority:

— nationally agreed data;

— independently provided information;

— internationally agreed data.

NOTE 1 There are some usable databases as officially agreed (approved) GHG emission coefficients (see References [20], [21] and [22]).

NOTE 2 GHG emission coefficients for each fuel type could be the same as those used under national reporting for flexible mechanisms for the Kyoto Protocol for the six major greenhouse gases.

NOTE 3 Because some officially agreed (approved) GHG emission coefficients are based on default emissions, they may not necessarily reflect the specific types of fuel combustion and emissions control technologies at each building.

NOTE 4 Additional geographically or technologically specific GHG emission factors could result in more accurate calculations and can be used as long as they are credible and as long as the sources are documented and reported.

NOTE 5 For certain sources, GHG emissions could be calculated in different ways to accommodate differences in the type of GHG activity data available to individual reporting offices or to help ensure that the calculations are as accurate as possible.

For international carbon trading mechanisms (such as the Clean Development Mechanism), it is recommended that the source of the GHG emission coefficient(s) be the internationally agreed sources appropriate to the fuel that is being consumed and the technology used for the energy carrier.

NOTE 6 This document includes the principle of avoidance of double-counting. This is considered especially in some situations where supplier/generator-specific emission factors for electricity are used. For example, where

— the process which used the electricity (or used an equivalent amount of electricity of the same type to that generated) and another process did not claim the generator-specific emission factors for that electricity; and

— the generator-specific electricity production does not influence the emission factors of any other process or organization.

— some electricity attributes such as green certificates are sold without direct coupling to the electricity itself. In some countries, parts of the electricity from renewable energy sources might already be sold/exported as renewable electricity without being excluded from the supplied mix.

5.3.5.2 Treatment of delivered energy

The GHG emission coefficients associated with the use of delivered energy shall take into account, where relevant, GHG emissions arising from the energy supply system.

When a supplier of energy delivers a specific energy product with a specific GHG emission coefficient and guarantees that the energy sale and the associated GHG emissions are not double counted, the GHG emission coefficient for that specific energy product shall be used. When the supplier of energy does not provide a specific GHG emission coefficient for the specific energy product delivered, the GHG emission coefficient associated with the utility (e.g. the national grid for electricity) shall be used.

Where a country does not have a national supply system but has several unconnected supply systems or several countries share a supply system, the GHG emission coefficient(s) associated with the relevant system from which the energy is obtained shall be used.

Where the GHG emission coefficient(s) for the energy supply system are difficult to access, GHG emission coefficients for similar energy supply systems, from recognized databases, may be used.

5.3.5.3 Treatment of on-site energy

When energy is internally produced (e.g. on-site generated electricity) and consumed by the building under study, the GHG emission coefficient for that energy shall be used for that building.

6 Reporting and communication of the carbon metric

6.1 General

The carbon metric may be used for a variety of purposes, which can include internal or external benchmarking, public information, property evaluation, policy information asset evaluation, etc. (see Annex A for further information).

In order to use and apply the carbon metric appropriately, the reporting of the carbon metric shall include information necessary to describe the building and give sufficient information to allow traceability and transparency of the measurement.

This information shall include, but not be limited to, the items in 6.2 and 6.3.

The treatment of energy shall be documented in the carbon metric study report.

NOTE This document does not set benchmarks. However, it is recognized that the carbon metric could be used for this purpose and further information in this respect is given in Annex A.

6.2 Reporting of the carbon metric

6.2.1 Mandatory requirements

The carbon metric study report shall include the following:

a) building identification (name of building(s), physical address);

b) type of the carbon metric (e.g. CM1, CM2, or CM3);

c) value of the carbon metric(s);

d) value(s) of the carbon intensity(ies) determined;

e) purpose of the reporting;

f) reporting period, 12 consecutive months, mm/yyyy-mm/yyyy (e.g. 07/2013-06/2014)

g) whether the carbon metric has been normalized to average annualized conditions such as local climate (if yes, include the method used to normalize the carbon metric for average conditions);

h) date of the evaluation;

i) name of the organization or individual doing evaluation (self-measurement or third party);

j) client of the evaluation;

k) description/illustration of the system boundary;

l) list of energy end use included in the carbon metric in relation to the type of CM;

m) whether delivered energy end uses (e.g. heating, lighting, cooling, etc.) are measured or estimated (see Tables 1 to 3);

n) inventory of energy carriers (see Table 4 and 5);

o) source of GHG emission coefficient (publication, organization, year of the coefficient measured);

p) year of construction of building (for each building of a complex);

q) year of latest major renovation affecting energy use (e.g. change of HVAC, change of building envelope);

r) year of any (latest) change in use;

s) total site area;

t) location (country and climate).

