ITUPublications
Recommendations

International Telecommunication Union
Standardization Sector

Recommendation

ITU-T L.1480 (12/2022)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

Assessment methodologies of ICTs and CO2 trajectories

Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

OPTICAL FIBRE CABLES	
Cable structure and characteristics	L.100–L.124
Cable evaluation	L.125–L.149
Guidance and installation technique	L.150–L.199
OPTICAL INFRASTRUCTURES	
Infrastructure including node elements (except cables)	L.200–L.249
General aspects and network design	L.250–L.299
MAINTENANCE AND OPERATION	
Optical fibre cable maintenance	L.300–L.329
Infrastructure maintenance	L.330–L.349
Operation support and infrastructure management	L.350–L.379
Disaster management	L.380–L.399
PASSIVE OPTICAL DEVICES	L.400–L.429
MARINIZED TERRESTRIAL CABLES	L.430–L.449
E-WASTE AND CIRCULAR ECONOMY	L.1000–L.1199
POWER FEEDING AND ENERGY STORAGE	L.1200–L.1299
ENERGY EFFICIENCY, SMART ENERGY AND GREEN DATA CENTRES	L.1300–L.1399
ASSESSMENT METHODOLOGIES OF ICTS AND CO2 TRAJECTORIES	**L.1400–L.1499**
ADAPTATION TO CLIMATE CHANGE	L.1500–L.1599
CIRCULAR AND SUSTAINABLE CITIES AND COMMUNITIES	L.1600–L.1699
LOW COST SUSTAINABLE INFRASTRUCTURE	L.1700–L.1799

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T L.1480

Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors

Summary

Recommendation ITU-T L.1480 provides a methodology for assessing how the use of information and communication technology (ICT) solutions impacts greenhouse gas (GHG) emissions of other sectors. More specifically, the methodology provides guidance on the assessment of the use of ICT solutions covering the net second order effect (i.e., the resulting second order effect after accounting for emissions due to the first order effects of the ICT solution), and the higher order effects such as rebound. By providing a structured methodological approach, it aims to improve the consistency, transparency and comprehensiveness of assessments of how the use of ICT solutions impacts GHG emissions over time.

Guidance is provided to assess the net second order effect and higher order effects of the following cases:

– ICT solution(s) implemented in a specific context by the user of the ICT solution(s).

– ICT solution(s) implemented at different scales, including at an organizational level (whether private or public organizations), at a city level, at a country level or at worldwide level.

– ICT solution(s) seen from the perspective of an ICT organization contributing to the ICT solution(s). This includes:

  • Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all its customers;

  • Assessment of the aggregated effect of one or several ICT solutions provided by an ICT organization across some of its customers;

  • Assessment of the effect of one or more specific ICT solutions implemented in an actual context for a specific customer.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1480	2022-12-06	5	11.1002/1000/15030

Keywords

Added emissions, avoided emissions, decarbonization, enabled effects, enablement, first order effects, greenhouse gas emission, higher order effects, ICT sector, induced effects, information and communication technology, rebound effects, second order effects.

---

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Introduction

The *Paris Agreement* of the United Nations Framework Convention on Climate Change [b-UNFCCC-2], which aims to keep the global temperature rise by 2100 well below 2°C above preindustrial levels, entered into force on 4 April 2016. Subsequently, in 2021, the Glasgow Climate Pact recognized that limiting global warming to 1.5 °C above preindustrial levels requires rapid, deep and sustained reductions in global greenhouse gas emissions, including reducing global carbon dioxide emissions by 45 per cent by 2030 relative to the 2010 level and to Net Zero around mid-century, as well as deep reductions in other greenhouse gases [b-UNFCCC-1].

In this context, companies across sectors are establishing strategies to increase their decarbonization efforts. In this regard, [ITU-T L.1471] encourages ICT organizations to, in addition to their Net Zero reduction and removal approaches, to also help society to reach a Net Zero state. Thus, beyond working on their own transition to a Net Zero state, ICT organizations should also use their deliverables to support other sectors in their transformation. Here, ICT, unlike many other products and services, distinguishes itself by its double-edged nature.

ICTs though their physical existence have environmental impacts at each stage of their lifecycles (first order effects) which need decarbonization. ICTs can also enable vast efficiencies in lifestyle and in all sectors of the economy through the provision of solutions that can improve energy efficiency, inventory management and business efficiency by reducing travel and transportation, and by substituting digital information for physical products (positive second order effects). At the same time, ICT can be employed in uses that serve to maintain or even increase the fossil-based economy (negative second order effects), resulting in higher GHG emissions. Additionally, effects enabled by the use of ICT solutions can be modified due to rebound, i.e., the tendency that increased efficiency is offset by increases in emissions due to e.g., consumption. Moreover, ICTs have structural effects at the societal level by reshaping how people lead their lives. (These two effects are jointly referred to as higher order effects and can be positive or negative.**)**

These different effects of ICT could be illustrated by a high-security videoconference system (the ICT solution) installed in a bank with offices in several countries to reduce company-internal travelling as well as travelling to meet customers (the reference activities). The first order effects of the videoconferencing system would be associated with the lifecycle GHG emissions of any hardware and software used for the service (i.e., its footprint). A change in the first order effects could for example be due to an update of software resulting in lower energy consumption in laptops or data centres and thereby lower GHG emissions. Second order effects of the service occur when the service is used by the bank and represents the direct effect of the ICT solution on the reference activity (i.e., the travelling of the bank employees). This represents any change in GHG emissions resulting from reduction in internal business travel and customer visits due to the introduction of the service (the effect associated with the intended usage) and associated company policies. Typically, the size of the second order effect depends on company policies and incentives. Higher order effects categorize any further consequence of introducing the videoconference system. These are associated with any other change in GHG emissions resulting from e.g., direct change in behaviour such as increases in the number of meetings between offices due to the accessibility of the service, changes in investment patterns due to the financial savings made by the reduced travelling, or indirect changes in behaviours due to aspects such as financial gains and time saving spent on other activities.

The potential of ICT solutions to reduce the GHG emissions of other sectors and to foster the transition to Net Zero has been brought forward by many parties. This Recommendation covers the assessment of GHG emissions reduction in other sectors due to specific ICT solutions, while providing enhanced methodological guidance to help society to identify ICT solutions and implementations enabling Net Zero. Though this is the main aim, the methodology also acknowledges that some ICT solutions may have neutral or even adverse second order effects, and that the identification of the later would be an equally important task. Hence the methodology is

agnostic to the outcome of the assessment whether it be a reduction or an increase of GHG emissions. Addressing both cases, the methodology provides guidance on the assessment of the use of ICT solutions covering the net second order effect (i.e., the remaining second order effect after accounting for the emissions due to the aggregated first order effect of the ICT solution), and the higher order effects.

This Recommendation applies a hybrid approach including elements of both consequential and process-sum life cycle assessment (LCA) — the scoping considers consequential principles, whereas the quantitative assessment is based on process-sum LCA.

NOTE – [b-EC-2] provides a detailed assessment of the differences between consequential and attributional (process-sum) LCAs.

This Recommendation provides a comprehensive methodology for several types of assessment targeting the effects associated with the usage of ICT solutions while intending to foster good assessment practice and the transparent reporting of results. The Recommendation is intended to give generic guidance to practitioners representing different stakeholders including, inter alia, ICT companies, organizations and researchers. However, this Recommendation cannot be used as is for accounting purposes but would need specific provisions regarding its application to be issued by the commissioner of such initiatives.

The starting point for this Recommendation is ITU-T L.1410 which describes the assessment of the enabling effects of ICT in its Part II on Comparative analysis/LCA between ICT and reference product systems (baseline scenario): framework and guidance.

Moreover, this Recommendation builds on [ITU-T L.1440], [ITU-T L.1430] and [ITU-T L.1451] and has also considered previous work by organizations, authorities and researchers including but not limited to work by the French Agency for Ecological Transition (ADEME), GSMA, the World Resources Institute (WRI), Mission Innovation and individual researchers.

Further details on these methodologies are given in appendix I.

This Recommendation is limited to assessment of GHG emissions. However, in principle, it could also be used to identify other environmental effects such as induced pollution, enabling biodiversity preservation, reduced use of raw materials or water resources.

Recommendation ITU-T L.1480

Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors

1 Scope

This Recommendation provides guidance for assessing how the use of ICT solutions impacts GHG emissions of other sectors, using a robust and sound methodology. The guidance is agnostic to the outcome of the assessment, whether it be an addition or an avoidance of GHG emissions, and addresses both positive and negative effects.

Specifically, the methodology provides guidance on the assessment of the use of ICT solutions covering the net second order effect (i.e., the resulting second order effect after accounting for emissions due to the first order effects of the ICT solution), and the higher order effects. Moreover, the methodology also distinguishes between effects associated with actual reductions of GHG emissions and lesser increases in GHG emissions, as well as between immediate and mid-term/long-term effects.

The methodology is provided for the following types of assessments:

- Assessment of the second order effect of one or several ICT solution(s) implemented in a specific context by the user of an ICT solution while also considering higher order effects.
- Assessment of the second order effect of one or several ICT solution(s) implemented at different scales, including at an organizational level (whether private or public organizations), at a city level, at a country level or at worldwide level, while also considering higher order effects.
- Assessment of the second order effect of one or several specific ICT solution(s) from the perspective of an ICT organization contributing to ICT solution(s) while considering also higher order effects. This includes:
    - Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all customers;
    - Assessment of the aggregated effect of one or more ICT solutions provided by an ICT organization across some customers;
    - Assessment of the effect of one or more specific ICT solutions implemented in an actual context for a specific customer.

The methodology covers different depths of assessment, referred to as Tier 1–3. Each of these is associated with specific requirements on data quality and provides specific guidance for the consideration of rebound effects. Moreover, the Recommendation addresses assessments from three different time perspectives:

- Ex-ante, i.e., a prospective assessment taking place before the assessed operation period of the ICT solution(s);
- Mid-way, i.e., an assessment of a present situation during the operational life of the ICT solution(s);
- Ex-post, i.e., a retrospective assessment that takes place after the assessed operation period of the ICT solution(s).

Effects associated with increases of GHG sinks are not included in the present version of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a standalone document, the status of a Recommendation.

[ITU-T L.1400] Recommendation ITU-T L.1400 (2011), *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies*.

[ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services*.

[ITU-T L.1430] Recommendation ITU-T L.1430 (2013), *Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects*.

[ITU-T L.1440] Recommendation ITU-T L.1440 (2015), *Methodology for environmental impact assessment of information and communication technologies at city level.*

[ITU-T L.1451] Recommendation ITU-T L.1451 (2019), *Methodology for assessing the aggregated positive sector-level impacts of ICT in other sectors*.

[ITU-T L.1471] Recommendation ITU-T L.1471 (2021), *Guidance and criteria for information and communication technology organizations on setting Net Zero targets and strategies.*

[ISO 14044] ISO 14044:2006, *Environmental management – Life cycle assessment – Requirements and guidelines*.

[ISO 14064-3] ISO 14064-3:2019, *Greenhouse gases – Part 3: Specification with guidance for the verification and validation of greenhouse gas statements*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 activity data [ITU-T L.1410]: A quantitative measure of a level of activity that results in GHG emissions.

NOTE – See clause 7.2 of [b-GHGP-2].

3.1.2 CO_2 equivalent (CO_2e) [ITU-T L.1410]: The universal unit of measurement to indicate the global warming potential (GWP) of each of the seven greenhouse gases, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate releasing (or avoiding releasing) different greenhouse gases against a common basis.

NOTE – See [b-GHG Protocol CS], glossary.

3.1.3 comparative analysis [ITU-T L.1410]: Analysis aiming to compare two different product systems based on the same functional unit.

3.1.4 cut-off [ITU-T L.1410]: Amount of energy or material flow, or the level of environmental significance associated with unit processes or product systems excluded from the study.

NOTE – Unit processes excluded from the studied product system in an LCA.

3.1.5 emission factor [ITU-T L.1410]: A factor allowing GHG emissions to be estimated from a unit of available activity data (e.g., tonnes of fuel consumed, tonnes of product produced) and absolute GHG emissions. See [b-GHG Protocol CS], glossary.

NOTE – Another example is: $kgCO_2e/kWh$ electricity, $kgCO_2e/(tonne \times km)$.

3.1.6 environmental impact [ITU-T L.1410]: Impact including positive and negative aspects on the environment.

3.1.7 environmental load [ITU-T L.1410]: Environmental aspect which potentially causes interference with environmental conservation.

3.1.8 functional unit [b-ISO 14040]: quantified performance of a product system for use as a reference unit.

NOTE 1 – In an assessment of second order effects both the ICT solution scenario and the reference scenario are considered product systems and the functional unit must be chosen in a way that makes it applicable to both.

NOTE 2 – The functional unit defines the performance characteristics delivered by the ICT solution scenario and the reference scenario. The functional unit shall have a function and a quantifiable unit measuring the performance of that function. [ITU-T L.1410] clause 6.2.2 gives guidance on the functional unit.

3.1.9 global warming potential (GWP) [ITU-T L.1410]: Ratio of the warming of the atmosphere caused by one greenhouse gas to that caused by a similar mass of carbon dioxide. GWP is calculated over a specific time frame, generally 100 years.

3.1.10 ICT goods [ITU-T L.1410]: Tangible goods deriving from or making use of technologies devoted to or concerned with:

- the acquisition, storage, manipulation (including transformation), management, movement, control, display, switching, interchange, transmission or reception of a diversity of data;
- the development and use of the hardware, software, and procedures associated with this delivery; and
- the representation, transfer, interpretation, and processing of data among persons, places, and machines, noting that the meaning assigned to the data is preserved during these operations.

NOTE – [b-ETSI TS 103 199] used the word "equipment" instead.

3.1.11 ICT network [ITU-T L.1410]: Set of nodes and links that provide physical or over the air information and communication connections between two or more defined points.

EXAMPLE – Wireless network, fixed network, local area network (LAN), home network and server network, access networks, core networks, cloud computing networks.

3.1.12 ICT organization [b-ITU-T L.1420]: An ICT organization is an organization, the core activity of which is directly related to the design, production, promotion, sales or maintenance of ICT goods, networks or services.

3.1.13 ICT project [ITU-T L.1430]: A set of activities intended to implement a specific task that uses mainly ICT goods, networks and services. The task may consist of undertaking one or more ICT project activities with the ICT goods, networks and services.

3.1.14 ICT sector [ITU-T L.1451]**:** The ICT sector includes industrial companies producing goods or services that must primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display.

NOTE – This definition is based on [b-ISIC].

3.1.15 ICT service (application) [ITU-T L.1410]: Use of information and communication technology (ICT) goods and/or networks to provide value to one or more users.

NOTE – Examples are teleconferencing, teleworking, e-ticketing, e-learning, e-healthcare, smart transport and logistics, procurement systems, supply chain management systems, music/film distribution over the Internet or voice over IP, machine-to-machine systems.

3.1.16 ICT-specific data [ITU-T L.1410]: Data emerging from ICT-specific applications and processes.

NOTE –These data could be either primary or secondary.

3.1.17 infrastructure [ITU-T L.1410]: Basic structures needed for the operation of the society.

EXAMPLE – Transportation systems, buildings and power plants.

3.1.18 life cycle [b-ISO 14040]: Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal

NOTE – Recommendation ITU L.1410 defines the life cycle of ICT goods, networks and services.

3.1.19 life cycle stage [ITU-T L.1410]: One of several consecutive and interlinked stages of a product system.

3.1.20 metadata [b-ISO/IEC 2382]: Data about data or data elements, possibly including their data descriptions, and data about data ownership, access paths, access rights and data volatility.

NOTE – In this Recommendation metadata regarding ownership, access and violation is not addressed

3.1.21 modelled data [ITU-T L.1410]: Assumption-driven estimates, such as estimates resulting from scenarios, which are forward looking or scaled up from smaller pilot studies.

3.1.22 operator [ITU-T L.1410]: Organization operating networks and services.

3.1.23 primary data [b-ISO 14046]: Quantified value of a unit process or an activity obtained from a direct measurement or a calculation based on direct measurements at its original source.

NOTE 1 – Primary data need not necessarily originate from the product system under study because primary data may relate to a different but comparable product system to that being studied.

NOTE 2 – In practice, primary data may be emission factors and/or activity data.

NOTE 3 – Primary data includes site-specific data, i.e., data from one specific unit process within a site; and site-average data, i.e., representative averages of site-specific data collected from organizations within the product system which operate equivalent processes.

3.1.24 product system [b-ISO 14040]: Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product

3.1.25 raw material[b-ISO 14040]: Primary or secondary material that is used to produce a product.

NOTE – Secondary material includes recycled material.

3.1.26 raw material extraction [ITU-T L.1410]: Production of extracted raw materials used in raw material processing×.

3.1.27 raw material processing [ITU-T L.1410]: Production of processed raw materials used in the production of a part.

3.1.28 reference product system [ITU-T L.1410]: System (basically non-ICT but can also be ICT) which is replaced by ICT.

EXAMPLE – Traditional service which is replaced by an ICT service.

3.1.29 secondary data [b-ISO 14046]: Data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source.. NOTE – Such sources can include databases (a list of LCA databases (publicly available and licence based)) provided by the EU, published literature, national inventories and other generic sources.

3.1.30 traffic [ITU-T L.1410]: Total volume of cells, blocks, frames, packets, calls, messages or other units of data carried over a circuit or network, or processed through a switch, router or other system.

3.1.31 unit process [ITU-T L.1410]: Smallest element considered in the life cycle inventory analysis for which input and output data are quantified (see also [b-ISO 14040],[ISO 14044]).

EXAMPLE – Part unit process such as IC Encapsulation and Display module assembly.

3.1.32 waste [b-ISO 14040]: Substances or objects which the holder intends or is required to dispose of.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 added emissions: Emission increases resulting from the use of a solution but occurring outside of that solution's lifecycle or value chain.

3.2.2 aggregated first order effect of the ICT solution: The combined impact of the first order effects occurring throughout the lifecycle of the ICT solution.

3.2.3 avoided emissions: Emission reductions resulting from the use of a solution but occurring outside that solution's lifecycle or value chain.

NOTE – Based on [b-WRI-1]. Sometimes the term is used to denote emission reductions within a product's lifecycle. Such a definition is impractical as it leads to overlapping avoided emissions and other concepts such as scope 3 [b-GHGP-2]. Hence such a definition is avoided. Parallel concepts are enablement, positive second order effects and abatement.