The following building information, as a minimum, shall be provided to describe the functional equivalent:

a) building type and use, including multi-use building;

b) floor area (gross, net lettable, conditioned, occupied) for each use;

c) number of floors (above ground, underground);

d) occupancy [number of persons {on a Full Time Equivalent (FTE) basis for commercial buildings}, operation schedule].

Both the type and the quantity of the energy carrier (e.g. oil, coal, natural gas, electricity, biomass fuels) shall be presented according to the actual delivered energy and exported energy, such as 1 m^3 (natural gas), 1 kWh (electricity).

Units of energy carriers for reporting may be chosen nationally, depending on the purpose of the carbon metric.

Table 1 — List of energy end use included in the carbon metric for CM1

	Energy consumption-related building service		Present in the building[a]	Included in the CM[b]	Separately metered[c]	Measured or estimated[d]	Energy carrier if known[e]
1	Building-related energy use	Space heating					
2		Space cooling					
3		Air movement					
4		Domestic hot water					
5		Lighting for basic building function (fixed lighting, etc.)					
6		Auxiliary energy (e.g. for heat pumps)					
7		Indoor transportation					
8		Building auxiliary devices					

[a] Use “P” to indicate if building services are present in the building.

[b] Use “I” to indicate if the energy end use for the building service is included in the carbon metric.

[c] Use “X” to indicate if energy end use for the building service is separately metered.

[d] Use “M” or “E” to indicate if delivered energy end use is based on either measurement or estimation.

[e] Report may indicate the energy carrier for each energy end use, if known.

Table 2 — List of energy end use included in the carbon metric for CM2

	Energy consumption-related building service		Present in the building[a]	Included in the CM[b]	Separately metered[c]	Measured or estimated[d]	Energy carrier if known[e]
1	Building-related energy use	Space heating					
2		Space cooling					
3		Air movement					
4		Domestic hot water					
5		Lighting for basic building function (fixed lighting, etc.)					
6		Auxiliary energy (e.g. for heat pumps)					
7		Indoor transportation					
8		Building auxiliary devices					
9	User-related energy use (Examples)	Plug-in supplementary lighting					
10		Household/office appliances					
11		Refrigerator					
12		Devices in data centre					
13		Other specific functional devices					
14		……..					

[a] Use “P” to indicate if building services are present in the building.

[b] Use “I” to indicate if the energy end use for the building service is included in the carbon metric.

[c] Use “X” to indicate if energy end use for the building service is separately metered.

[d] Use “M” or “E” to indicate if delivered energy end use is based on either measurement or estimation.

[e] Report may indicate the energy carrier for each energy end use, if known.

Table 3 — List of energy end use included in the carbon metric for CM3

	Energy consumption-related building service		Present in the building[a]	Included in the CM[b]	Separately metered[c]	Measured or estimated[d]	Energy carrier if known[e]
1	Building-related energy use	Space heating					
2		Space cooling					
3		Air movement					
4		Domestic hot water					
5		Lighting for basic building function (fixed lighting, etc.)					
6		Auxiliary energy (e.g. for heat pumps)					
7		Indoor transportation					
8		Building auxiliary devices					
9	User-related energy use (Examples)	Plug-in supplementary lighting					
10		Household/office appliances					
11		Refrigerator					
12		Devices in data centre					
13		Other specific functional devices					
14		……					
15	Other building-related sources	Other < specified > sources of GHG					
16		……					
17		……					

[a] Use “P” to indicate if building services are present in the building.

[b] Use “I” to indicate if the energy end use for the building service is included in the carbon metric.

[c] Use “X” to indicate if energy end use for the building service is separately metered.

[d] Use “M” or “E” to indicate if delivered energy end use is based on either measurement or estimation.

[e] Report may indicate the energy carrier for each energy end use, if known.