3.2.4 baseline: The quantification of a reference scenario.

3.2.5 decarbonization: The process of stopping or reducing carbon gases from being released into the atmosphere as the result of a process.

3.2.6 direct economic rebound: When the increased economic efficiency in providing some ICT solutions affects the price which leads to increased consumption of those ICT solutions.

3.2.7 direct operational efficiency rebound: When the increased operational efficiency in operating tasks leads to more of those tasks or a broader set of them being performed.

3.2.8 direct rebound effect: A rebound effect where increased efficiency, associated cost reduction and/or convenience of a product or service results in its increased use because it is cheaper or otherwise more convenient.

NOTE – Based on [b-EC-1].

3.2.9 economy-wide rebound effect: Rebound effect where more efficiency drives economic productivity overall resulting in more economic growth and consumption at a macroeconomic level.

NOTE 1 – Based on [b-EC-1].

NOTE 2 – This is not about the individual gains of the user or provider of an ICT solution

3.2.10 enablement: Enablement (also described as the enabling effect) is the reduction of emissions that occurs outside a solution's lifecycle or value chain but resulting from the use of that solution.

NOTE – See also 'avoided emissions'. Parallel concepts are avoided emissions, positive second order effects, handprint and abatement.

3.2.11 first order effect: Direct environmental effect associated with the physical existence of an ICT solution, i.e., the raw materials acquisition, production, use and end-of-life treatment stages, and generic processes supporting those including the use of energy and transportation.

NOTE 1 – First order effects include GHG and other emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.

NOTE 2 – First order effects are sometimes referred to as environmental footprints.

NOTE 3 – This definition has been amended from [ITU-T L.1410].

NOTE 4 – This Recommendation only addresses GHG emissions.

3.2.12 higher order effect: The indirect effect (including but not limited to rebound effects) other than first and second order effects occurring through changes in consumption patterns, lifestyles and value systems.

NOTE 1 – Rebound effects include effects occurring through financial gains, savings in time and space, and others.

NOTE 2 – Higher order effects could be associated with both second and first order effects.

NOTE 3 – This is amended from [ITU-T L.1410] where it is referred to as other effects, and is also referred to as higher order effects in some academic literature

3.2.13 ICT solution: A system encompassing ICT goods, ICT networks and/or ICT services that contributes to meeting a technical, societal or business challenge.

3.2.14 ICT solution scenario: A situation with the studied ICT solution applied.

3.2.15 indirect economic rebound: When the efficiency financial savings from specific ICT solutions are spent elsewhere.

3.2.16 indirect operational efficiency rebound: When the increased operational efficiency in operating tasks leads to more other tasks or a broader set of such tasks being performed.

3.2.17 indirect rebound effect: A type of rebound effect where savings from efficiency cost reductions enable more income to be spent on other products and services.

NOTE 1 – Both direct and indirect rebound effects are microeconomic.

NOTE 2 – Based on [b-EC-1].

3.2.18 induced effects: Induced effects are the reduction or increase in emissions that occurs outside a solution's lifecycle or value chain but resulting from the use of that solution.

NOTE – See also avoided and added emissions. Second order effects is a parallel concept.

3.2.19 induction: When an ICT application stimulates increased use of the application itself.

3.2.20 modifying usage: A usage of an ICT solution that modifies an activity in the reference scenario.

3.2.21 net second order effect: The resulting second order effect after accounting for emissions due to the first order effects of an ICT solution.

3.2.22 practitioner: Person(s) or organization(s) performing an assessment.

NOTE 1 – Based on the [ITU-T L.1410] definition of LCA practitioner.

NOTE 2 – Practitioners could belong to academia, private and public organizations and so on (including also ICT organizations and their customers).

3.2.23 raw material acquisition: Raw material acquisition is a life cycle stage encompassing raw material extraction and raw material processing.

3.2.24 rebound effect: Increases in consumption due to environmental efficiency interventions that can occur through a price reduction or other mechanism including behavioural responses (i.e., an efficient product being cheaper or in other ways more convenient and hence being consumed to a greater extent).

NOTE 1 – This encompasses both price-induced and psychological rebound effects leading to behavioural changes.

NOTE 2 – Based on [b-EC-1].

3.2.25 rebound usage: Usage of an ICT solution which is additional to modifying an activity in the reference scenario.

NOTE – Such usage is referred to as induction and is due to the convenience of the ICT solution.

3.2.26 reference activity: The activity which the studied ICT solution modifies (e.g., by optimizing it or substituting it partially or entirely).

3.2.27 reference scenario: The situation without the studied ICT solution applied, i.e., a situation with only the reference activity in place.

3.2.28 second order effect: The indirect impact created by the use and application of ICTs which includes changes of environmental load due to the use of ICTs that could be positive or negative.

NOTE – Second order effects can be either actual or potential.

NOTE – This definition has been amended from [ITU-T L.1410].

3.2.29 space rebound: Changes in emissions due to the use of saved space (may be direct or indirect).

3.2.30 time rebound: Changes in emissions due to the use of saved time (may be direct or indirect).

4 Abbreviations and acronyms

BACH Bank for the Accounts of Companies Harmonized

CGE Computable General Equilibrium

GHG Greenhouse Gas

GWP Global Warming Potential

ICT Information and Communication Technologies

IPCC Intergovernmental Panel on Climate Change

ISO International Organization for Standardization

LAN Local Area Network

LCA Life Cycle Assessment

LULUCF Land use, land-use change, and forestry.

UPS Uninterruptible Power Supply

WRI World Resources Institute

5 Conventions

In this Recommendation, The expressions "is required" and "shall" indicate a requirement which must be strictly followed and from which no deviation is permitted if *full compliance* to this Recommendation is to be claimed. Assessments may also declare themselves *partially compliant* to this Recommendation by complying to the majority of the requirements, if they are unable to fulfil all of them due to data gaps, a lack of transparency in databases, and so forth.

The expressions "is recommended" and "should" indicate a requirement which is recommended but not absolutely required. Thus, this requirement need not be present to claim compliance with this Recommendation.

The expressions "can optionally" and "may" indicate an optional requirement which is permissible, without implying any sense of being recommended.

6 Principles

The following principles shall be taken into consideration within the framework of this Recommendation.

- **Relevance**: Selected data and methods shall be appropriate to the assessment.
- **Completeness**: All impacts that have a material GHG emission effect and contribute to the overall result shall be included and assessed.
- **Consistency**: Meaningful analysis regarding the development of results over time shall be enabled by using the same methodological approaches for compared results.
- **Accuracy**: Biases and uncertainties shall be reduced as far as practicable.
- **Transparency**: When communicating the results, sufficient information shall be given to support the interpretation of the results. This means that data sources, data collection processes as well as the modelling and the assumptions made shall be clearly stated and motivated in the documentation, as well as all the assessment boundaries and cut-offs.
- **Conservativeness**: Conservative assumptions and values shall be used when there are uncertainties. Conservative quantification results are underestimated rather than overestimated.

7 Guidance on how to use this Recommendation

This Recommendation has been developed to support the assessment of the net second order effects of ICT solutions. The net second order effect is the resulting second order effect after accounting for the emissions due to the first order effects of an ICT solution. This Recommendation also addresses higher order effects. Clause 8 outlines different categories of ICT solutions and clause 9 summarizes the assessment procedure which is further detailed in clause 10. Finally, clauses 11–13 give specific guidance for assessments for different purposes, summarized in Table 1.

Table 1 – Overview over assessments of different aims

	Assessment of the effect of specific ICT solution(s) implemented in a specific context	**Assessment of the effects of ICT solution(s) implemented at different scales**	**Assessment of the effect of ICT solution(s) from the perspective of an organization contributing to the ICT solution**		
			Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all customers	***Assessment of the aggregated effect of one or more ICT solutions provided by an ICT organization across some customers***	***Assessment of the effect of one or more specific ICT solutions implemented in an actual context for a specific customer***
Clause	**Clause 11**	**Clause 12**	**Clause 13**	**Clause 13**	**Clause 13**
Aim	Investigation/ exploration	Investigation/ exploration	Company claims	Company claims	Company claims
Commissioned by	Any practitioner	Any practitioner	ICT organization	ICT organization	ICT organization

Table 1 – Overview over assessments of different aims

	Assessment of the effect of specific ICT solution(s) implemented in a specific context	**Assessment of the effects of ICT solution(s) implemented at different scales**	**Assessment of the effect of ICT solution(s) from the perspective of an organization contributing to the ICT solution**		
			Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all customers	***Assessment of the aggregated effect of one or more ICT solutions provided by an ICT organization across some customers***	***Assessment of the effect of one or more specific ICT solutions implemented in an actual context for a specific customer***
Assessment type	Mid-way, Ex-post: Tier 1–2 Ex-ante: Tier 1, 2 and 3 *Tier 1 recommended at meso and macro scale/ jurisdictional level*	Mid-way, Ex-post: Tier 1–2 Ex-ante: Tier 1, 2 and 3 *Tier 1 recommended at meso and macro scale/ jurisdictional level*	Mid-way, Ex-post: Tier 1–3 *Tier 1 recommended*	Mid-way, Ex-post, Ex-ante: Tier 1–3 *Tier 1 recommended*	Mid-way, Ex-post, Ex-ante:: Tier 1–3 *Tier 1 recommended*
Communication	Tier 1, 2 and 3 Reporting according to 10.5	Tier 1, 2 and 3 Reporting according to 10.5	Public: Tier 1–2 Business: Tier 1, 2 and 3 Reporting according to 10.5	Public: Tier 1–2 Business: Tier 1, 2 and 3 Reporting according to 10.5	Public: Tier 1–2 Business: Tier 1, 2 and 3 Reporting according to 10.5
Critical review required?	Recommended	Recommended	Public: required Business: recommended	Public: required Business: recommended	Public: required Business: recommended

NOTE 1 – Scales of implementation addressed in clause 12 refers to organizational level (including private and public sector organizations), city level, country level and worldwide level.

NOTE 2 – Assessment type is descripted in clause 10.1.2.

NOTE 3 – Tier 3 assessment can only give initial guidance on the effect of ICT solutions.

NOTE 4 – For assessment of the effect of ICT solution(s) from the perspective of an organization contributing to the ICT solution, communication refers either to communication intended for information exchange between business and other partners (business) and/or publicly available information aimed at consumers, public administrations external to the assessment and/or the general public (public).

Table 1 – Overview over assessments of different aims

	Assessment of the effect of specific ICT solution(s) implemented in a specific context	**Assessment of the effects of ICT solution(s) implemented at different scales**	**Assessment of the effect of ICT solution(s) from the perspective of an organization contributing to the ICT solution**		
			Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all customers	***Assessment of the aggregated effect of one or more ICT solutions provided by an ICT organization across some customers***	***Assessment of the effect of one or more specific ICT solutions implemented in an actual context for a specific customer***
NOTE 5 – Reporting according 10.5.4 includes the use of appropriate disclaimers clearly describing any uncertainty and limitations in results. NOTE 6 – Organizations may choose to self-publish their assessments. However, credibility is usually higher for studies that have undergone external review. NOTE 7 – For critical review, see clause 10.6.					

8 Identification of ICT solutions and sectors

ICT solutions are ubiquitous and appear in all sectors of society. While the first order effect always represents an environmental load, second order effects may be either beneficial or detrimental and may take effect through different GHG emissions impacting mechanisms such as:

- Substitution;
- Enablement of new usages;
- Optimizations:
  - More efficient operations and processes in terms of GHG emissions, i.e., increased efficiency;
  - More frequent use of assets and infrastructures, i.e., intensification, which give a more GHG efficient use of resources.
- Induced consumption;
- Provision of information and managing data;
- Facilitation, accessibility, affordability and rising motivation.

Of these, the effects of the first three bullets are seen as more quantifiable and hence these are the main focus of this Recommendation.

The following non-comprehensive list identifies sectors where ICT may have an impact on carbon emissions:

- Energy supply, especially for the transition to renewables;
- Transport and travel;
- Buildings;
- Industry;
- Agriculture and forestry.

ICT is also expected to have an impact on the protection of nature-based sinks.

A non-exclusive list of ICT solutions associated with these sectors are listed in Annex A.

9 Overall assessment procedure

This clause outlines the different activities that shall be included in an assessment of any ICT solution. The overall assessment procedure is summarized in Figure 1.

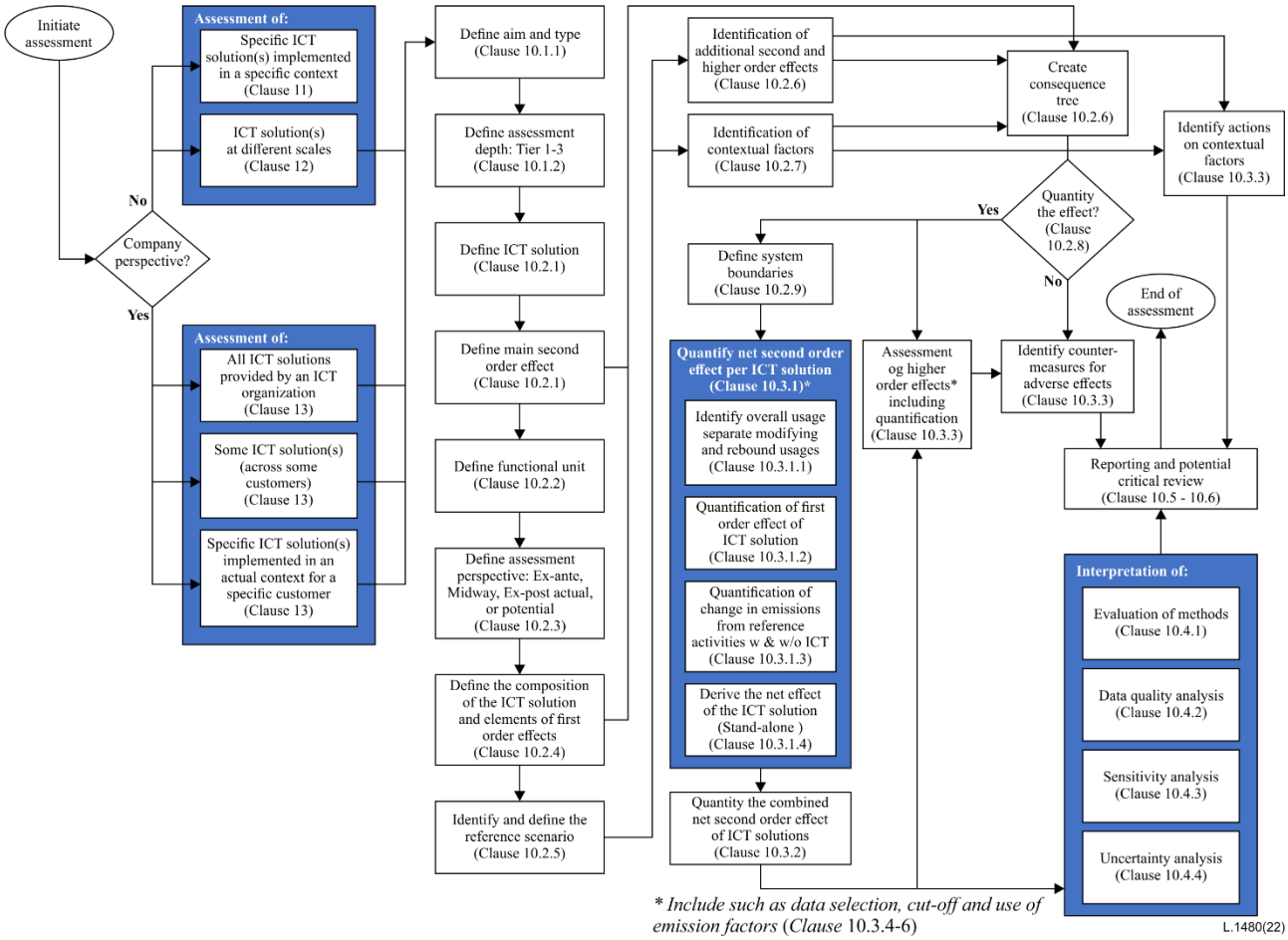


Figure 1 – Assessment procedure overview

Further details are given in clause 10 and specific guidelines for different applications of the methodology are given in clauses 11–13.

Step 1 – Define the goal of the assessment

1.1) Define the aim and type of the assessment (Clause 10.1.1);

1.2) Define the assessment depth: Tier 1, Tier 2 or Tier 3 (clause 10.1.2).

Step 2 – Scoping

2.1) Define the scope by:

- Defining the ICT solution(s) and their main second order effects (clause 10.2.1);
- Defining the functional unit (clause 10.2.2);
- Defining the assessment perspective (clause 10.2.3);
- Defining the composition of the ICT solution(s) and identifying the contributors to its overall first order effects (clause 10.2.4);

- Identifying and defining the reference scenario(s) (Clause 10.2.5);
- Identifying additional second and higher order effects of the ICT solution(s) and any relevant contextual factors and document those together with main second order effect and the first order effects following the guidelines for establishment of a consequence tree (clauses 10.2.6 and 10.2.7);
- Selection of effects to be quantified (clause 10.2.8);
- Defining the system boundaries of the ICT solution(s) and the reference scenario(s) (clause 10.2.9).

Step 3 – Modelling, data collection and calculation

3.1) Quantify the second order effect of each assessed ICT solution through:

- Identifying the overall usages of the ICT solution while separating modifying and rebound usages (clause 10.3.1.1);
- Quantifying the aggregated first order effect of the ICT solution(s) (clause 10.3.1.2);
- Quantifying the change of GHG emissions due to changes in the reference activities (clause 10.3.1.3);
- Deriving the net effect of the ICT solution(s) in a standalone scenario (clause 10.3.1.4).

3.2) Quantify the combined induced effect of several ICT solutions addressing the same emissions (clause 10.3.2);

3.3) Assessment of higher order effects including quantification (clause 10.3.3).

Step 4 – Interpretation of results

Perform interpretation of results through:

4.1) Evaluation of the applied method (clause 10.4.1);

4.2) Data quality analysis (clause 10.4.2);

4.3) Sensitivity analysis (clause 10.4.3);

4.4) Uncertainty analysis (clause 10.4.4).

Step 5 – Reporting

5.1) Perform reporting according to the guidance (clause 10.5).

Step 6 – Critical review

6.1) Perform critical review according to the guidance (clause 10.6).

10 General guidance on ICT solution assessment

This clause establishes the general methodological approach which is further specified for different applications in clauses 11–13.

10.1 Define the goal of the assessment

10.1.1 Define the aim and type of the assessment

This first step corresponds to the definition of the aim of the assessment. In particular, it shall define whether the assessment focuses on a specific implementation of one or several ICT solution(s) (clause 11), a general usage of one or several ICT solution(s) (clause 12), or the impact from an ICT company's perspective (clause 13).

Moreover, this step shall define the intended receiver or audience of the assessment, as well as whether the assessment aims to capture actual or prospective contextual conditions.

10.1.2 Define the assessment depth: Tier 1, Tier 2 or Tier 3

Before starting the assessment, the practitioner shall decide its intended depth. This Recommendation refers to three tiers of assessments:

a) **Tier 1 assessments**: Tier 1 assessments shall assess net second order effects and shall also assess impact from contextual factors and higher order effects, by quantitative means if such assessment is considered robust, or else by qualitative means. These assessments are the most in-depth ones.

b) **Tier 2 assessments**: Tier 2 assessments shall assess net second order effects, and shall identify contextual factors and higher order effects. These are assessments of intermediate depth which do not assess the magnitude of higher order effects.

c) **Tier 3 assessments**: Tier 3 assessments shall consider net second order effects and should identify contextual factors and higher order effects. These are the simplest assessments and are not considered rigorous.

The characteristics of the tiers are further specified in Table 2.

Table 2 – Overview of assessment depth

Specification	Tier 1	Tier 2	Tier 3
Type	Detailed, and including higher order effects	Detailed, and identifying higher order effects (See Note 1)	Screening / first approximation
Lifecycle stages	All (as material)	All (as material)	All (as material)
Data quality	Combination of primary, sector-specific and secondary data in line with [ITU-T L.1410]	Combination of primary, sector-specific and secondary data in line with [ITU-T L.1410]	Secondary (generic, proxies, averages)
ICT solution boundaries	Full life cycle	Full life cycle	Full life cycle
Reference scenario boundaries	Full life cycle	Full life cycle	Full life cycle
Data coverage and cut-off within boundaries	Proxy data used to cover data gaps. Cut-off rules apply.	Proxy data used to cover data gaps. Cut-off rules apply	Proxy data used to cover data gaps. Cut-off rules apply
Second order effects including induction	Yes	Yes	Yes
Higher order effects	Shall be assessed – by quantitative means if considered robust	Shall be identified	Should be identified
Long term effect of any order	To be identified and reported. Considered in accordance with Tier 1 rules.	To be identified and reported. Considered in accordance with Tier 2 rules.	To be identified and reported. Considered in accordance with Tier 3 rules.
Adverse environmental and social effects	To be identified and reported. Considered in accordance with Tier 1 rules.	To be identified and reported. Considered in accordance with Tier 2 rules.	To be identified and reported. Considered in accordance with Tier 3 rules.
Contextual factors	Shall be specified – quantitatively if considered robust	Shall be identified	Should be identified

Table 2 – Overview of assessment depth

NOTE 1 – Inclusion of higher order effects means that they form part of the assessment (qualitatively or quantitatively), identification of them means that they are identified but not assessed.

NOTE 2 – Induction means that the convenience of an ICT solution stimulates increased use of it. This rebound usage is directly associated with understanding the effect of the solution as opposed to that of higher order effects where the mechanism originates in general behavioural patterns associated with access to economic means, time and space. See clause 10.2.7.

NOTE 3 – Excluding part of the life cycle without consideration of its materiality may lead to overstating the potential of an ICT solution (by partially disregarding first order effects of the ICT solution) or understating it (by partially disregarding the effects on the reference scenario).

NOTE 3 – This Recommendation prefers proxy and screening data to cut-off, in line with common LCA practice.

10.2 Scoping

An assessment of the second order effect is an assessment of the use of an ICT solution encompassing both the solution itself and a (present or potential) scenario for its usage, where higher order effects are typically associated with side-effects.

The following general principles shall be applied for assessments of ICT solutions. The scoping activities are the same for Tier 1, Tier 2 and Tier 3 assessments with the exception of the establishment of the consequence tree, which is required for Tier 1 and Tier 2 but only recommended for Tier 3 assessments.

NOTE – In some assessments, the effects of an ICT solution are derived based on a case study, i.e., the effect of the ICT solution is calculated for a specific setting and the results are used to model its effects in a different situation. This is addressed in clause 12.

10.2.1 Definition of the ICT solution(s) and the main second order effect

The definition of the ICT solution(s) encompasses the following steps:

- Define and describe the ICT solution(s) under study.
- Describe the main impact of the ICT solution on emissions in other sectors. In particular, specify the mechanism through which emissions are affected in other sectors, i.e., whether the main effect is via substitution, optimization or other means (see clause 8).
- Define the geographical and temporal coverage of the assessment.
- Clarify whether the quantification of the main second order effect will be based on primary data (emerging from the actual implementation of the ICT solution or from case studies) or collected from other sources.

NOTE 1 – Make sure that the targeted effect of the selected ICT solution (e.g., reduced travel) is referring to an effect associated with non-ICT activities. In cases where the ICT solution brings changes to the GHG emissions of ICTs, this is considered a reduction of first order effects as this only impacts the footprint of ICTs themselves, not the effect on non-ICT activities. Hence such solutions are out of scope for assessments of second order effects, which refers to effects on emissions other than those associated with first order effects of ICTs.

NOTE 2 – In the case of an ICT solution aiming to reduce GHG emissions, its main second order effect equals its intended effect.

If the assessment is performed from the perspective of an organization or jurisdiction aiming to identify its aggregated effect, the choice of ICT solutions shall be specific (only consider relevant services) and complete (i.e., consider all relevant ICT solutions, also those without an expected positive effect) within the assessment boundaries, unless a more limited and specific boundary is declared. In any case, cherry picking (i.e., only including ICT solutions with an expected positive

effect) shall be avoided. Moreover, selected ICT solutions shall directly impact the change in emissions, i.e., solutions with ICT as a peripheral component shall not qualify, such as those only engaged in administration of information.

Appendix II provides checklists that could be used as a support the identification of relevant effects.

10.2.2 Definition of the functional unit

The functional unit shall be defined so that it is applicable both to the ICT solution scenario and the reference scenario. For example, when comparing a videoconferencing system with a travelling-based reference scenario, an appropriate functional unit may be one meeting or the total number of meetings in one year.

A reference flow shall be defined to quantify the functional unit. A reference flow is a quantified number of products that is necessary for the ICT solution under study to deliver the performance described by the functional unit. In other words, for the functional unit of one meeting, for instance, the reference flow for the systems needed for the ICT solution and the reference scenario shall both be defined. See clauses 10.2.4 and 10.2.5 for additional guidance on what to include.

10.2.3 Definition of the assessment perspective

To define the assessment perspective, it shall first be decided whether the assessment will be evaluating an actual effect of the ICT solution(s), or its (their) potential effect (either present or future), yet partially or fully untapped.

Moreover, an actual effect can be assessed from both the following perspectives: mid-way addressing a present situation and ex-post addressing a finished situation. The potential effect could be assessed ex-ante, addressing a future potential, or mid-way, addressing an existing but as yet untapped potential. The difference between present and future potentials could be found in aspects such as technological development and policy changes.

The selection of the assessment perspective will impact the assessment and results for both the reference scenario and the ICT solution and shall therefore be clearly defined.

NOTE 1 – Independent of the time perspective, the assessment is always hypothetical in the sense that either the ICT solution or the reference scenario is contrafactual as they cannot, by principle, exist at the same time. In some cases, both will be based on assumptions as a future development cannot be known.

NOTE 2 – See Annex B for details.

NOTE 3 – The total environmental effect will depend on both the number of usages and the effect per usage, which can both change over time.

To define the assessment perspective, it shall also be specified whether the assessment shall focus on the ICT solution as such, or be considered from the perspective of e.g., a company contribution, for which additional guidelines apply. Refer to clauses 11–13 for different types of assessments.

NOTE 4 – An assessment of present effects or present potentials refers to effects in a current context, while prospective assessments may refer to a different contextual setting.

10.2.4 Definition of the composition of the ICT solution scenario and identification of the elements contributing to its overall first order effect

To define the boundaries of an ICT solution(s), its composition and associated life cycle processes shall be identified, including the life cycle stages defined by [ITU-T L.1410] i.e., raw material acquisition, production, usage and end-of-life treatment, as well as the generic processes associated with those such as transportation, use of energy and waste treatment.

To define the building blocks and life cycle processes belonging to an ICT solution's life cycle, practitioners shall refer to [ITU-T L.1410], which defines a comprehensive list of building blocks and processes.

Moreover, a practitioner shall also develop an initial usage scenario for the ICT solution. This scenario will need refinement after subsequent steps in the scoping process. The definition of the usage scenario shall, when relevant, also consider supporting systems other than the ICT solution itself that are necessary for its operation.

It is important to avoid a biased assessment of the ICT solution that would occur if using usage scenarios that correspond to the lowest GHG emissions. The assessment of the ICT solution effects shall thus take into account a typical representation of its usage.

Annex B provides further guidance on how to build scenarios.

10.2.5 Identification and definition of reference scenarios

The identification and definition of one or more reference scenarios is as important to the result of the assessment as the definition of the ICT solution scenario, and the most probable reference scenario shall be selected to serve as the baseline. In cases where several developments are equally likely, more than one reference scenario should apply. For the selection, a quantitative statistical approach should be taken if feasible. However, in reality, educated reasoning may often be the only option.

For each selected reference scenario, the assumed or expected development over time shall be transparently described.

Reference scenarios based on previous adoption of the reference activity shall be projection-based i.e., technological progress and other developments of the reference activity shall be considered (see Figure 2). Such developments shall consider relevant knowledge, and shall refer to recognized scenarios (such as IPCC scenarios) where they exist and are relevant to the assessment.

NOTE 1 – Figure 2 shows the comparison of the effect of an ICT solution already in use at the time of assessment. In this case, a (real) situation that includes the solution is compared with a (hypothetical) situation without it.

NOTE 2 – Depending on the uptake and development of the service and of the reference scenario, the gap between the effect of the ICT solution and the reference scenario may both increase and decrease over time.

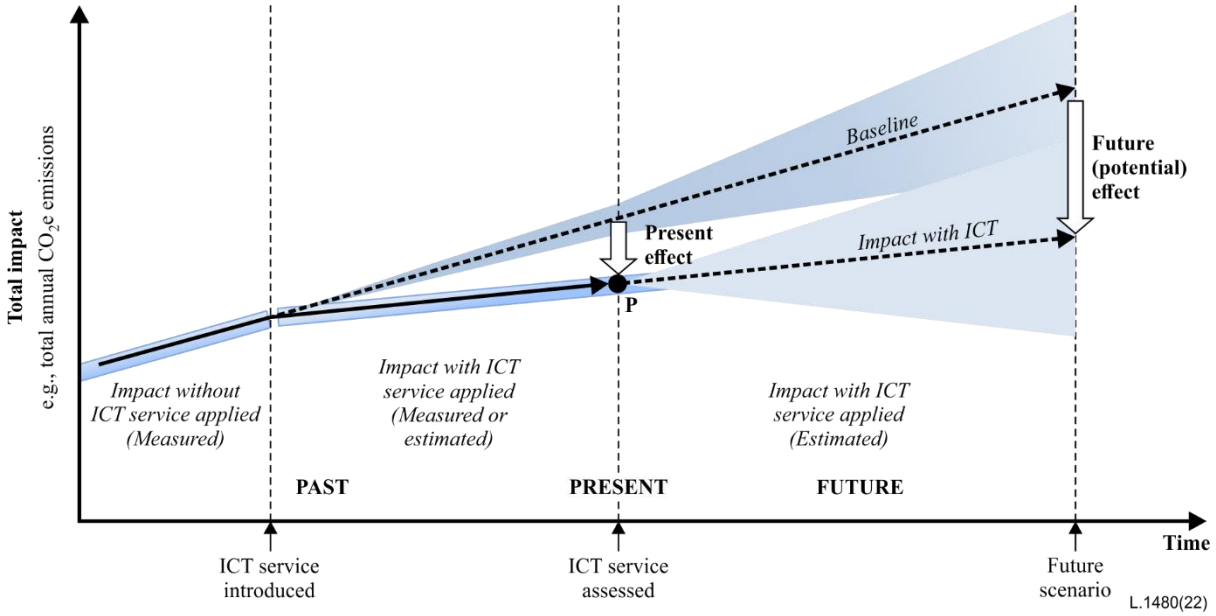


Figure 2 – Illustration of the induced effect resulting from a projection-based reference scenario (baseline). (Source: [b-C&B])

To define the boundaries of a selected reference scenario its composition and associated life cycle processes shall be defined.

To define the composition of an ICT solution and the life cycle processes belonging to its life cycle, practitioners shall refer to [ITU-T L.1410] and shall also refer to other general or sector-specific LCA guidance for the reference scenario, such as [ISO 14044].

The reference scenario shall also be defined in a way that is a viable alternative to introducing the ICT solution. Otherwise, baselines may become outdated and will then lack relevance and credibility. Though a strict boundary is missing, ICT solutions at some point become part of business-as-usual and a commodity. At that point, it would be hard to credibly refer to their effect e.g., in a company claim. Usually, from a relevance perspective the reference scenario should not refer to cases before a relevant base year but be defined in a way that can trigger forward looking action.

Example: An assessment studying the effect of an AI-based driver assistance should not refer to a car from the 1980s in the reference scenario but should refer to the average car used at the time of the AI-based solution deployment or at a target base year (including the ICT systems for driver assistance that have already become part of mainstream automotive technology).

Annex B provides further guidance on how to build scenarios.

Appendix II provides checklists that could be used as a support to identify relevant effects.

10.2.6 Identification of the additional second and higher order effects of the solution and any relevant contextual factors

Tier 1 and 2 assessments shall and Tier 3 assessments should include all the effects in a consequence tree before any limitation or cut-off associated with the depth of the assessment and the chosen functional unit is performed. Appendix II provides checklists that could be used as a support to identify relevant effects.

NOTE – This step is mandatory for Tier 1 and Tier 2 assessments, and recommended for Tier 3 assessments.

10.2.6.1 General guidance for developing a consequence tree

In order to identify the second and higher order effects of an ICT solution, a consequence tree or a similar systematic and comprehensive approach following the principles of clause 10.2.6 shall be used. The consequence tree provides an analytical basis for identifying the effects induced as consequence of the deployment and use of the ICT solution, and delivers a set of collateral effects (consequences) connected to the solution in addition to its main second order effect.

In cases where the assessment involves several ICT solutions or ICT solution scenarios, these could be covered within the same or in separate consequence trees depending on what is practical. The same is valid in case of several reference scenarios for the same solution. In any case, assumptions regarding the contextual factors (see clause 10.2.7) that are relevant across ICT solutions and reference scenarios shall be the same for all.

Each identified consequence that has a GHG effect should be included. Moreover, non-GHG environmental consequences should also be added to the consequence tree(s) in order to identify unwanted side-effects on other environmental categories.

In particular, the identification of solution effects shall also consider long-term effects. Hence, the risk for a solution to become obsolete or to bring lock-in effects in other sectors over a longer time perspective, despite bringing emission reductions in the short run, shall be identified. Such effects are often associated with long-life capital investments. The identification process shall also include adverse effects on other environmental and social dimensions.

NOTE – This is in line with [b-MI].

In the first step, the ambition is to identify the effects of the studied ICT solution(s) as broadly as possible. Hence, the consequence tree shall be made as exhaustive as possible, without prejudging

the relative importance of the effects, while keeping in mind that not all effects identified in this step will be the subject of a precise quantification. The consequence tree shall separately include:

- **Second order effects**: This includes any second order effects which can be either actual or potential, including the main second order effect such as travel substitution, transportation optimization, working environment changes, etc. (see clause 10.2.6.2).
- **Higher order effects including rebound**: Rebound occurs when the use of the ICT solution brings increased efficiencies, which in turn lead to savings in time, money, energy, etc. Some of these freed resources can be used for other activities that often decrease the positive impact of the ICT solution. There is also direct rebound associated with the additional usage of the ICT solution itself due to its convenience. This is known as induction and shall be considered when modelling the second order effect. As many ICT solutions boost economic efficiency, any reinvestment of financial gains provided by the solution shall be included in the consequence tree for potential assessment (see clause 10.2.6.3).

For reference and completeness, the tree shall also include the **first order effects** identified in clause 10.2.1.

From the initial identification of effects and classification of them as either first, second or higher order effects, the following step-by-step guidelines apply for the design of the consequence tree:

- The effects shall be sorted in a logical way that reflects the directness of their impact, i.e., short-term, or mid/long-term, as well as their duration.
- Effects related to second and higher order effects are divided into separate branches. Moreover, the first order effects are included as a separate branch.

An illustration of the layout of a tree is given in Figure 3.