Table 4 — Inventory of energy carriers and calculation of the carbon metric for CM1 and CM2

		Energy carrier **C1**	Energy carrier **C2**	...	C	
1	Energy delivered	$E_{\mathrm{del,c1}}$	$E_{\mathrm{del,c2}}$			
2	GHG emission coefficient for delivered energy	$K_{\mathrm{del,c1}}$	$K_{\mathrm{del,c2}}$			
3	Mass of GHG emissions (as kg CO_2 equivalent) for delivered energy	$m_{\mathrm{del,c1}}$	$m_{\mathrm{del,c2}}$		$\eta m_{\mathrm{del,ci}}$	

NOTE 1 The quantity of energy carrier can be described “N/A” in case where its GHG emission coefficient is zero.

NOTE 2 The energy carrier type is identified based on the GHG coefficient.

Table 4 *(continued)*

		Energy carrier **C1**	Energy carrier **C2**	**...**	**C**	
4	Energy generated and used on-site	$E_{site,c1}$	$E_{site,c2}$			
5	GHG emission coefficient for energy produced and used on-site	$K_{site,c1}$	$K_{site,c2}$			
6	Mass of GHG emission (as kg CO_2 equivalent) for energy produced and used on-site	$m_{site,c1}$	$m_{site,c2}$		$\eta m_{site,ci}$	
7	Total (Carbon metric 1/2)				mCO_2e_{ci}	

NOTE 1 The quantity of energy carrier can be described “N/A” in case where its GHG emission coefficient is zero.

NOTE 2 The energy carrier type is identified based on the GHG coefficient.

Table 5 — Inventory of energy carriers and calculation of the carbon metric for CM3

		Energy carrier **C1**	Energy carrier **C2**	**...**	Refrigerant **R1**	**...**	**C**	
1	Mass of GHG emissions (as kg CO_2 equivalent) for delivered energy	$m_{del,c1}$	$m_{del,c2}$				$\eta m_{del,ci}$	
2	Mass of GHG emission (as kg CO_2 equivalent) for energy produced and used on-site	$m_{site,c1}$	$m_{site,c2}$				$\eta m_{site,ci}$	
3	Energy exported	$E_{exp,c1}$	$E_{exp,c2}$					
4	GHG emission coefficient for exported energy	$K\,\alpha_{exp,c1}$	$K\,\alpha_{exp,c2}$					
5	Weighted mass of GHG emission for exported energy	$m\alpha_{exp,c1}$	$m\alpha_{exp,c2}$				$\eta m\alpha_{exp,ci}$	
6	Refrigerant				F_{r1}			
7	Global Warming Potential of GHG				$W\,\alpha_{r1}$			
8	Weighted mass of GHG emission from refrigerant				m_{rr1}		ηm_r	
9	Total (Carbon metric 3)						MCO_2e_{ci}	

NOTE Information described in Table 4 is also included in CM3.

6.2.2 Additional information

The report should indicate the following information, where relevant:

a) owner’s name and contact information;

b) category of industry the building serves (in case of non-residential use);

c) detailed inventory of appliances;

d) point of time of last change of tenant;

e) technical information depending on the purpose of measurement;

f) exported energy including the related greenhouse gas emissions.

6.3 Communication of the carbon metric

6.3.1 Type of communication

There are two types of communication that may be used to make the carbon metric publicly available (see Figure 5):

— a carbon metric declaration;

— a carbon metric claim.

NOTE In relation to a carbon metric communication, the term “publicly available” means a communication that is deliberately placed in the public domain or intended to be available to consumers, for instance, through an intentional publication or through an open Internet site. Communications which are, for instance, exchanged between businesses or posted on a restricted access Internet site are not classified as publicly available even if they subsequently enter the public domain through the unforeseen actions of a third party.

6.3.1.1 Carbon metric declaration

A carbon metric declaration is the communication of a carbon metric that has been verified by an independent third party in accordance with ISO 16745-2.

Assumptions made to create the declaration shall be included in the documentation of the organization or individual determining the carbon metric, which shall be referenced in the declaration and made available upon request.

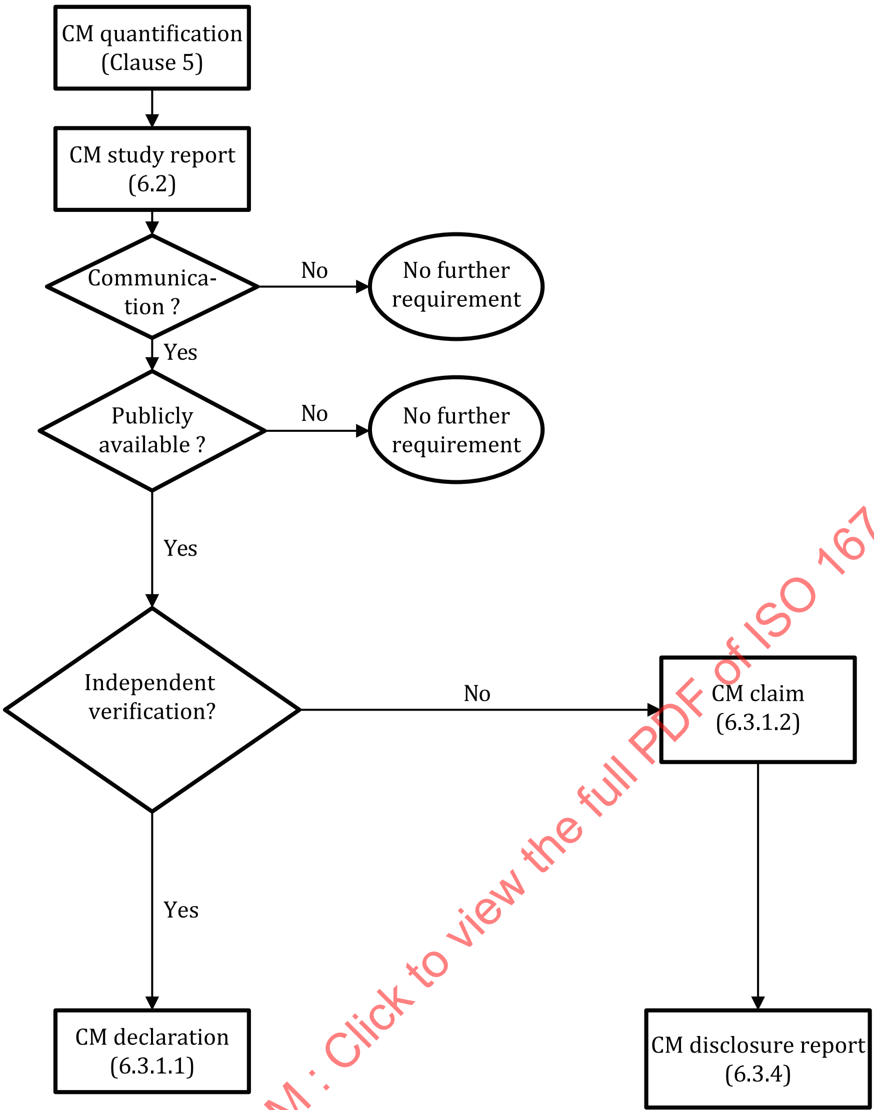

Figure 5 — Communication flow of carbon metric

6.3.1.2 Carbon metric claim

A carbon metric claim is the communication of a carbon metric that has not been verified by an independent third party.

When an organization decides to make a carbon metric claim publicly available, the communication of the evaluation of the carbon metric shall be supported by a carbon metric disclosure report (see 6.3.4).

Assumptions made to create the claim shall be included in the documentation of the organization or individual determining the carbon metric, which shall be referenced in the claim and made available upon request.

6.3.2 Provision of information

For the purpose of communication, information included in the carbon metric study report may be condensed and presented in tabular, graphical, or other format.

For any form of communication, it shall include the following:

a) value(s) of the carbon metric(s);

b) value(s) of the carbon intensity(ies) determined;

c) purpose of the communication;

d) type(s) of the carbon metric (e.g. CM1, CM2, or CM3);

e) measurement period and date of the evaluation;

f) name of the company or individual doing evaluation (self-measurement or third party);

g) list of energy end use included in the carbon metric in relation to the type of CM;

h) whether the allocations are measured or estimated (see Table 1);

i) source of GHG emission coefficient (publication, organization, year of the coefficient measured);

j) building type and use including multi-use building.