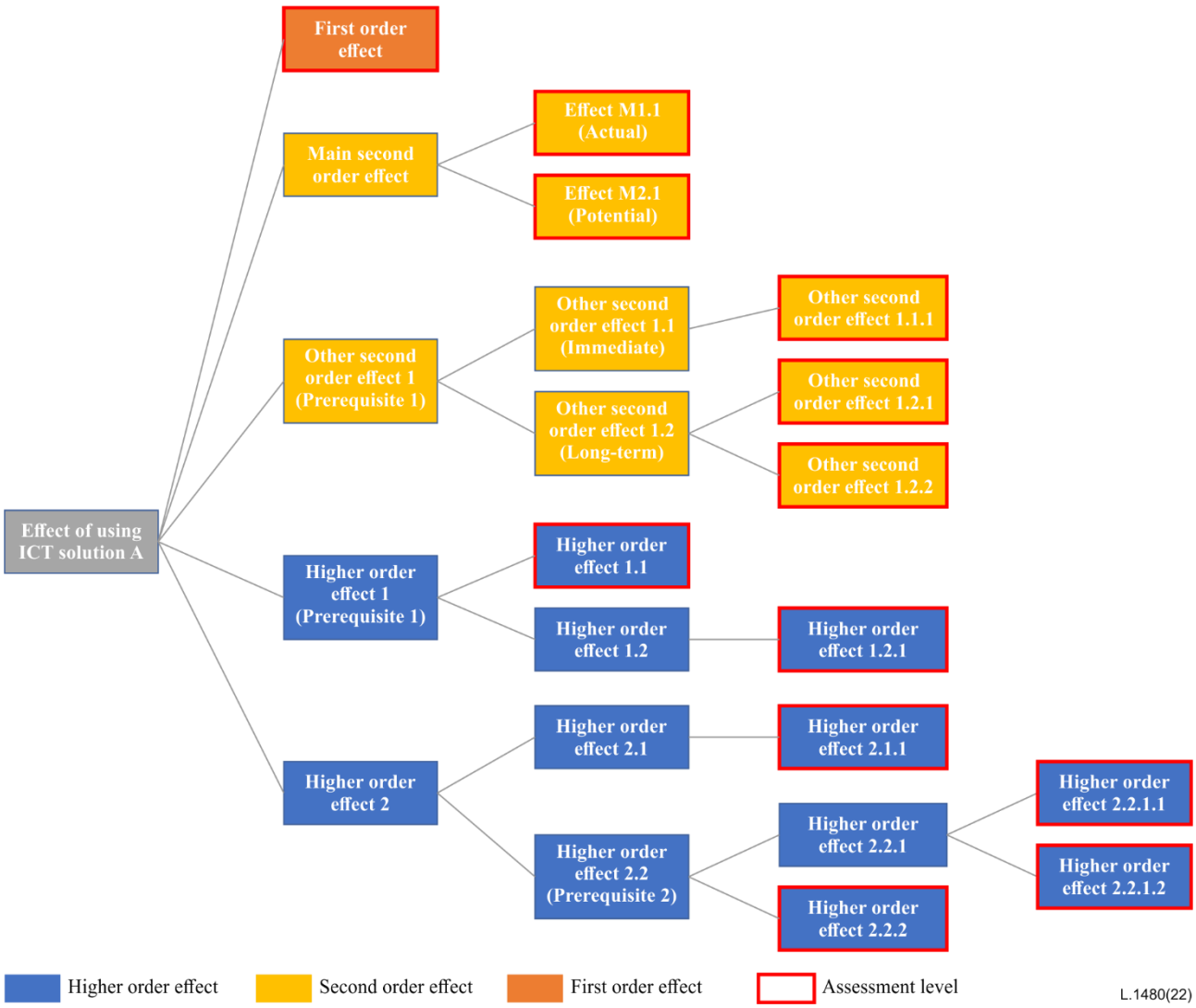


Figure 3 – Principle sketch of a consequence tree where each effect denotes an action or event which is due to using the ICT solution and which impacts overall GHG emissions

NOTE 1 – Assessments are made at the deepest level of detail in the tree, highlighted with red lines around the boxes. This figure is illustrative, and the actual number of effects differs with solution and scenario. (Adapted from: [b-ADEME-1]).

NOTE 2 – What is considered an effect and at which level it applies looks different whether making an assessment from the perspective of the solution, the provider, the user or society in general.

Following the development of the tree, subsequent additional activities shall be performed:

- Identification of assumptions used in the tree;
- Description of the effects;
- Identification of the origin of emissions (if necessary).

Moreover, for each effect in the consequence tree, the following shall be identified:

- The types of GHG emissions involved;
- The time span of the effect and how it relates to the assessment period.

The outcome of these steps shall be documented in a table or similar.

NOTE 3 – The identification of effects may be an iterative process and additional relevant effects may be identified during the assessment

10.2.6.2 Identification of second order effects

The main second order effect shall be identified in accordance with clause 10.2.1. The main second order effect is usually the intended effect when assessing an enabling ICT solution. However, additional second order effects may also occur. These are effects that are outside the assessment boundaries but related to the usage of the ICT solution. These should also be added to the consequence tree.

In the example of a high-security videoconference system of a bank (see introduction), an additional effect would occur if an assessment would aim to understand the impacts of the system only for internal travelling. In this case the customer visits, also using this system, would be considered an additional second order effect.

For any second order effect (main or additional), the consequence tree should consider effects such as the consumption of goods, the consumption of energy, the movement of goods or people, work efficiency, building infrastructure and waste etc. outside the ICT sector.

Appendix II provides checklists that could be used as a support to identify relevant effects.

The effects of introducing an ICT solution may be immediate or mid- or long-term. Those two categories shall be kept separate in the assessment, and it is noted that mid- or long-term effects may be associated with changes in conditions such as policy changes. Moreover, the identification and assessment shall also distinguish between effects associated with actual reductions of GHG emissions and lesser increase of GHG emissions. In this case, comparison with an additional reference scenario (e.g., historical) may be required as a benchmark.

10.2.6.3 Identification of higher order effects

Identification of higher order effects (including rebound effects) shall consider any effect associated with changes in the behaviour of the users and others affected, e.g., links to potential financial benefits realized by the solution, and (if known) also such as associated reinvestment in activities of different carbon intensities. In particular, induction, i.e., the direct rebound which is associated with the convenience of the ICT solution itself, shall be considered.

NOTE 1 – For the identification of higher order effects, it is observed that different services are more or less prone to rebound. Moreover, indirect rebound could both increase and decrease emissions depending on use of time and resources (long-distance flight vs investment in solar panels or increased circularity).

For the identification of higher order effects, the following mechanisms should be considered:

- **Induction**: when an ICT application stimulates increased use of itself.

NOTE 2 – From an assessment perspective, induction is associated with the modelling of the second order effect (see clause 10.3.1.)

- **Direct economic rebound**: when the increased economic efficiency in providing some ICT solutions affects the price which leads to increased consumption of those ICT solutions. This is a type of induction. i.e., an effect which is due to or induced by the use of the ICT solution.
- **Indirect economic rebound**: when the increased economic efficiency due to ICT solutions leads to spending in other parts of the economy. This is also known as the income effect.
- **Direct operational efficiency rebound**: when the increased operational efficiency in operating tasks due to an ICT solution leads to more or broader set of those tasks performed. This is a type of induction.
- **Indirect operational efficiency rebound**: when the increased operational efficiency in operating tasks due to an ICT solution leads to more or broader set of other tasks performed.
- **Time rebound**: changes in emissions due to the use of saved time (may be direct (induction) or indirect).

- **Space rebound**: changes in emissions due to the use of saved space (may be direct (induction) or indirect).
- **Learning in production and consumption**: When ICT develops a production-consumption system and facilitates informed customer decisions, e.g., with respect to environmental impact (this effect is often positive). Potential effects related to learning occur through the ability of ICT to enhance knowledge-sharing, and transparency throughout the production supply chain, to offer consumers increased transparency regarding production conditions or to improve the coordination between producers and consumers.
- **Scale effects**: When changes in the production scale lead to changes in emissions.
- **Changed practices (behaviours and routines)**: Transforming the everyday practice of people due to using ICT solutions in a way that either increases or decreases emissions (additionally to intended changes). This includes aspects such as skill rebound: changes in engaging in other tasks due to the ICT-induced reduction in the skills needed to perform those tasks, e.g., driving a car due to autonomous driving systems.
- **Transformational impact**: When changes in technology lead to changes in consumer preferences, alter social institutions and the organization of production.

NOTE 3 – An emerging rebound effect would be "mental rebound" where a feelgood perception of being "green" encourages increased consumption for certain products where "green" or lower impact options are readily available. This could for example refer to "compensated" flights. Mental rebound is also sometimes referred to as moral licensing or self-licensing. This effect could potentially be seen as changed practices.

10.2.7 Identification of contextual factors

The second and higher order of effects of an ICT solution will depend on a range of contextual factors such as policy, other technology and user behaviour. These will impact the reference scenario and the future use of ICT as well as any rebound effect. Although it is challenging to consider such factors, an initial step is to list any assumptions around contextual factors.

Thus, the practitioner shall define theses contextual factors that "set the scene" for the ICT solution, for example, by acting as incentives and obstacles towards the application of the ICT solution.

Contextual factors include structural conditions due to, for example, policy and financing, variations in preconditions such as temperatures and performance aspects. This includes both factors which are associated with the solution and those independent of it. Those should be kept separate. In particular, they refer to the following types of factors:

- Economic obstacles and incentives;
- Business obstacles and incentives;
- Structural obstacles and incentives;
- Social obstacles and incentives;
- Attitudes and behaviours.

Incentives and obstacles should also be identified from the perspective of each applicable stakeholder:

- End users;
- ICT operators and vendors;
- Investors;
- Policy makers;
- Society.

Incentives and obstacles should also be considered from the perspective of the different stages of an ICT solution's life span including all perspectives such as planning, execution, deployment, operation, maintenance and end-of-life treatment.

Once incentives and obstacles have been identified they should be categorized with respect to importance, probability and addressability.

These contextual factors serve as prerequisites for the analysis of the second and higher order effects.

NOTE – This approach is in line with [ITU-T L.1440] clause 8 and also aims to capture the idea of external factors in the framework developed by ADEME [b-ADEME-1].

Once identified, the contextual factors are mapped towards the different effects included in the consequence tree and are to be inserted in the tree.

10.2.8 Selection of effects to be quantified

Once all effects have been identified, inserted in the consequence tree and structured, the effects that shall be part of the quantitative assessment shall be selected.

The following selection criteria apply while keeping second and higher order effects separate from each other and from first order effects:

- Make a high-level estimate of the relative magnitude of each effect in the consequence tree.
- Exclude effects without an expected significant impact on GHG emissions (see clause 10.3.6 for cut-off principles), as well as multiplier effects (if applicable), i.e., the effects that arise when using the ICT solution emerge (partially and in total) in contexts other than those applicable to the intended use of the ICT solution.

NOTE 1 – An example of a multiplier effect would be if an organization introduces an incentive programme to encourage the use of online meetings instead of travelling. In this case, the targeted staff will increase their use of online meetings for their work as a direct consequence of the programme. While adopting this practice in this intended context, they may also increase the number of online meetings in their private life.

NOTE 2 – At this stage, the assessment of the impact of ICT solutions on the rest of the economy (economy-wide rebound) is not covered by this Recommendation.

NOTE 3 – Guidance for assessing the GHG emissions consequences of the financial effects generated by an ICT solution is provided in Appendix IV.

The selection of effects shall be transparent, defendable and follow the principles of good assessment practice (see clause 6). Moreover, the ambition shall be to cover the second order effects in relation to the assessed scenarios as completely as possible within the scope of the study, and potential cumulative effects of any omissions shall be considered. See clause 10.3.6 regarding principles for cut-off.

The selection process shall distinguish between effects that can be quantified in a reasonable way, and those that cannot. When doing so, the general principles of clause 6 apply, i.e., significant effects shall not be omitted from quantitative assessment if robust data exist. Effects deemed significant but not quantifiable shall be addressed by qualitative means and transparently reported. A qualitative assessment intends to create an understanding of how substantial an effect is, including its magnitude, how long it lasts and so on.

NOTE 4 – The identification and selection of effects may be an iterative process and further relevant effects may be identified during the assessment.

Once the selection has been performed, the expected order of magnitude of effects shall be estimated and the documentation should be restructured to reflect the expected relative order of magnitude. Moreover, the probability of the effect and how it could be amplified if positive and diminished if negative should be estimated based on educated reasoning unless relevant data are available that enable a quantitative approach.

10.2.9 Definition of the boundaries of the ICT solution scenario(s) and the reference scenario(s)

Based on the identified life cycle processes of the ICT solution scenario(s) and the reference scenario(s), as well as the selected additional effects from the consequence tree, the boundaries of the ICT solution scenario and the reference scenario shall be defined in line with the goal and scope, for:

1) First order effects of the ICT solution(s) and the ICT solution scenario;

2) Life cycle GHG emissions of the reference activity and the reference scenario(s);

3) selected second and higher order effects from the consequence tree.

NOTE 1 – Boundaries are defined based on the intended goal and scope, while cut-off of insignificant emissions may occur within these boundaries during the assessment. Cut-off is addressed in clause 10.3.6.

In particular, the boundaries shall be defined for the following characteristics:

- The geographical boundaries of the assessment;
- The temporal boundaries of the assessment;
- The usage scenario(s) for the ICT solution, applicable activities/processes and assumptions made regarding those;
- The reference scenario(s), applicable activities/processes and assumptions made regarding those;
- To what extent the assessment will be based on primary data (e.g., own implementation or case studies) and collected secondary data.

NOTE 2 – For both the ICT solution(s) and the reference scenario(s), [ITU-T L.1410] and [ITU-T L.1430] provide further guidance.

See also Annex B for further guidance on scenarios.

10.3 Modelling, data collection and calculation

This clause describes the general case. Further guidance for assessments of specific implementations, assessment of aggregated effects of ICT solutions and assessments of effects at an organizational level is given in clauses 11–13.

The guidance applies together with the guidance for different types of assessments in clause 7, and further specific guidance in clauses 11–13, which specifies any deviations from the different activities to be performed as part of the modelling, data collection and calculation.

10.3.1 Quantification of net second order effect of each assessed ICT solution

For each combination of ICT solution and reference scenario the following shall be performed:

- Identification of the overall usages of the ICT solution while distinguishing between modifying and rebound usages (clause 10.3.1.1);
- Quantification of the aggregated first order effect of the ICT solution (clause 10.3.1.2);
- Quantification of the change in GHG emissions due to changes in the reference activities (clause 10.3.1.3);
- Deriving the net second order effect of the ICT solution in a standalone scenario (clause 10.3.1.4).

NOTE 1 – To identify the net second order effect of the ICT solution, only those activities and processes of the reference scenario affected by the ICT solution need quantification since the aim is to calculate a difference between two scenarios, not an absolute impact level. See [ITU-T L.1410] for further details.

NOTE 2 – The quantification of second order effects is dependent on the first order effects, as first order effects or ICT solutions are part of the quantification of net second order effects. In contrast, first order effects are independent of any second order effect.

Depending on the assessment perspective, data are evaluated from former studies and known conditions (ex-ante) or collected during implementation (mid-way) or after the use of the ICT solution (ex-post).

10.3.1.1 Identification of overall usage of the ICT solution while separating modifying and rebound usages

For the selected scenarios, the expected usage of the ICT solution shall be identified. The second order effect calculation shall identify usages associated with induction, though this is semantically a rebound effect. Induction represents rebound usage of the ICT solution that is not associated with modifying activities of the reference scenario.

Hence, as a next step, separate the usages of the ICT solution that replaces activities in the reference scenario (referred to as modifying usages), and those that are likely to represent rebound usages associated with the convenience of the ICT solution.

NOTE 1 – Induction means that the convenience of an ICT solution stimulates increased use of it. This rebound usage is directly associated with understanding the effect of the solution as such, as opposed to other higher order effects where the mechanism comes from general behavioural patterns associated with access to economic means, time and space. An example is a conference that moves online and gains millions of viewers. In the physical world, only a fraction of those viewers would have been able to attend in person and only this fraction could be associated with a saved journey.

NOTE2 – To identify the addressable activities of the reference scenario, it may help to differentiate between modifying and induced usages.

Appendix III provides further guidance on how to distinguish induced rebound usage from modifying usage when assessing the second order effects of an ICT solution.

10.3.1.2 Quantification of the aggregated first order effect of the ICT solution

The first order effects shall be calculated both for the usages of the ICT solution that modify activities in the reference scenario, and those associated with the induction effect, while separating the two.

Effects may be excluded if considered insignificant according to the cut-off criteria (clause 10.3.6).

NOTE 1 – The full assessment of first order effects of ICT solutions is detailed in [ITU-T L.1410] part I.

NOTE 2 – The application of [ITU-T L.1410] shall be aligned with the applicable tier of assessment and the significance of the different contributors to the aggregated first order effect.

NOTE 3 – In general, data and modelling aligned with [ITU-T L.1410] are preferred for the first order effects of the ICT solution. However, other data of sufficient quality are acceptable, especially if the significance of these first order effects is limited.

NOTE 4 – To derive the aggregated first order effect of an ICT solution involves allocation. If the ICT solution is an ICT service, this would include allocation of first order effects of ICT goods and ICT networks attributable to this service. This is detailed in [ITU-T L.1410].

For recalculation of activity data to GHG emissions, refer to clause 10.3.5.

10.3.1.3 Quantification of the change in GHG emissions due to changes in the reference activities between the reference scenario and the ICT solution scenario

The change in GHG emissions of the reference activities between the reference scenario and the ICT solution scenario is calculated based on the change in the life cycle GHG emissions with and without the ICT solution applied. GHG emissions shall hence be calculated for those life cycle processes representing differences in emissions between the two scenarios. This shall be carried out in line with relevant LCA guidance, such as [ITU-T L.1410] part II and [ISO 14044]. Only modifying usages of the ICT solution shall be considered in this step.

NOTE – The change in the reference scenario differs between substitutions and optimizations: While substitutions replace the reference activity entirely, optimizations may reduce its emissions, but the activity may still exist.

10.3.1.4 Deriving the net second order effect of the ICT solution in a standalone scenario

The net effect of the ICT solution(s) in a standalone scenario, i.e., a scenario where the ICT solution represents the sole impact on the addressable emissions of the reference activities, is derived as follows:

1) Calculate the change in GHG emissions due to changes in the reference activities with and without the ICT solutions applied (derived according to clause 10.3.1.3). In this step, the rebound usage of the ICT solution that is not associated with modifying the reference scenario shall be excluded when calculating the change in GHG emissions.

2) In cases of reduction in GHG emissions in the reference activity, the aggregated first order effect of the ICT solution shall be subtracted from the reduction in order to derive the net second order effect. In case of an increase in GHG emissions in the reference activity, the aggregated first order effect of the ICT solution shall be added to the increase (derived according to clauses 10.3.1.1 and 10.3.1.2). This includes both modifying and rebound usages of the ICT solution.

This shall be repeated for each combination of ICT solutions and reference scenarios.

An example of this is a lecture that was planned for 500 participants in a particular event location that was subsequently moved online and viewed by 10 000 people. In this case the reduction in travelling of only the 500 participants (change in first order effects of the reference activity) is considered when deriving the GHG emission reduction of the reference activity. The other 9500 views are considered rebound usages and do not add to the reduction of emissions as these viewers would not have travelled to the physical event. However, all associated first order effects of the ICT solution that made the online event possible are adding to the first order effect of the ICT solution.