In addition, the following building-related information shall be included, where relevant:

a) building identification [name of building(s), physical address];

b) floor area (gross, net lettable, conditioned, occupied) for each use;

c) occupancy (number of persons, operation schedule);

d) year of construction of building (for each building of a complex);

e) year of latest major renovation affecting energy use (e.g. change of HVAC, change of building envelope);

f) year of change in use.

6.3.3 Availability of information

When carbon metric declarations are made, they shall be made available to any party with business or consumer interest who requests the information.

6.3.4 Carbon metric disclosure report

6.3.4.1 General

Carbon metric claim that is disclosed to the public and supported by a carbon metric disclosure report shall not imply that the communication is verified by a third party.

The results, data, methods, assumptions, and limitations shall be published in a transparent manner and presented in sufficient detail to allow the reader to comprehend the complexities inherent in the carbon metric. The carbon metric disclosure report shall also allow the results and interpretation to be used in a manner consistent with the goals of the carbon metric determination.

6.3.4.2 Requirements for the carbon metric disclosure report

The carbon metric disclosure report shall contain the carbon metric study report and the following information:

a) a disclaimer stating the relevant limitations of various potential uses;

b) disclosure and justification of the methods used.

6.3.5 Explanatory material

The organization making the declaration or the claim shall provide, upon request, available explanatory material to facilitate understanding of the data in the declaration or the claim, e.g. a carbon metric disclosure report. Means of obtaining the explanatory material shall be clearly stated. This may be a telephone number, address, or electronic access (e.g. email, URL).

Annex A
(informative)

Aim of carbon metric

A carbon metric aims to ensure comparability and consistency in global reporting of measurement of greenhouse gas emissions associated with activities related to the use of buildings.

A carbon metric is calculated by a common protocol and ensures that data are collected through the same method and parameters.

With detailed analysis, a carbon metric of a building can be used for the following:

— benchmarking, by provision of a consistent reporting framework for both industry and government that work in a local and international context;

— baselining, by supporting consistent reporting of operational carbon footprints from buildings to enable comparisons of buildings across cities and countries and provide a basis for funding allocations and international agreements;

— monetizing, by provision of a consistent measurement basis for monetization of carbon trading measures for the building and construction sector, which will in turn stimulate market activity by incentivising energy efficiency.

Annex B
(informative)

Building energy use defined by usage by ISO 12655

B.1 Classification of building energy use by usage

According to the energy usage in buildings, as shown in Figure 1, the total building energy use is classified as follows:

— energy for HVAC and domestic hot water, including energy for space heating, energy for space cooling, energy for air movement, and energy for domestic hot water;

— energy for lighting and plug-in, including energy for lighting and energy for household/office appliances;

— energy for other ultimate usage, including energy for indoor transportation and energy for building auxiliary devices;

— energy for other special usage, including energy for cooking, energy for cooling storage, energy for devices in data centre, and energy for other specific functional devices.

See Figure B.1.

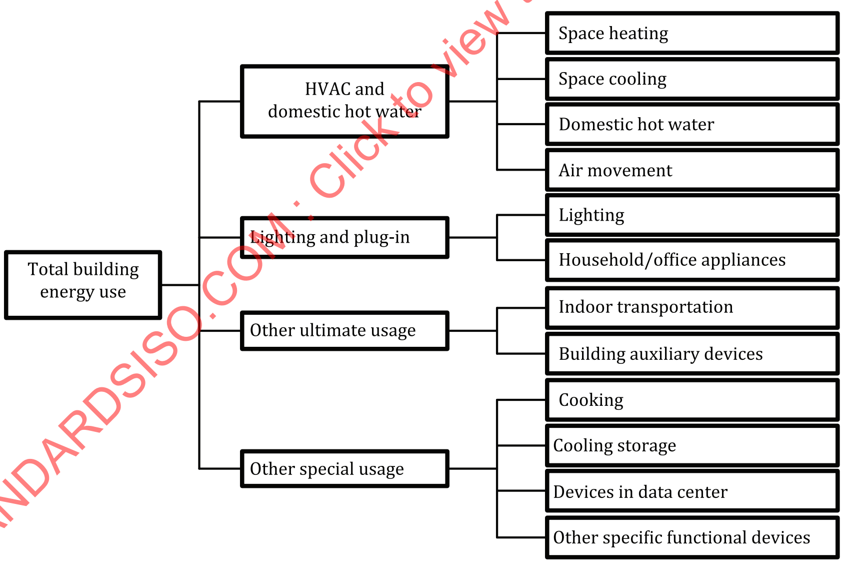

Figure B.1 — Usage of energy in buildings

B.2 Energy for space heating

The energy used to provide heat (including humidification) for space heating of the building is energy for space heating.