10.3.2 Quantify the combined induced effect of several ICT solutions addressing the same emissions

When aggregating the second order effect of ICT solutions that 'compete' to address the same GHG emissions, there is a risk that effects are inadvertently double counted. This happens, for example, if several of the ICT solutions considered target behavioural changes of the same group of users, thereby impacting the same emissions through different mechanisms.

When two or more ICT solutions interact by competing to impact the emissions of the same reference activity, their individual effects cannot simply be added. Once one modification has been applied, the next one has only a smaller footprint left to modify, the third one an even smaller one, and so on. The aggregated effect of an ICT solution modifying the same reference activity shall then be computed via the residual footprint of the original reference activity after applying each modification in turn. This sequential approach leads to a smaller, more accurate, overall effect than by simply adding the individual effects.

Thus, when more services modify a reference activity, their joint effect is typically smaller than what the sum of the individual effects would be.

NOTE – If the approach undertaken would render different results depending on the order of consideration of the different ICT solutions, averaging should be used.

10.3.3 Assessment of higher order effects including quantification

Higher order effects, which often occur in the mid and long term, emerge from such as behavioural changes induced by the deployment and use of the ICT solution. These effects can have a positive or negative climate impact. Because they impact the environment in a lasting way, they cannot be ignored in a comprehensive assessment of the effects of ICT solution(s). In some cases, a change of

behaviour could even be the objective of any ICT solution designed to reduce the environmental impact of its user e.g., any system intended for reducing energy usage.

For each selected higher order effect, the practitioner shall make a qualitative assessment of its effect including how and where it would occur and within what time-frame. Moreover, practitioners should also seek to quantify these effects. If relevant data (including proxy data) is lacking, such effects should be assessed by qualitative means.

NOTE 1 – Guidance for quantifying the GHG emissions due to the financial effects generated by an ICT solution is provided in Appendix IV.

The analysis is limited to direct and indirect higher order effects and excludes highly complex economy-wide rebound effects on the basis that such effects are independent of the manner in which the ICT solution is implemented and rather refer to the economic system as such. In any case, the assessment of an ICT solution should not be separated from the manner in which the ICT solution is implemented.

If possible, identify countermeasures and analyse the ability of such measures to prevent the negative higher order effects from occurring, or to reduce their impact.

Also, if possible, analyse the contextual factors to identify measures to suppress obstacles and magnify incentives to leverage the potential benefit of the ICT solution.

NOTE 2 – To establish a comprehensive understanding of the magnitude of higher order effects ex-ante and ex-post assessments are expected to provide different opportunities.

10.3.4 Selection of data and data quality requirements

For each process falling within the boundaries of the assessment, whether belonging to the reference scenario or the ICT solution scenario, an identification of potential data sources shall be performed in line with the goal and scope. Depending on goal, scope and data quality requirements, data can be either primary, representative, secondary or proxy data.

Data sources shall be documented as well as the metadata. Metadata are needed for the interpretation of data points and, indirectly, the results and include information such as time, number of samples and representativeness.

The following requirements (ITU-T L.1410 Table 4) on data quality shall apply for the different life cycle stages and unit processes (primary vs representative, secondary and proxy). In general, ICT-specific data are required for ICT-specific processes. Data shall be collected (or modelled) at least one step up in the value chain. For further guidance see [ITU-T L.1410], appendix I.

Data selected shall consider the following quality criteria:

- Methodological appropriateness and consistency;
- Completeness (total LCA level);
- Uncertainty;
- Data representativeness;
- Data age (timeliness);
- Acquisition method;
- Supplier independence;
- Geographical correlation;
- Technological correlation;
- Cut-off rules (rules of inclusion/exclusion).

The following guidance shall be followed:

In general, data age and technological correlation are especially important in LCAs for ICT goods, networks and services due to fast technology evolution and growth in network traffic.

Primary data shall be used for all individual processes under the financial or operational control of the organization undertaking the LCA, and data shall be representative of the processes for which they are collected.

When available, data compliant with the ITU-T L.14xx series of Recommendations take precedence before other secondary data sources. However, it is acknowledged that the availability of ITU-T L.14xx compatible data may be limited. Given this situation, other data are acceptable and proxy data may be used to cover data gaps.

Overall, for Tier 1–2, the target shall be as high a level data of quality and relevance as possible. This includes a combination of primary, sector-specific and secondary data in line with [ITU-T L.1410]. However, for Tier 3, other sources of secondary data are usually applicable and include, for example, generic data, proxies and averages.

NOTE – This clause is based on [ITU-T L.1410].

10.3.5 Use of emission factors

Emission factors used shall be consistent with the assessed scenarios and should be the most up to date factors from publicly available sources. Where emission factors are sourced from non-public sources, or are not the most up to date, a justification for their use shall be provided. Emission factors shall also be as specific as possible from a temporal and geographical perspective.

In addition, supply chain, transport and distribution losses from electricity generation shall be included.

All GHG emissions shall be expressed as their CO_2-equivalent values. The emission factors used for converting GHG emissions other than CO_2 emission to CO_2 equivalent emissions shall be taken from the latest UN IPCC reports.

10.3.6 Cut-off

As a general principle, cut-offs shall be avoided to the extent possible, and the practice of using proxies is preferred to that of using cut-offs. However, if cut-off is to be performed, the principles of [ITU-T L.1410] shall apply.

NOTE – Although cut-off based on GHG emissions is preferable, such a cut-off basis is often not practical as the reason for cut-off may be a lack of GHG emissions data for the activity. For this reason, cut-off based on physical (weight) and economic (value) parameters may be accepted.

Normally the cumulative effect of cut-off shall not exceed 5% of the cut-off parameter.

10.4 Interpretation of results

10.4.1 Evaluation of the applied method

To evaluate the applied method of the assessment, answers to the following questions shall be evaluated:

- Is the study identifying the mechanism for the avoided or added emissions?
- Is the study clear about the time perspective of the assessment?
- Is the study clear about the geographical perspective of the assessment?
- How does the study address reference scenarios and baselines?
- How does the study handle case studies?
- How does the study deal with the influence of direct rebound? In particular, does it consider the importance of collecting "before and after data"?

- How does the study address other kinds of rebound?
- Does the study provide guidance for multiple ICT solutions?
- How were the ICT solution(s) selected?
- In case of a company assessment
  - How were the boundaries identified?
  - How were any allocation between different actors addressed?
- How are the induced effect of different ICT solutions aggregated?
- Is the study biased towards positive effects?
- Does the study communicate transparently and advice regarding use of results?
- How is uncertainty considered e.g., by considering a best and worst case?
- Is the method transparently described?
- Are the data sources transparently stated?
- Are meta data provided?
- Are the conditions of any used case studies transparently described?
- Is the quality of any case studies sufficient?
- Are the case studies (if any) representative of the conditions of the study?
- Is the aggregation of data transparently described?

10.4.2 Data quality analysis

A qualitative analysis of the data quality and any efforts taken to improve it shall be performed while considering the data quality indicators stated in clause 10.3.4.

NOTE – Data quality analysis may appear different between a specific deployment and a generic analysis. In particular, the robustness of the data and the relative importance of primary, ICT-specific and secondary data shall be summarized, and a distinction shall be made between primary data, secondary data and estimates.

10.4.3 Sensitivity analysis

For the handling of a sensitivity analysis refer to [ITU-T L.1410] part I, clause 10.3.

Especially when modelled data are used, different scenarios shall be assessed to establish a range of potential outcomes to limit the uncertainty. For instance, to understand the impact of an ICT solution, it is advisable to assess how its impact varies with the scale of adoption, considering different relevant scenarios.

10.4.4 Uncertainty analysis

The uncertainty of the results of a study shall be assessed in accordance with [ISO 14044] to the extent needed to understand the study results. Also, the sources of uncertainty and methodological choices made shall be assessed and disclosed. This includes the dependence of results on broader policies and technologies, e.g., electricity system decarbonization

NOTE – The root sum of uncertainties demands a data granularity which is usually not available – usually uncertainties are uncertain.

Alternative approaches to dealing with uncertainties could be e.g., by deriving a best and a worst scenario. Moreover, results may be presented as ranges rather than single values. The applicability, relevance and feasibility of such approaches shall be considered.

10.5 Reporting

The report shall follow the principles of clause 6 and is intended to give readers a comprehensive and transparent understanding of how the results were derived.

In particular, the report shall include descriptions of:

- The aim and type of assessment (see clauses 7 and 10.1.2 for details).
- The assessment depth (Tier 1–3) and an associated disclaimer regarding any uncertainty and limitations in results, particularly mentioning that the results are only valid under the conditions of the study and that the assessment of second order effects are always hypothetical by comparing impacts with a reference scenario.
    - If presenting results based on a Tier 3 type of assessment, it shall be clarified that this can only give initial guidance on the effect of ICT solutions as those are less accurate and also do not consider higher order effects.
- The intended receiver and audience.
- The organization issuing the report.
- The review process, whether internal, third party or scientific peer review. For third-party review refer to the reviewers, whereas for a scientific review give proper reference to the publication.
- The functional unit.
- The assessment perspective.
- The main assumptions of the study including those regarding contextual factors.

For each selected ICT solution describe:

- The selected ICT solution and its main second order effect.
- The selected reference scenario(s) and how it was derived.
- The consequence tree and the selection of effects to analyse distinguishing between qualitative and quantitative analysis. This shall also include the mapping of effects and contextual factors.
- The induced effect of the ICT solutions and how it was derived. In particular describe how rebound and modifying usages have been distinguished (see clause 10.3.1.1).
- The net induced effect of the ICT solutions in a standalone scenario.
- The applied boundaries of any quantitative calculation.
- The assumptions, extrapolations and cut-offs undertaken.
- The data sources used, and the data quality.

In cases where the assessment is based on case studies (See clause 12), also, in addition to the previous bullets, describe:

- The set-up of any case study and its relevance (time, number of samples, representativeness etc.).
- The footprint of the ICT solution in the case study (or state clearly if that is not considered and why).
- Describe also how an estimate of the ICT solution's emission reduction was derived from case studies taking into account any differences in their quality while considering the principles of transparency and conservativeness.

Moreover, describe how the impact of different ICT solutions were combined while avoiding double counting.

In cases of a company claim, describe the company contribution to the ICT solution and any potential allocation (see clause 13). Without allocation, highlight that the claim is non-exclusive.

Any quantification of higher order effects shall be transparent, and the additional uncertainties related to the higher order effects shall be stated. In particular, higher order effects shall be

distinguishable from second order effects in the results. Moreover, immediate and mid-term/long-term effects shall be distinguishable in the reporting, as well as reductions and lesser increases of GHG emissions (see clause 10.2.6). Additionally, ICT solutions designed so that their use will reduce GHG emissions shall be listed separately from ICT solutions whose use may generate GHG emissions reductions.

If applicable, describe also suggested countermeasures to address negative higher order effects. Moreover, describe measures to suppress obstacles and magnify incentives to leverage the potential benefit of the ICT solution. Additionally, highlight that knowledge of rebound should not be used as an excuse to not increase environmental efficiencies of solutions and systems.

A qualitative description of the data quality and any efforts taken to improve it shall be disclosed.

Concrete actions on how to reduce negative impacts and increase positive impacts shall be presented and added in communication to direct stakeholders such as customers.

Moreover, it shall be described how results can be communicated based on the overall quality of the assessment. This shall consider

- The scope of the assessment;
- Data coverage;
- Quantification rigour;
- The items listed in Table 1 and 2.

Based on the principles of clause 6, the practitioner shall give an honest estimate of the overall quality of the assessments and judge its applicability for various communication and decision-making purposes.

NOTE – It is recommended that decision-makers refer to the most comprehensive analysis available. Hence, Tier 2 takes precedence over Tier 3, and Tier 1 is preferred to Tier 2. Consequently, in general, Tier 1 assessments are preferred as inputs for decision making while Tier 3 should not be used as a sole input for this.

10.6 Critical review

It remains the sole responsibility of the organization(s) performing the study to demonstrate compliance with this Recommendation.

However, depending on the aim of the assessment, critical review may be recommended or required. Such a review shall be made by an independent third party or through a scientific peer review process. The following applies:

- In cases of critical review by an independent third party, the name and coordinates of this third party shall be given. Moreover, this third-party verification shall be managed in accordance with [ISO 14064-3], which specifies the requirements for the selection of GHG validators or verifiers, the establishment of the assurance level, objectives, criteria and scope, the determination of the validation or verification method, evaluation of data, information, information systems and GHG controls, assessment of GHG declarations and development of validation or verification opinions. Furthermore, a review statement shall be provided.
- In cases of critical review through a scientific peer review process, it shall be organized according to the state-of-the-art of scientific journals.

In either case, if compliance with this Recommendation is claimed, practitioners are encouraged to send a copy of the report to the ITU-T SG5 Secretariat (tsbsg5@itu.int) for information.

11 Assessment of the effect of specific ICT solution(s) implemented in a specific context

This chapter describes the application of the methodological principles described in clauses 6–10 considering the effects of one or several ICT solution(s) implemented in a specific context, assessed for a specific time interval.

For instance, this could be a railway company or a public hospital wishing to assess how the impact of its digitalization develops over time.

This clause gives additional guidance for studies that seek to answer questions such as:

- What changes in emissions were associated with the usage of ICT solution A within organization B during a specific (past) time interval with a known usage profile?
- What changes in emissions could be expected from the usage of ICT solution A within organization B during a specific (future) time interval with an expected usage profile?

This application is the most straightforward as it can rely on specific conditions and data which enable relatively high accuracy. Moreover, the need for extra guidance is limited and the approach developed in clause 10 could be applied without additions.

In particular, from the perspective of higher order effects, this application allows for including effects of reinvestments of financial gains (see Appendix IV) if such data are made available.

Hence, the methodological principles described in clauses 6–10 shall be followed.

Tiers 1, 2 or 3 assessments may be performed. Tier 1 assessment is recommended.

Ex-ante, mid-way and ex-post assessment may be carried out. As far as possible, the assessment of the effects of the implementation of one or several ICT solution(s) shall be made and shall be:

- Preferably extrapolated from ex-post assessment of the actual situation;
- Alternatively, using a model or the result for a similar solution under similar conditions that shall be explained and documented while evaluating the applicability for the assessed situation.

NOTE – [ITU-T L.1440] Part II provides guidance on how the applicability of results of other studies can be evaluated, and how results can be recalculated for a new context.

When performing an ex-post assessment (see clause 10), actual data shall be collected and taken into account for all relevant effects.

12 Assessment of the effect of ICT solution(s) implemented at different scales

This clause describes the application of the methodological principles described in clauses 6–10, considering effects at an organizational level (including private and public sector organizations), at a city level, at a country level or at worldwide level of one or several ICT solution(s).

For instance, this could be a city wanting to assess the impact of its traffic planning system, or a researcher studying the effect of a particular ICT solution at a country scale.

This clause gives additional guidance for studies that seek to answer questions such as:

- What changes in emissions could be estimated to be associated with the usage of one or more ICT solution(s) within the assessment boundaries during a specific time interval based on general information regarding the ICT solution?

This application refers to aggregated effects at different scales such as on an organizational (private or public) scale, city scale, country scale and worldwide.

The methodological principles described in clauses 6–10 shall be followed.

Tiers 1, 2 or 3 assessments may be performed. Tier 1 assessment is recommended.

Ex-ante, mid-way and ex-post assessment may be carried out. As far as possible, the assessment of the consequences of the implementation of one or several ICT solution(s) shall be made as follows:

- Preferably extrapolated from ex-post assessment covering the result for a similar solution under similar conditions applied referring to actual cases. The extrapolation methodology shall be explained and documented.
- Alternatively, using a model that shall be explained and documented.

When performing an ex-post assessment (see clause 10), actual data shall be collected and taken into account for all relevant effects.

More specifically, this kind of assessment usually starts from a case study which is extrapolated to larger scales, while considering the addressable emissions of the reference scenario within the boundaries of the assessed organization or jurisdictions.

NOTE 1 – [ITU-T L.1440] part II provides guidance on how the applicability of the results of other studies can be evaluated, and how results can be recalculated for a new context.

Case studies derived in accordance with clause 10 take precedence over other data, but other case studies of sufficient quality may also be considered to avoid data gaps. Clause 10.4.1 criteria shall be used to assess the quality of any used case study.

Typically, the resulting case study effect is scaled by multiplying the effect per usage by number of usages or another activity-based measure. Although widely deployed, this method is appropriate only if two conditions are met: (i) the assessment refers to a present effect or retrospective effect, and (ii) the case study sample is considered representative to the scale of the study.

When assessing the applicability of case studies, practitioners shall therefore be aware of two sources of uncertainties: Firstly, even if there is a good estimate for today's average impact of applying the ICT solution, the average impact per usage may change over time, between user groups or due to contextual factors.

Secondly, the representativeness of the sample (i.e., the case study) shall be analysed. Some sources of concern are:

- Over-representation of early adopters/volunteer bias sample;
- Novelty effects associated with a low number of initial users.

NOTE 2 – The effect of volunteer bias can be large.

As a pragmatic way to account for these uncertainties and biases, a conservatively chosen extrapolation coefficient should be applied, to bring the estimates more in line with realistic expectations.

More rigorous approaches would include statistical methods or generalization of long-term empirical insights into how initial effects evolved over time for different services. Alternatively, use of alternative scenarios and sensitivity analyses, which are important tools to make the uncertainty visible (see clauses 10.2.5 and 10.4.3).

NOTE 3 – The contextual factors would be helpful when scaling a case study into a larger effect.

13 Assessment of the effect of ICT solution(s) from the perspective of an organization contributing to the ICT solution

This clause presents the assessment of ICT solution(s) at the level of an ICT organization. Firstly, it presents two items needing special guidance when performing an assessment from the perspective of a company: (i) the identification of ICT solution(s), and (ii) allocation between contributors (see clauses 13.1 and 13.2, respectively). Secondly, in clause 13.3, it identifies three different types of assessment that an ICT organization may wish to perform in relation to the ICT solutions it contributes to and outlines common and specific guidance for those. The three cases are:

- Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all customers.
- Assessment of the aggregated effect of one or several ICT solution(s) provided by an ICT organization across some customers.
- Assessment of the effect of a specific ICT solution implemented in an actual context for a specific customer. This case is similar to clause 11 but takes a different perspective by focusing on the contribution of the provider rather than on the ICT solution in itself.

13.1 Identification of ICT solution(s)

The identification of solutions shall consider the relevance of the ICT solution in line with clause 10.2.1. Moreover, the role of the organization in relation to the solution shall be considered as well, including aspects such as the contribution to the change in emission and the criticality and uniqueness of the contribution.

Specifically, organizational boundaries shall be considered to identify the ICT solutions that belong to the company.

In cases where ICT organizations intend to derive their overall second order effects, they shall consider all ICT solutions independent of the expected effect, i.e., whether avoiding or adding emissions.

NOTE – Organizations that refer only to ICT solutions with a positive contribution, while neglecting other parts of their portfolio, are often seen as cherry picking. See e.g., [b-WRI-2].

In cases where only a part of the portfolio is considered, a percentage of turnover or similar shall be referred to, rather than comparing the result to the overall footprint.

13.2 Allocation between organizations

Assessments from a company perspective shall consider how to deal with allocations.

Allocation between companies is complex and may involve several layers of contributions (including providers of generic and specific components, as well as the integrated solutions). Moreover, it may include several roles such as the innovator, the developer, the service owner and the operator.

For the time being such allocations are considered too challenging.

Instead, companies shall classify their contribution as an A- B- or C-level contributions where:

- A-level means the contribution of the integrated ICT solution;
- B-level means the contribution of specific hardware and/or software;
- C-level means the contribution of platform and generic hardware or software.

This means that the company shall make clear whether it contributes to a generic component, a specific component or the integrated solution. Additionally, it shall clarify its role (one or several of innovator, developer, service owner, operator and/or other).

NOTE 1 – A company may contribute with one or more of the above levels, and may represent one or more roles.

NOTE 2 – In cases where a carbon reduction programme set up by an authority or a voluntary organization wishes to perform an actual allocation between actors to avoid double counting, some challenges and proposed solutions are presented in appendix V.

13.3 Assessment of the contribution of an ICT solution from the perspective of an ICT solution provider

13.3.1 Three types of assessments

This clause addresses the three different assessment types presented here with a question representing a typical assessment aim and an example:

- I. Assessment of the aggregated effect of all ICT solutions provided by an ICT organization:
  - *What is the contribution of Company A from the overall usage of its delivered ICT solution(s)?*
  - Example: The annual impact of the overall portfolio of Company A including all their ICT solutions regardless of end-user sector (for instance solutions for virtual meetings and traffic management).
- II. Assessment of the aggregated effect of one or several ICT solution(s) provided by an ICT organization across some customers:
  - What is the effect across all customers of some specific ICT solutions delivered by Company A?
  - Example: A fixed and mobile network operator assessing the impact of its teleworking and video communication services for two of its customers over one year.
- III. Assessment of the effect of a specific ICT solution implemented in an actual context for a specific customer:
  - What is the effect of ICT solution I delivered by Company A for the usage of Customer X?
  - Example: A videoconferencing solution implemented for a customer e.g., an insurance company.

13.3.2 Common guidance for assessments from the perspective of the ICT solution provider

In all cases, the general methodological principles described in clauses 6–10 shall be followed. This includes principles such as that:

- Tiers 1–3 assessments may be performed but Tier 1 assessment is recommended, and Tier 3 assessments shall not be used for public or consumer communication.
- Ex-ante, mid-way and ex-post assessments may be carried out. In the case of the ex-post assessment, actual data shall be collected and taken into account for all the relevant effects. This may include data such as travel data when assessing a videoconferencing solution.

NOTE – Reporting by a company may need to consider legal and other frameworks.

Following clause 6, first order effects shall be included unless these are insignificant according to the cut-off rules, i.e., on a relative scale in relation to the ICT solution.

13.3.3 Specific guidance for assessments from the perspective of the ICT provider

Table 3 summarizes the specific provisions that apply for each of the three categories of assessments performed from the perspective of the ICT provider.

Table 3 – Specific provisions for different kind of assessments performed from the perspective of the ICT provider

Assessment of the aggregated effect of all ICT solutions provided by an ICT organization across all customers	Assessment of the aggregated effect of one or more ICT solutions provided by an ICT organization across some customers	Assessment of the effect of a specific ICT solution implemented in an actual context for a specific customer
To evaluate mid-term and long-term evolution in behaviours, it is recommended that these are assessed through ex-post assessments performed at a sufficiently long time after installation for such effects to be established (typically a minimum time of two or three years after installation).	To evaluate mid-term and long-term evolution in behaviours, it is recommended that these are assessed through ex-post assessments performed at a sufficiently long time after installation for such effects to be established (typically a minimum time of two or three years after installation).	To evaluate mid-term and long-term evolution in behaviours, it is recommended that these are assessed through ex-post assessments performed at a sufficiently long time after installation for such effects to be established (typically a minimum time of two or three years after installation).
	When establishing a consequence tree to identify the impact of one or more ICT solutions, the following aspects shall be taken into account: • Yearly effects on the customer organization; • Yearly effects on the value chain.	When establishing a consequence tree to identify the impact of one or more ICT solutions, the following aspects shall be taken into account: • Yearly effects on the customer organization; • Yearly effects on the value chain; • Yearly effects on employees.
As far as possible, the assessment should: • Be recalculated from ex-post assessment of some relevant cases; • Use a model for their extrapolation; In either case, the selected approach shall be explained and documented".	As far as possible, the assessment should: • Be recalculated from ex-post assessment of some relevant cases • Use a model for their extrapolation In either case, the selected approach shall be explained and documented".	

Annex A

A non-exhaustive list of ICT solutions which could potentially enable reduction in GHG emissions

(This annex forms an integral part of this Recommendation.)

This annex gives a non-comprehensive list of ICT solutions, the use of which could potentially enable a reduction of GHG emissions. See Table A.1.

Table A.1 – ICT solutions which could enable GHG emission reduction

Sector	Solution	Mechanism
Energy supply transformation and consumption	Improved metering and forecasting of electricity supply and demand	Optimization
	Optimization of grids, including load balancing through demand response	Optimization
	Improved energy system through demand side management	Optimization
Industry	As-a-service and sharing solutions	Optimization and/or substitution
	Circularity	Optimization
	Production efficiency	Optimization
Buildings	Intelligent building energy and resource management	Optimization
	Optimized use and sharing of buildings	Optimization and/or substitution
Transport	Virtual meetings	Substitution
	Remote work	Substitution
	Route optimization	Optimization
	Fleet management and logistics	Optimization

Table A.1 – ICT solutions which could enable GHG emission reduction

Sector	Solution	Mechanism
	Ecodriving	Optimization
	Shared mobility	Optimization and/or substitution
Agriculture and forestry	Precision agriculture	Optimization
	Precision forestry	Optimization
Nature-based sinks	Forest protection	Providing information and managing data Facilitation, accessibility, affordability and rising motivation

Annex B

Establishing the scenarios

(This annex forms an integral part of this Recommendation.)

B.1 The use of hypotheses in assessments

An assessment of ICT's second order effects is an assessment of the situation with the ICT solution applied (the ICT solution scenario) and one without it (the reference scenario). As the two cannot exist at the same time, the assessment will always be based on hypotheses for at least one of them.

As outlined in Table B.1 the reference scenario will always be hypothetical as it will consider how the situation with the reference activity would have developed if the ICT solution would not have been introduced. Moreover, the ICT solution scenario is hypothetical except for the ex-post case and the mid-way estimate of the current effect.

Table B.1 – The hypothetical element of different types of assessments

	Assessment type	Reference scenario	ICT solution scenario
Ex-ante	Estimated expected effects (prospective)	Hypothetical	Hypothetical
	Estimated future potential (prospective)	Hypothetical	Hypothetical
Mid-way	Estimated present effect	Hypothetical	Actual
	Estimated present potential	Hypothetical	Hypothetical
Ex-post	Estimated actual effect (retrospective)	Hypothetical	Actual

Consequently, in most cases the assessment shall build scenarios for the usage of at least one of the scenarios to be compared. Building a usage scenario is thus an integrated part of both the reference scenario and the ICT solution scenario and refers to the use of the ICT solution and the reference activity, respectively.

Although the reference scenario is always hypothetical it should start from actual measurements of the situation before the ICT solution was implemented.

B.1 Building the usage scenarios

B.1.1 The impact of associated and independent contextual factors

Typically, an ICT solution scenario is impacted by contextual factors that are associated with it and independent contextual factors impacting the baseline. Both types of factors shall be considered.

Example: A videoconferencing system is established for Company A together with a new policy to restrict travelling. Before the ICT solution was introduced, Company A had 2000 employees but in parallel with establishing the new service, Company A outsourced part of its business to another company and the number of employees reduced by 500. The example focuses on Company A but the potential effect in the other company should be considered in the consequence tree. In this case the ICT solution situation can assume that the new travelling policy is in place and supports the application of the videoconferencing system. However, Company A cannot refer to the total travelling before the establishment of the ICT solution as a reference situation, but the practitioner would instead need to consider the reduction in number of employees by 25% and the expected travelling of those. That is, in this case the travelling of the previous year cannot form the reference

scenario as that would confuse the impact of the ICT solution and the organizational development. Note that if Company A instead was interested in the change of travelling emissions rather than the effect of the ICT solution, they could still make a year over year comparison of change in travelling related emissions. However, that kind of assessment is outside the scope of this Recommendation.

B.1.2 Distinguishing between variation in usage and rebound usage

Often, in an ex-post or mid-way assessment, the practitioner needs to understand the difference between usages that modify the reference activity and rebound activities in line with clause 10.3.1.1. This task is rendered more complex as variations in usage may also occur independent of the application of the ICT solution. Clause B.1.1 gave an example of a situation where the number of employees changed over time.

That kind of consideration is similar to the considerations that need to be taken into account when reusing case studies between different situations, a topic which is further elaborated in [ITU-T L.1440] part II.

Consequently, the assessment shall distinguish between variations in usage that would take place independent of the application of the ICT solution, i.e., effects that would also have affected the reference activity, and changes in usage associated with the solution representing rebound (i.e., induction).

B.1.3 Distinguishing between second and higher order effects

This Recommendation makes a distinction between second and higher order effects. However, where to draw the boundary between the two is not always obvious. This is in particular due to second order effects being assessed through scenarios that include (explicit and implicit) assumptions regarding contextual factors, which could have a connection to rebound.

One aspect to consider would be intention. The intended effect is more commonly captured as a second order effect, while other effects that are not captured within the assessment boundaries of second order effects could sometimes be interpreted as rebound.

From the perspective of this Recommendation the key focus is to build reasonable scenarios, which consider relevant conditions regardless of whether those are referred to as second or higher order effects.

B.1.4 Iterative modelling

The modelling of the scenario follows an iterative approach of gradual refinement. The consequence tree (see clause 10.2.6) is a useful tool in this process.

Appendix I

Other methodologies

(This appendix does not form an integral part of this Recommendation.)

The basis for this Recommendation is [ITU-T L.1410] which describes the assessment of the enabling effects of ICT in part II, Comparative analysis/LCA between ICT and reference product systems (baseline scenario): framework and guidance (see Figure I.1).

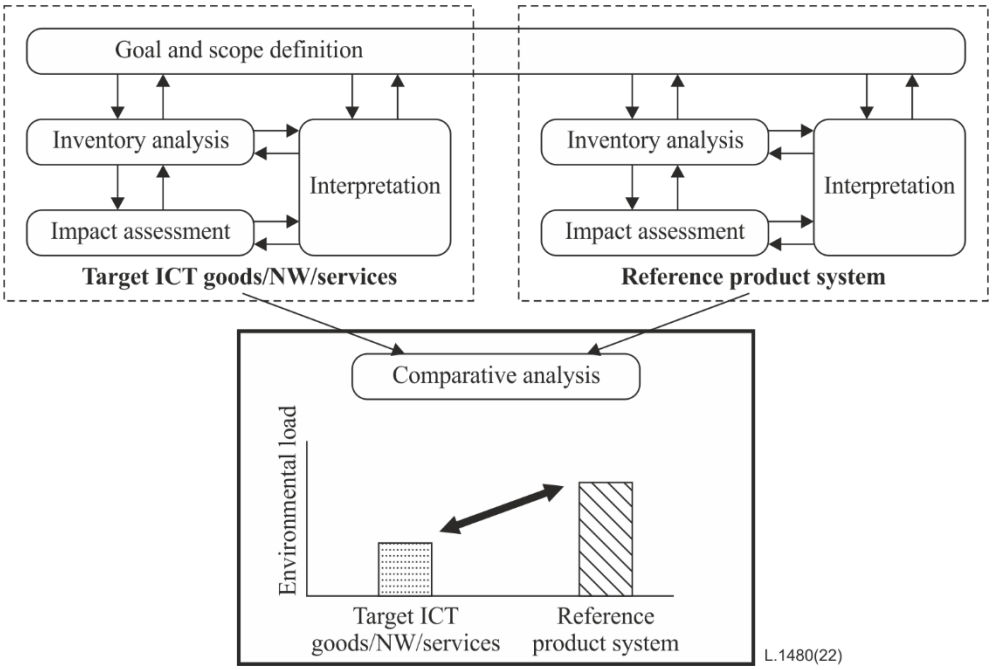


Figure I.1 – Comparative analysis overview

[ITU-T L.1410] has also formed a basis for [ITU-T L.1430] and [ITU-T L.1440], which have outlined additional guidance from the perspective of projects and cities, respectively. In addition, [ITU-T L.1451] addresses the opportunity to use a computable general equilibrium (CGE) model as a possible methodology for simultaneously assessing the environmental and economic impacts of ICTs at the sectoral level. Another approach based on macro analysis is put forward by [b-Hernnäs].

More recently, researchers have started to evaluate [ITU-T L.1410], proposing several enhancements for single services as well as introducing challenges specific to the assessment of multiple services (Figure I.2).

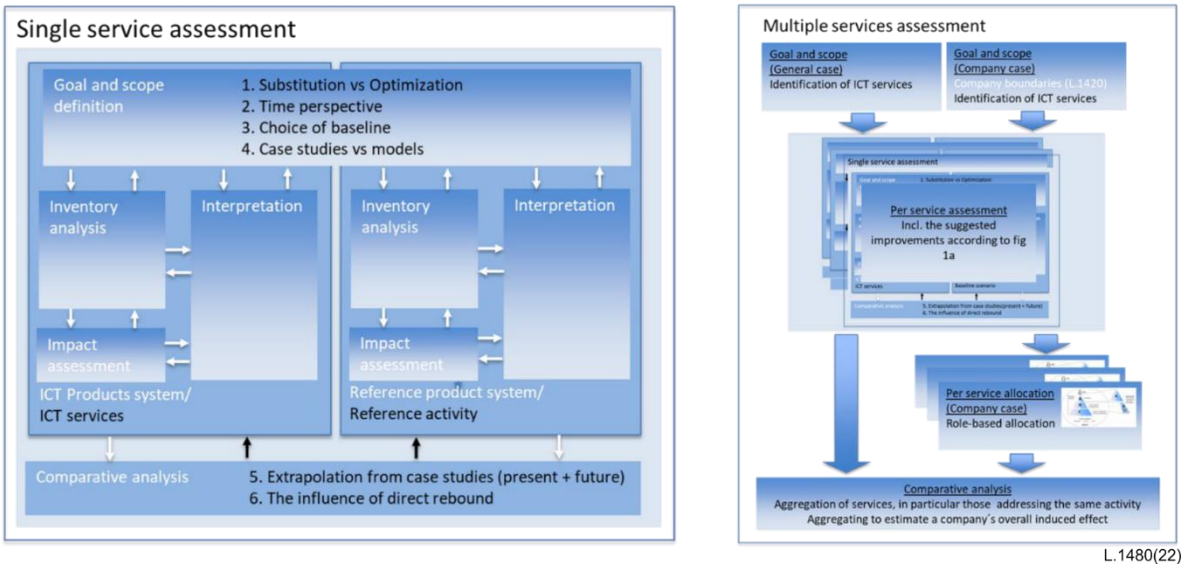


Figure I.2 – Enhancement areas for assessment of a) single services and b) multiple services (Source: [b-C&B] and [b-B&C])

Moreover, ADEME has developed a methodology to assess the impact of an action on GHG emissions. A methodology derived from the ADEME [b-ADEME-1] and the Net Zero Initiative framework [b-Net Zero Initiative] has been developed to assess the impact of an action on GHG emission reductions: when the action consists in selling a low-carbon ICT solution to a customer, there can be GHG emissions reductions enabled by the ICT solution at the customer side.

An example is a baseline scenario with face-to-face meetings attended by employees of an organization (Figure I.3). In this case, employees travel using more or less carbon-intense means to attend meetings. If the customer organization decides to purchase an ICT videoconferencing solution to reduce transportation needs, this action may reduce the GHG emissions associated with transport (Figure I.4). The difference in GHG emissions between the baseline scenario and the action scenario is shown in Figure I.4, where the GHG emissions in the ICT solution scenario are reduced relative to the historical scenario or the most probable baseline scenario at time T_1. However, the action scenario also accounts for the environmental load of the videoconference system life cycle, and the observation of behavioural changes, to verify, for example, the initial assumption that the use of the system effectively decreases travelling.