B.3 Energy for space cooling

The energy used to provide cold (including dehumidification) for space cooling of the building is energy for space cooling.

B.4 Energy for air movement

The energy used by the mechanical ventilation fans for building ventilation and air circulation is energy for air movement. It includes electricity consumed by fans inside air handling devices (air handling unit, outdoor air processor, fan coil unit, etc.), exhaust fans in toilet, ventilation fans in the garage, and other ventilated spaces.

B.5 Energy for domestic hot water

The energy used to produce and transport hot water for building domestic water service is energy for domestic hot water.

B.6 Energy for lighting

The energy used by the lamp(s), control gear, and control circuit in or associated with luminaries is energy for lighting. It includes the indoor lighting and exterior lighting. The indoor lighting is usually composed of lighting for public space and private space.

B.7 Energy for household/office appliances

The energy used by the household and office appliances, such as personal computers, printers, drinking fountains, and TVs, is energy for household/office appliances.

B.8 Energy for indoor transportation

The energy used by the indoor transportation devices in buildings, such as lifts, escalators, and passenger conveyors, is energy for indoor transportation.

B.9 Energy for building auxiliary devices

The energy used by all kinds of the building auxiliary devices that serve the building, such as pumps for water supply and drainage and automatic door, is energy for building auxiliary devices.

B.10 Energy for cooking

The energy used for cooking inside a building is energy for cooking. It includes the fuel and electricity consumed by cooking utensils and exhaust fans in the kitchen.

NOTE The energy used by the exhaust fans in the kitchen does not belong to the item of energy for air movement.

B.11 Energy for cooling storage

The energy used by the refrigeration devices for storage is energy for cooling storage.

B.12 Energy for devices in data centre

The energy used by the devices in data centres inside the building, including servers and ancillary air-conditioning, is energy for devices in data centre.

B.13 Energy for other specific functional devices

The energy used by other specific functional devices, such as medical equipment, laundry equipment, and auxiliary devices of swimming pool, is energy for other specific functional devices.

Annex C
(informative)

Types of factors or coefficients by ISO 16346

C.1 General

The aggregation uses factors and coefficients determined at a national level according to the rules given below. Values for factors needed to calculate the primary energy and/or CO_2 emissions should be defined in a national annex.

NOTE ISO 16346:2013, 6.4.2 provides factors that can be used if no national values are given.

In a multi-plant generation system (e.g. electricity, district heating), the weighting factor at any time depends on which generation plants operate continuously and which plants are affected by a change in energy demand. A distinction between average, marginal, and end-use factors or coefficients may therefore be appropriate for the aggregation.

C.2 Average factor or coefficient

The average factor or coefficient reflects the annual average impact of all plants delivering energy (directly or indirectly) to the building. It is calculated by estimating the total impact (primary energy use, CO_2 production) during a year and divided by the total energy delivered.

C.3 Marginal factor or coefficient

If energy use or production is reduced (or increased), not all power stations are affected equally: the operation of “base load” stations is unchanged. A decrease in demand is met by reduced operation of other plants. Exported energy by a building reduces the need of a new plant.

The marginal factor or coefficient takes into account only production units that are affected by such changes in energy demand or production. For example, the marginal new plant factor or coefficient relates to a new plant that should be built if the energy demand increases or that is saved due to exported electricity produced on the building sites.

C.4 End use factor or coefficient

Different building services produce demands at different times — lighting, heating, air-conditioning, for example, each having very different demand patterns — and this might justify the use of specific demand-weighted factors for different end-uses.

C.5 Use of environmental declaration

The environmental declaration, as defined in ISO 14025, is based on the life cycle assessment methodology (LCA). Information about use of energy resource and CO_2 can be used as a basis to express the useful indicator related to primary energy or CO_2.