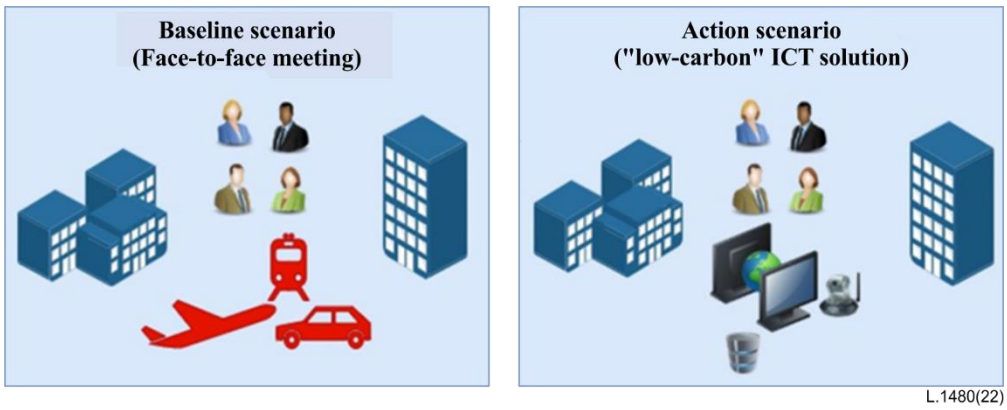


Figure I.3 – Example of a scenario with an action based on the deployment of an ICT solution to avoid transportation due to face-to-face meetings (baseline scenario)

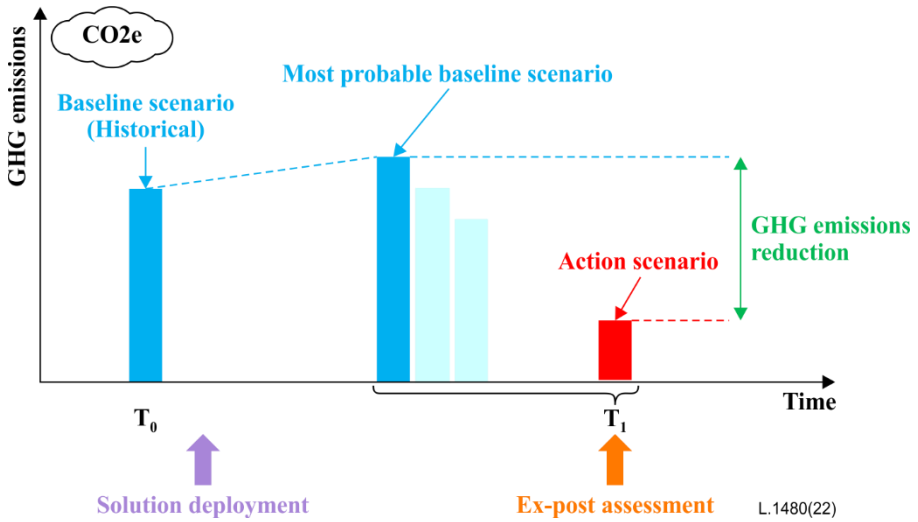


Figure I.4 – Impact of an action on GHG emissions reduction considering the most probable baseline scenario for an ex-post evaluation carried out at T_1

The methodological framework derived from ADEME is based on a consequential approach which is recommended for public claims based on comparative analysis that may involve market or rebound effects [b-WRI]. The enabled effect is evaluated considering a baseline scenario and all positive and negative effects on GHG emissions due to an action, for instance, the deployment of the ICT solution. Generally, the evaluation of the GHG emissions enabled effect consists of calculating the algebraic sum of the negative effects, i.e., the first order effects associated with the ICT solution and the rebound effects, and the positive effects related to the environmental benefits enabled by the same ICT solution, i.e., positive second order effects and the effects of behavioural changes consecutive to ICT solution implementation, which can be positive or negative, i.e., rebound effects (Figure I.5).

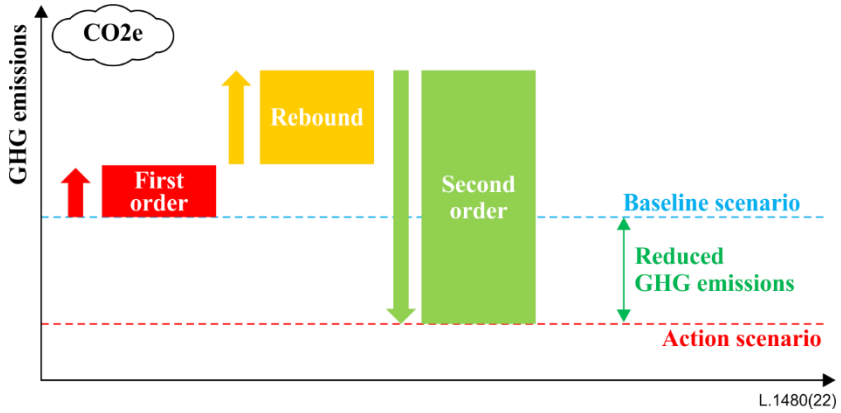


Figure I.5 – Calculation of reduced GHG emissions as the algebraic sum of negative (first order and rebound) and positive (second order) effects of the action on GHG emissions of a baseline scenario

Other frameworks of relevance, but not specific to ICT, include:

- The mission innovation solution framework [b-MI];
- Estimating and reporting the comparative emissions impacts of products [b-WRI];
- Avoided emissions framework by the World Business Council for Sustainable Development (WBCSD) (ongoing).

In particular, the report entitled The Enablement Effect by GSMA and Carbon Trust [b-GSMA] builds on [b-MI], and [b-WRI] and establishes a preference for consequential approaches, while at the same time seeing them as challenging to undertake in practice.

Mission Innovation [b-MI] is an initiative to promote global clean energy innovation that connects 23 countries plus the EU. They have developed a framework for avoided emissions which includes ICT solutions within its scope, and is intended to help decision-makers and investors to support and accelerate the innovation of low-carbon solutions. In particular, they suggest that investors seeking to change their portfolio profiles shall be enabled to identify products and services which can contribute positively to the decarbonization of society, not only those with high footprints. The framework argues that induced effects should thus in the long run be included in company accounting.

Appendix II

Checklist to support the identification of first, second and higher order effects

(This appendix does not form an integral part of this Recommendation.)

II.1 Introduction

[ITU-T L.1410] indicates that first order effects can be quantified by performing a life cycle assessment (LCA) related to ICT goods, networks and services. In the same way, the second order effect can be quantified by the comparison of LCA results between the ICT goods, networks and services product system and the reference product system performing the same function. The assessment of higher order effects is excluded from the scope of [ITU-T L.1410].

As the methodology described in [ITU-T L.1410] is based on LCAs, it is mentioned that "LCAs have a cradle-to-grave scope where all the life cycle stages (raw material acquisition, production, use, and end-of-life treatment) are included. Moreover, transport and energy supplies are included at each stage of the life cycle assessment."

II.2 Identification of first order effects

Clause 5.4 of [ITU-T L.1410] indicates: "As ICT networks are composed of ICT goods and as ICT services utilize ICT networks, the methodology for ICT goods is the basis for the methodologies for ICT networks and ICT services. In other words, the methodology for ICT networks is based on the methodology for ICT goods, and the methodology for ICT services accommodates both methodologies for ICT goods and networks. Consequently, the environmental impact assessment of ICT networks reflects the environmental impact of ICT goods employed in the ICT networks, and the environmental impact assessment of ICT services reflects the environmental impact assessments of ICT goods and ICT networks employed in the ICT services.

"In this context, ICT networks and ICT services can be seen as logical structures, which are physically made up of ICT goods, including hardware and software, but which also rely for instance on building premises, civil works to create cable ways, air conditioning, power generators and power storage such as an uninterruptible power supply (UPS)."

The first order effects of an ICT solution should consider the various goods used, e.g.:

- End-user goods;
- Customer premises equipment;
- Access network;
- Control and Core network;
- Operator activities;
- Data transport;
- Data centre(s);
- Service provider activities.

Moreover, the eight checklist items may be considered per functional unit (see [ITU-T L.1410] clause 6.2.3.5.2) to identify the life cycle processes contributing to the overall first order effect. In this case, [ITU-T L.1410] indicates:

- "The following eight checklist items should be considered in the system boundary setting of ICT services, including their associated goods and networks, to identify activities associated with their life cycle and usage…
- "The intention of the eight checklist items above is to ensure that all relevant impacts are considered for all life cycle stages when defining the impact from a product system

viewpoint. These are typical items to be often considered, but other items may be considered as well depending on study."

Thus, the eight checklist items to consider are:

- ICT hardware;
- ICT software;
- Consumables and other supportive products;
- Site infrastructure;
- Transport (movement of goods);
- Travel (movement of people);
- Storage of goods;
- Working environment.

To illustrate the use of these checklist items to identify and quantify first order effects, the [ITU-T L.1410] provides an example which indicates that the assessment of a telepresence service may include ICT hardware (telepresence audiosets, networks, and servers), ICT software (telepresence software), site infrastructure (facility for servers), travel (business trip for setting telepresence system and having meetings) and working environment (cooling and lightning of the meeting room).

For a more detailed structure of the life cycle activities associated with an ICT good (including one belonging to an ICT network or ICT service), practitioners could refer to Figure IV.1.

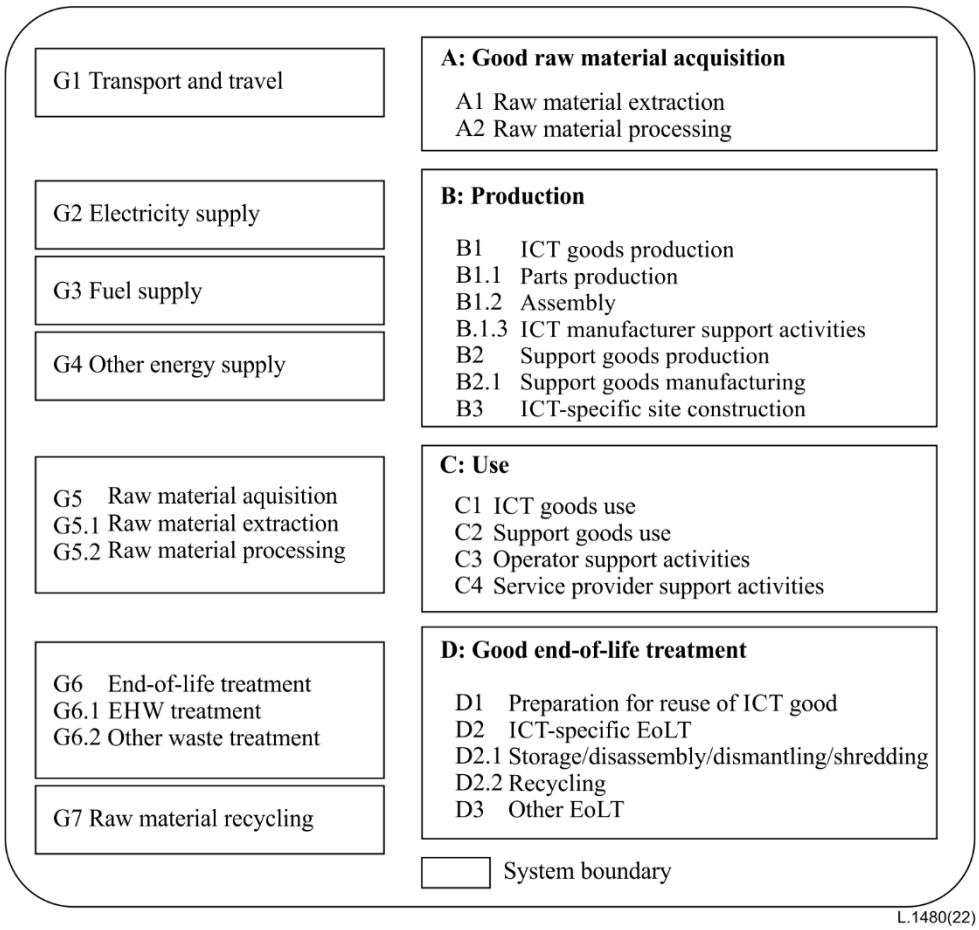


Figure II.1 – The system boundary of the product system for LCAs of ICT goods, networks or services (Source: [ITU-T L.1410] Figure 7)

For further guidance and a full understanding of first order effects refer to [ITU-T L.1410] directly.

II.3 Identification of second order effects

Table 7 of [ITU-T L.1410] shows an example of six categories which could be used to derive potential second order effects.

These six categories and the related potential corresponding second order effects are:

- Consumption of goods (paper, CDs, DVDs, etc.): by reducing the consumption of goods (paper, etc.), the environmental impact related to goods can be reduced.
- Power consumption/energy consumption (electricity, gasoline, kerosene, light oil, heavy oil, town gas, etc.): by enhancing the efficiency of power and energy use, the environmental impact related to power can be reduced.
- Movement of people (car, bus, railroad, aircraft, etc.): by reducing the movement of people, the environmental impact required for travel can be reduced.
- Movement and storage of goods (mail, truck, railroad cargo, air cargo, cargo ship, etc.): by reducing the movement of goods, the environmental impact required for transportation and storage can be reduced.
- Improved work efficiency (electricity, office area, etc.): by using office space efficiently, power consumption for lighting, air conditioning and so on can be reduced, thus reducing the environmental impact.
- Waste (wastepaper, garbage, plastic, industrial waste, etc.): by reducing waste emissions, the environmental impact for waste disposal, etc. can be reduced.

NOTE 1 – See clause 12.5 of [ITU-T L.1410] and Appendix X in [ITU-T L.1410] for details.

NOTE 2 – Depending on the type of ICT solution scenario and the corresponding reference scenario, these categories may not be used, and other categories may be added.

II.4 Summary: Checklist to consider for the identification of first and second order effects

To summarize, these eight checklist items, together with the list of categories of goods from clause II.2 and Figure II.1, may be used to ensure that relevant first order effects are considered:

- ICT hardware;
- ICT software;
- Consumables and other supportive products;
- Site infrastructure;
- Transport (movement of goods);
- Travel (movement of people);
- Storage of goods;
- Working environment.

In the same way, these six comparison items may be used as a starting point for ensuring that most of the relevant impacts of the second order effects are considered:

- Consumption of goods,
- Power consumption/energy consumption,
- Movement of people,
- Movement and storage of goods,
- Improved work efficiency,
- Waste.

II.5 Identification of higher order effects

[ITU-T L.1410] does not provide any guidance for higher order effects. However, the list provided for second order effects for the six comparison items (see clause II.4) could provide a starting point to consider higher order effects in relation to each of those.

Moreover, the identification of higher order effects could consider changes in behaviours and usage patterns in relation to such as inter alia

- Financial means;
- Time;
- Space;
- Knowledge.

Appendix III

Consideration of direct rebound and induction

(This appendix does not form an integral part of this Recommendation.)

NOTE – This appendix is based on [b-C&B].

Figure III.1 shows the effect of misinterpreting rebound usages by illustrating the impact from rebound activities (a), and an often-encountered error in existing assessments (b). In Figure III.1 (a), an ICT solution (dark green) substitutes a reference activity inducing – before subtracting rebound – the enablement represented by the dashed rectangle. The induced rebound effect (light green), however, reduces this assumed enablement. Figure III.1 (b) shows the effect when all usages of the ICT solution are considered to be modified activities although some are in fact additional usages, due to rebound. This can lead to a large overstatement of the positive effect of the ICT modification (grey area). Figure III.1 shows a substitution case.

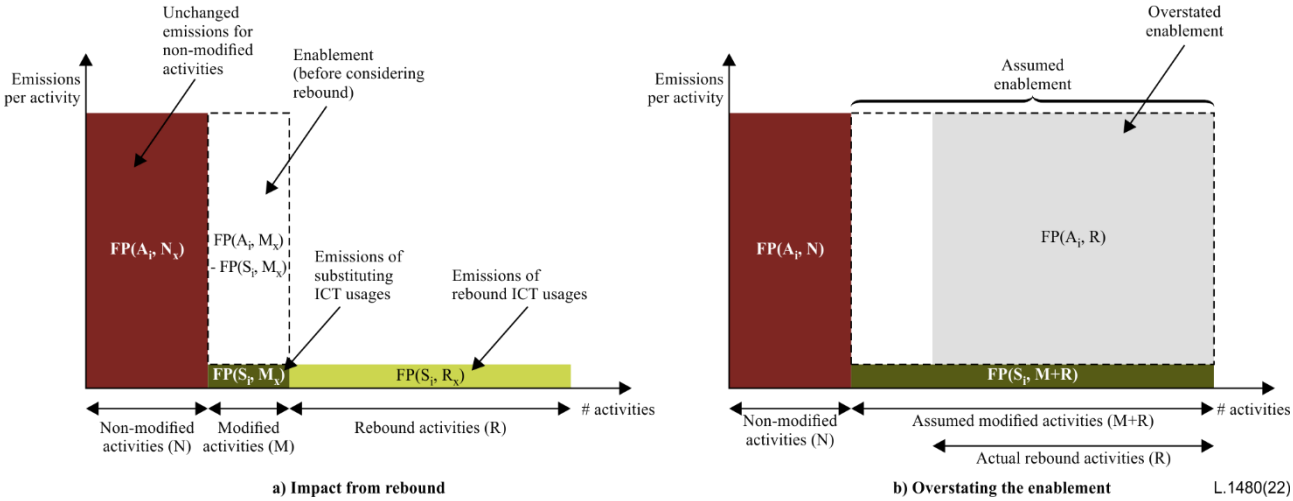


Figure III.1 – Schematic illustration of (a) the impact from rebound activities, and (b) an often-encountered error in existing assessments (Source: [b-C&B])

The main rebound-related source of error is to consider all usages to be modifying usages replacing more carbon-intensive activities. To distinguish those which are modifying from those that are not, is a challenging but necessary task. This stems from the fact that once the service is in place, it is in most cases an ontological uncertainty to distinguish between modified activities and rebound activities.

To illustrate this error in practice, a telecom company computed an enabling effect of 10 Mt CO_2e for its ICT services. Among several services, the largest part of this reduction came from mobile phone conversations that replaced other means of communication. The company claims that 5.5% of the mobile phone calls in 2010 replaced physical meetings, resulting in considerable GHG emission reductions. It is, however, impossible to exactly determine whether any particular instance of the substitute replaced the reference activity or not. Rebound effects might be responsible for 1% or for 99.9% of the usage, as compared with the reference activity.

It is even more important to consider rebound effects for future assessments.

The same example further asserts that the enablement almost tripled from 10 Mt CO_2e in 2010 to 29 Mt CO_2e in 2013. For 2013, the study used the same 5.5% as a percentage of calls replacing travel. As in 2013, the absolute number of calls over the cellular network grew abruptly, and therefore the same percentage of 5.5% represents a much higher absolute value. This seems a second fallacy related to rebound effects and extrapolation. Even if this percentage were a correct

estimate for 2010, the later increased service usage is most likely a consequence of the attractiveness of the service, i.e., a rebound effect, as it does not seem plausible that the need for face-to-face meetings would increase drastically between 2010 and 2013. This example shows how the influence of rebound effects may become more significant over time.