Annex D
(informative)

Allocation of emissions related to target energy in combined heat and power generation by VDI 4660 Part 2

NOTE The content of this annex was primarily derived from VDI 4660 Part 2 (2003).

D.1 Allocation of the produced emissions to the cogeneration products

For combined generation of heat and power (or even more cogeneration products) in the same plant, there is always the problem of how to allocate the produced emissions to the cogeneration products.

a) Heat and/or power supplied from cogeneration system outside the boundary (Figure D.1).

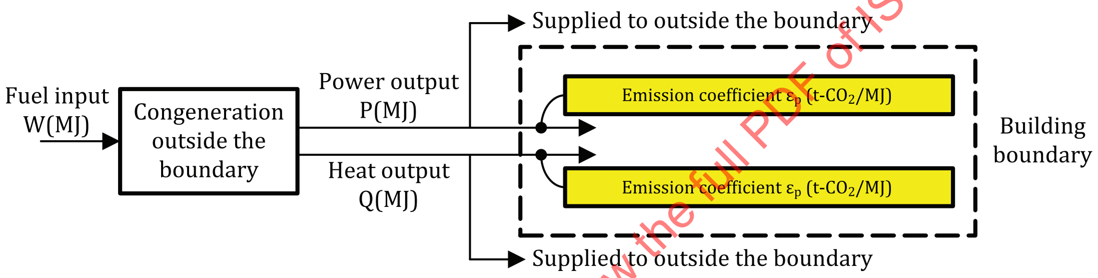

Figure D.1 — Cogeneration system outside the boundary

b) Heat and/or power produced by cogeneration system inside and part of them supplied to outside (Figure D.2).

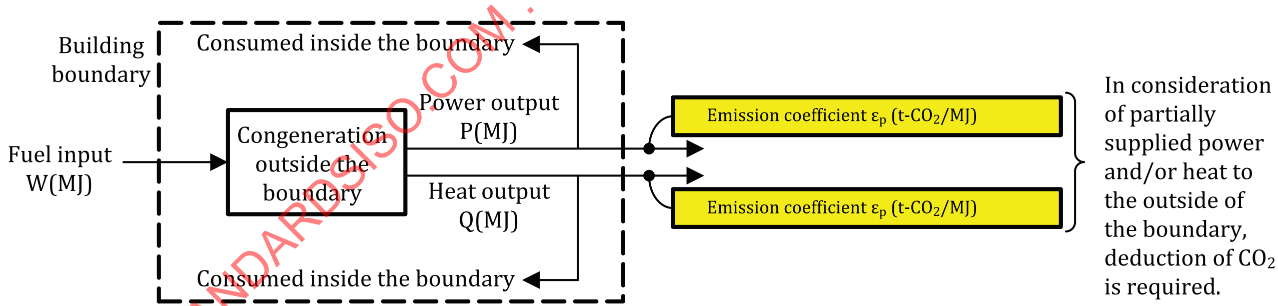

Figure D.2 — Cogeneration system inside and part supplied to outside the boundary

D.2 Methods of allocation in VDI 4660 Part 2 (2003)

In the literature, various methods of allocating specific emissions are suggested, all of which must satisfy the energy balance equation. VDI 4660 Part 2 introduces various methods:

D.2.1 Balance

Formula (D.1) applies for the allocation of the emissions E of exhaust components to the different types of target outputs (P: power, Q: heat) from combined heat and power (CHP) generation:

$$E = P \cdot \varepsilon_p + Q \cdot \varepsilon_q \qquad (D.1)$$

where

P (MJ)	is the target power output(1 MJ = 1/3.6 kWh);
Q (MJ)	is the target heat output;
W (MJ)	is the input fuel for CHP;
E (t-CO_2)	is the emission flow rate;
ε_p (t-CO_2/MJ)	is the emission coefficient of the exhaust component for target power output (P);
ε_q (t-CO_2/MJ)	is the emission coefficient of the exhaust component for the target heat output (Q).

The emission coefficients can be determined using the methods described below. The methods of allocation described in D.2.2 to D.2.4 can be applied regardless of the conversion technology used and of the considered comparison of separate generation as against cogeneration of the same flow rates of useful energy. The methods of allocation described in D.2.5 to D.2.7, on the other hand, require varying degrees of detailed knowledge of the separate generation technology used for comparison. Different primary fuels used for CHP and for separate generation of heat and power therefore affect the results.

D.2.2 Method 1: Energy (calorific value) method

In the energy method, the specific emissions are allocated to the cogeneration products according to the energy of the different types of target energy, as shown in Formula (D.2):

$$\varepsilon_p = \varepsilon_q = E/(P + Q) \quad \text{(D.2)}$$

D.2.3 Method 2: Electricity reduction (power loss) method

The electricity reduction method takes into account the electric output and the electric power reduction ΔP due to heat extraction. The latter represents the electric output that could be obtained if the extraction steam expands completely in a corresponding condensing turbine.

For the emission coefficients, Formulae (D.3) and (D.4) then apply:

$$\varepsilon_p = E / (P + \Delta P) \quad \text{(D.3)}$$

$$\varepsilon_q = E / Q \cdot (\Delta P / (P + \Delta P) = \varepsilon_p \cdot (\Delta P / Q) \quad \text{(D.4)}$$

NOTE In Europe, the “electricity reduction method” is sometimes referred to as the “power loss method”.

D.2.4 Method 3: Exergy (carnot) method

The exergy method takes into account the electric output and the exergy of heat.

The exergy flow rate (Ex_p) of the electric output is shown as Formula (D.5):

$$Ex_p = P \quad \text{(D.5)}$$

Formulae (D.6) and (D.7) apply with respect to the exergy flow rate transferred to the heat-utilization system (heating medium):

$$Ex_q = \eta c \cdot Q \quad \text{(D.6)}$$

$\eta c = 1 - (T_{amb}/T_m)$, Carnot factor at ambient temperature T_{amb} (D.7)

If the specific heat capacity of the heating medium remains constant and if pressure drops are neglected, the thermodynamic mean temperature, T_m [K], between the supply and return lines is given in Formula (D.8):

$$T_m = (T_{supply} - T_{return}) / \ln(T_{supply}/T_{return}) \quad (D.8)$$

For small ΔT, arithmetic mean temperature may also be used as shown in Formula (D.9):

$$T_m = (T_{supply} + T_{return}) / 2 \quad (D.9)$$

Thus, Formulae (D.10) and (D.11) apply for the emissions factors:

$$\varepsilon_p = E/P * Ex_p / (Ex_p + Ex_q) = E / (P + \eta_c \cdot Q) \quad (D.10)$$

$$\varepsilon_q = E/Q * Ex_q / (Ex_p + Ex_q) = \eta_c \cdot E / (P + \eta_c \cdot Q) = \eta_c \cdot \varepsilon_p \quad (D.11)$$

NOTE In Europe, the “exergy method” is sometimes referred to as the “Carnot method”.

D.2.5 Method 4: Exergy loss method

In the exergy loss method, the primary energy saved by employing CHP generation is calculated from the different exergy losses between separate generation and co-generation.

As a result, the primary energy saved via CHP can be assigned to the two cogeneration products, and the specific emissions can be allocated accordingly.

This analysis requires detailed information concerning the parameters of the CHP plant and the parameters of the processes for comparison, e.g. the thermodynamic mean temperatures of the heat supplied for the generation of live steam, of the extracted heat, and of the waste heat removed to the heat sink.

D.2.6 Method 5: Exergy remainder value (residual) method

Similar to the allocation of costs to the products of cogeneration, the remainder value method allocates a certain specific emission to one of the two types of target energy, and the remainder is attributed to the other target energy. In CHP plants, it appears opportune to attribute those specific emission ε_p to the net eclectic energy produced which are calculated from the national power plant mix. Alternatively, specific emissions ε_q can be attributed to the co-generated heat, which are calculated from heat generated separately using the same fuel in a district heating plant or boiler, for example. There are, therefore, different possible ways to allocate the emissions:

a) given ε_p:

   It follows from balance formula ($E = P \cdot \varepsilon_p + Q \cdot \varepsilon_q$) that

   $\varepsilon_q = (E - P \cdot \varepsilon_p) / Q$;

   NOTE 1 In Europe, it is known as the “residual heat method” or “power bonus method”.

b) given ε_q:

   It follows from balance formula ($E = P \cdot \varepsilon_p + Q \cdot \varepsilon_q$) that

   $\varepsilon_p = (E - Q \cdot \varepsilon_q) / P$