As rebound effects may have a crucial influence on the result, well-founded and possibly conservative assumptions seem key to a robust assessment. User speculation on rebound and original usage does not provide a solid scientific basis. When the usage intensity of an ICT service is used as a basis for computing the environmental benefits of the service, overstatements may occur, intentionally or not. A possible solution could be to consider the usage intensity of the service as one variable among many. Other criteria should be used for validation. When assessing the effect of high-quality videoconferencing on travel, for example, the usage intensity should not be the only nor the determinant factor in computing the induced effect. Other attributes should be considered, such as past levels of travel for the particular company under assessment, changes in travel costs and number of employees, rate of travel by similar companies not deploying the service, specific travel demand, broader societal trends and so on. Rebound effects tend to become more relevant as time passes. Future assessments should thus be even more cautious in avoiding usage intensity as a sole basis for the assessment.

Appendix IV

Guidance for assessing the GHG emissions consequences of the financial effects generated by an ICT solution

(This appendix does not form an integral part of this Recommendation.)

IV.1 Introduction

ICT solutions, by improving processes, often enable economic efficiency gains through the reduction of costs they generate. By generating financial gains for economic actors, they contribute to overall economic growth.

Moreover, one consequence of the deployment of ICT solutions, sometimes their very objective, is to increase the financial benefits of users. Symmetrically, the associated business transaction is usually accompanied by a financial profit for the solution vendor.

The carbon footprint (modelized by a consequence tree) of the implementation of such an ICT solution therefore implies assessing these direct consequences, which are sometimes their very purpose: financial profits for the vendor on the one hand, and financial gains for the user on the other.

This appendix proposes a calculation method to evaluate these common cases of rebound effect, so as to make it possible to take them into account when evaluating the GHG emission effects of an ICT solution.

The rebound effects related to financial gains fall into the category of behavioural changes resulting from the implementation of an ICT solution. Indeed, the allocation of the cash flow made available is decided by the economic actor. This allocation decision is by nature new, thereby changing its behaviour with respect to the previous situation.

This appendix is in particular intended to support Tier 3 assessments and represents a first approach which has been further elaborated in [b-ITU-T Suppl. 54].

IV.2 Overview of the proposed methodology

IV.2.1 Historical development of the methodology

The question of the environmental impacts of financial investments has been raised for the past 20 years, in parallel with the concern of investment funds to assess the environmental impact of their choices [b-ADEME-2] [b-GHGP-2]. It is becoming increasingly important as financial actors are increasingly required to justify their priorities, not only in terms of financial profitability – which only exceptionally exceeds a time horizon of 5 or 6 years – but also in terms of their contribution to the sustainability of the planet's habitability.

IV.2.2 Main principles and components of the calculation

The method distinguishes, according to the typology of the beneficiary, the economic actor of the financial gains:

- Either a private individual who, depending on national regulations, will often be considered as a household in the tax sense;
- Or a company.

In each case, account is taken, from the most precise to the least precise, of:

- Firstly, the actual allocation of these gains if it is known and traced;
- The prior allocation of resources of the same nature by the economic actor;

- The average allocation of financial resources by actors of the same category (individual/household or company activity sector).

This method thus allows for a simple evaluation, at least in an initial approach, of the carbon impact of the financial gains generated by the implementation of an ICT solution.

IV.3 Method for evaluating the carbon impact of financial gains generated by the implementation of an ICT solution

IV.3.1 Calculating financial gains

The financial gains generated by the ICT solution are measured according to the reference situation used in the consequence tree, with respect to the actor's financial situation and expenses without the implementation of the ICT solution.

This profitability is evaluated net of any remaining expenses including taxes, and thus corresponds to the cash flow effectively available to the economic actor.

IV.3.2 Calculation of the carbon impact of financial gains

IV.3.2.1 Calculating the carbon impact of financial gains for an individual level: Person or household

A – Distribution of an individual's financial gains

An individual's financial gains are split between savings and consumption on an annual basis.

B – Allocation of an individual's financial gains

- If the allocation of the gains is known or can be traced, they are allocated according to it.

Example – If gains are used for debt reduction contracted for ICT solution purchases, or to purchase an insurance related to the ICT solution, then the carbon impact of the debt reduction or of the insurance purchased is used in the calculation of the carbon impact of these financial gains.

NOTE 1 – If a loan was taken out to acquire the ICT solution evaluated, the gains will be assumed to be allocated to the payment of the loan terms for the duration of the loan.

- By default, for gains whose allocation is not tracked, they are allocated according to the individual's financial saving profile when it is known.

Example – When the bank has observed the average savings rate of its client over time, this observed personalized average rate can be applied.

Otherwise, non-tracked gains of individuals with unknown financial saving profile are allocated according to the average saving propensity of individuals in their country of tax residence.

NOTE 2 – Several databases are available to estimate household savings rate per country:

- World Bank [b-World Bank 1]
- OECD [b-OECD]
- Data sources combined by Statista [b-Statista]

C – Calculating the carbon footprint of an individual's financial gains

- If the allocation of the gains is known and it is linked to a specific carbon footprint that is commonly recognized, the associated emission factor data should be applied.

Example – Allocation of gains to savings in a specific (ecological) investment fund, or to spending in a specific economic sector

- By default, once the split between savings and consumption has been evaluated for the consumed part, the average $kgCO_2e/k€$ (or applicable unit of account) emission factor of households in the considered country is applied.

Example – source [b-World Bank 2]

- For the saved amount, apply:
  - The $kgCO_2e/k€$ emission factor placed with the institution that manages the savings or that of the destination of the savings, depending on the fund selected, if either has been assessed in a recognized manner;
  - Otherwise, the $kgCO_2e/k€$ average emission factor of household savings in the country where the savings are invested.

IV.3.2.2 Financial gains of a company

A – Possible uses of a company's financial gains

The allocation of a company's gains can be made in three ways:

- Reinvestment in the company;
- Distribution to the owners of the company (shareholders if company is listed on stock market);
- Distribution to employees (profit-sharing, incentives or salary increases and extra bonuses).

B – Allocation of a company's financial gains

- If the destination and use of some gains are known or can be traced, these gains are allocated according to these destination and use.

Example: The exclusive allocation of gains to the purchase of carbon sink shares.

The allocation of gains to a specific use or project should be applicable only for companies that isolate the allocation in their accounts in an auditable manner, without any circumvention (as for an "earmarked tax").

Example: "80% of our profits on this offer are allocated to...", with the associated auditable control.

This allocation can be partial, in which case the percentage not allocated is evaluated as in the following section.

- If no preferential allocation is known, the gains are split between the three possibilities detailed above.

The percentage allocated to each possibility is determined according to the history of the company's use of its after-tax profit, preferably averaged over more than one year with a degressive factor of 2 per year beyond year $(n - 1)$ so as to give more weight to the most recent behaviour of the company.

NOTE – In the case of a net financial loss generated by the ICT solution, this loss can be split according to the same rules. This loss, which reduces the after-tax profit, thus reduces the carbon footprint of the consequences of the ICT solution.

C – Calculating the carbon footprint of a company's financial gains

i) Calculation of the carbon footprint of the share of financial gains reinvested in the company

- Data availability

This amount, when not directly available, is calculated from the profit after tax, after the deduction of dividends paid to shareholders during the year, and of profit-sharing, incentives and exceptional bonuses also distributed during the year to employees.

In the absence of a financial report specifying these points, this information is included in the company's accounting data, usually available at a registry office.

- Calculus

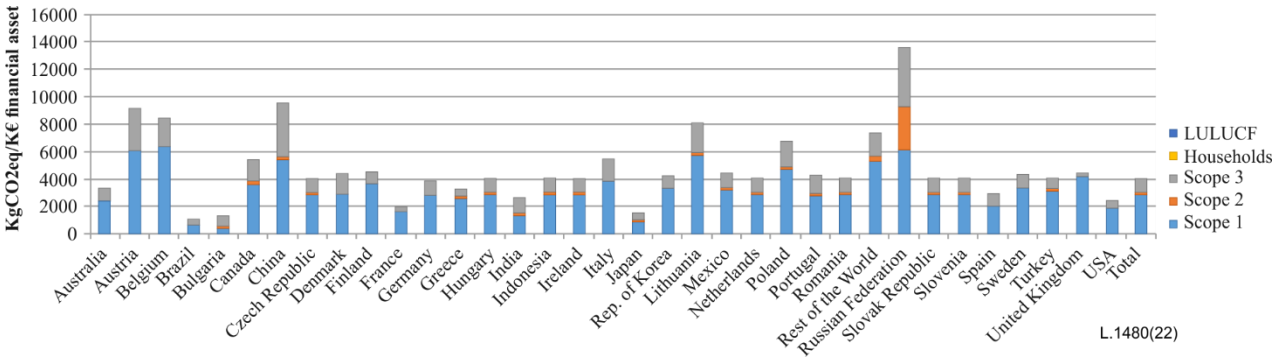
The kgCO_2e/k€ of financial assets of the company's sector of activity is applied to the relevant geography, which provides the emissions per monetary unit of assets per country for the sector [b-ADEME-2].

The data are taken from the BACH (Bank for the Accounts of Companies Harmonized) database, by applying correspondences with the French or OECD nomenclatures (cf. p. 124 in [b-ADEME-2]). However, this database only contains data for certain European countries (Austria, Belgium, the Czech Republic, France, Germany, Italy, Luxembourg, Netherlands, Poland, Portugal and Spain).

BACH database [b-Bach] (access upon registration):

For other geographical areas equivalent bases should be applied.

In the case of multiple activities or geographical areas, distribution keys can be used, according to the volume of business in the activity or geographical area; see Figure IV.1 for an example.



NOTE – LULUCF and Household categories do not appear in the graph due to their limited impact on air transport emissions

Figure IV.1 – Example regarding air transport carbon emission factors per country [Source: b-ORSE]

Table IV.1 and Table IV.2 give further details regarding the BACH database.

Table IV.1 – Sectors considered in the BACH database:

01 Aeronautics/Aerospace	13 Distribution/industry/goods/consumption
02 Maritime	14 Energy
03 Other transport	15 Immovable property/real estate
04 Agrifood	16 Information/technology
05 Assurance	17 Media/Publishing
06 Automotive	19 Health/pharmacy
07 Heavy industries	20 Non-commercial services
08 Other industries	21 Telecom
09 Banks	22 Tourism/hotel/restaurant
10 Other financial activities	23 Utilities
11 Wood/paper/packaging	24 Other
12 Building and civil engineering	(no #18)

The resulting investment data by sector and geography in terms of carbon emissions are available in the Excel file produced by ADEME and Carbone 4, established by correspondence (pages 124–126 in [b-ADEME-2]) as listed in Figure IV.2.

Table IV.2 – ADEME/Carbone 4 sectors

1) Agriculture, hunting, forestry and fishing 2) Mining and quarrying 3) Food, beverages and tobacco 4) Textiles and textile products 5) Leather, leather and footwear 6) Wood and products of wood and cork 7) Pulp, paper, printing and publishing 8) Coke, refined petroleum and nuclear fuel 9) Chemicals and chemical products 10) Rubber and plastics 11) Other non-metallic mineral 12) Basic metals and fabricated metal 13) Machinery, not classified elsewhere 14) Electrical and optical equipment 15) Transport equipment 16) Manufacturing, not classified elsewhere; recycling 17) Electricity, gas and water supply 18) Construction 19) Sale, maintenance and repair of motor vehicles and motorcycles; retail Sale of Fuel	20) Wholesale trade and commission trade, except of motor vehicles and motorcycles 21) Retail trade, except in motor vehicles and motorcycles; repair of household goods 22) Hotels and restaurants 23) Inland transport 24) Water transport 25) Air transport 26) Other supporting and auxiliary transport activities; activities of travel agencies 27) Post and telecommunications 28) Real estate activities 29) Renting of machinery and equipment and other business activities 30) Public admin and defence; compulsory social security 31) Education 32) Health and social work 33) Other community, social and personal services 34) Average emission of all the sectors listed above

ii) Calculation of the carbon footprint from the share of financial gains distributed to the company's owners

A company, whether listed or not, is owned by shareholders.

If the shareholders are individuals, the dividends are treated as expenses of an individual in the country concerned, according to the same rules.

If the shareholders are companies, the geographical area and main sector of activity of the shareholder company are considered. Dividends are then treated as reinvestments in these companies, as described above.

Individual shareholders with a small number of shares are treated as residents in the territory of activity of the company.

In practice, the main owners are identified, i.e., those whose sum represents at least a third of the shareholders.

iii) Calculation of the carbon footprint resulting from the share of financial gains distributed to employees

It is allocated according to the employees' geographical area, split between savings and consumption as indicated above.

IV.4 Use of the method to calculate the effects over several years of the implementation of an ICT solution

The calculation of the carbon effects generated by the financial gains generated by the ICT solution is carried out each year the solution takes effect, based on the data available at the time the estimate is made.

As with each of the consequences of the ICT solution in the consequence tree, this estimate needs to be updated based on actual observed financial behaviour (household savings/consumption

distribution and observed distribution of net corporate earnings), and changes in external factors in the databases, such as decarbonization of the gross domestic product in countries or financial investment direction towards green funds.

Appendix V

Allocation between actors

(This appendix does not form an integral part of this Recommendation.)

This appendix presents a possible starting point for the allocation between actors introduced by [b-B&C].

Each ICT solution relies on a large variety of equipment and supporting services at three main contribution levels:

- A-level: The main ICT solution itself, which directly leads to an induced effect.
- B-level: Dedicated building blocks (equipment or software), developed specifically for the A-level service.
- C-level: General-purpose building blocks (equipment or software) required by the A-level service.

It is important to keep in mind that the A-, B- and C-levels are addressing different layers of the same systems and thereby of the same effect and cannot be added together without double counting.

Starting from the least specific level, typical C-level ICT building blocks are telecom and computer networks (equipment and protocols), frontend devices such as smartphones or computers, and backend devices such as servers in data centres. The attribute best describing this level is necessary commonalities. Considering lower-level commonalities such as components or raw materials does not seem meaningful.

On the B-level, the equipment or software has been specifically built for the A-level ICT service. For a smart metering service, for example, the smart meter itself is a B-level device. Likewise, a tablet application providing users with real-time information on their energy consumption is a B-level software component for smart metering. B-level equipment and subservices typically use one or more C-level ICT building blocks. In addition to being necessary, B-level components are specific.

Level A contains the overall ICT service that brings together all the B-level building blocks into one integrating service. Such a service typically makes use of several building blocks from both the B- and C-levels. Smart metering, for example, is a service that uses smart meter devices (B), backend data centres (C), a user feedback app (B), a network transmission protocol (C), a billing app (B) and several more such components. Level A is the integrating level.

Furthermore, A- and B-level contributions can be more accurately allocated to specific actors. For these essential contributions, a "100% rule" applies per level, which means that the sum of all enabling claims at that level should equal 100% of the total estimated induced effect. Double counting between actors is thus avoided. On the C-level such a principle does not seem practically feasible – for such generic building blocks it would be too challenging to identify all ICT services supported as well as the many individual actors contributing to those. For the C-level, the "touch it and it's yours" principle is proposed, while noting that an enablement statement on the C-level is less specific and perhaps less useful than an enablement statement on the A- or B-levels. Theoretically, an allocation could also be made between the A- and B-levels to allow for the aggregation of the two without double counting.

To apply the 100% rule, the allocation principle needs to consider both the different building blocks associated with each level – for the B-level, its specific equipment and software blocks, for the A-level only the ICT solution itself – as well as the various stakeholders contributing to them. The first allocation step, only needed for the B-level, is to allocate between the specific building blocks

needed for the service. As a first approach, assuming all building blocks to be necessary for the service to function as intended, it is proposed that each block receives an equal share.
In a next step, the various stakeholders contributing to the ICT service at the A-level, and to each building block at the B-level, are considered. For each of them, these stakeholders can be:

I) The innovator;

II) The developer;

III) The service owner;

IV) The operator.

The user is also an essential actor here – the one ultimately influencing the service usage. The user, however, whether an individual or a private or public organization, is different from the stakeholders contributing to the service. Private users are not expected to make public environmental claims, while company users will take advantage of the reduction through the reduced footprint enabled by the service. The user is thus not part of the allocation of reductions induced by ICT. This is summarized in Figure V.1.

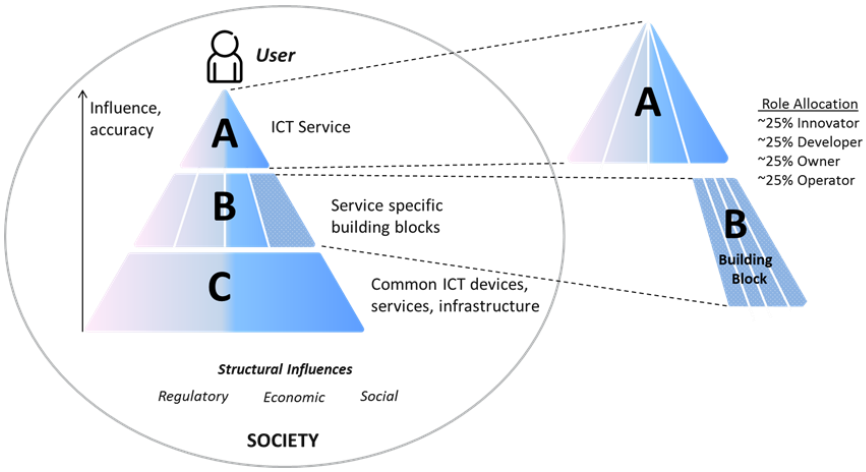


Figure V.1 – Illustration of the contribution and role-based allocation (Source: [b-B&C])

Based on these observations, several rules are defined for allocating the induced environmental effect among actors I–IV:

- The default allocation to roles I–IV is 25% each.
- If no distinct innovator can be identified, that role is attributed to the developer.
- If a stakeholder plays several roles for an ICT service, it can claim the cumulated percentages of its roles.

The argument for using equal shares between the roles is not definitive, but is rather of a pragmatic nature – all the roles are needed for the ICT solution to take place. The important message here is not to state an optimal allocation coefficient, but to identify the stakeholders and to agree that the aggregated effect should be 100%.

For this role-based allocation, the A- and B-levels can each be aggregated to a sector level but not added together unless an allocation is made between them; in any the case C-level cannot be aggregated.

Figure V.2 shows a flow chart for the assessment process when the allocation framework is applied.

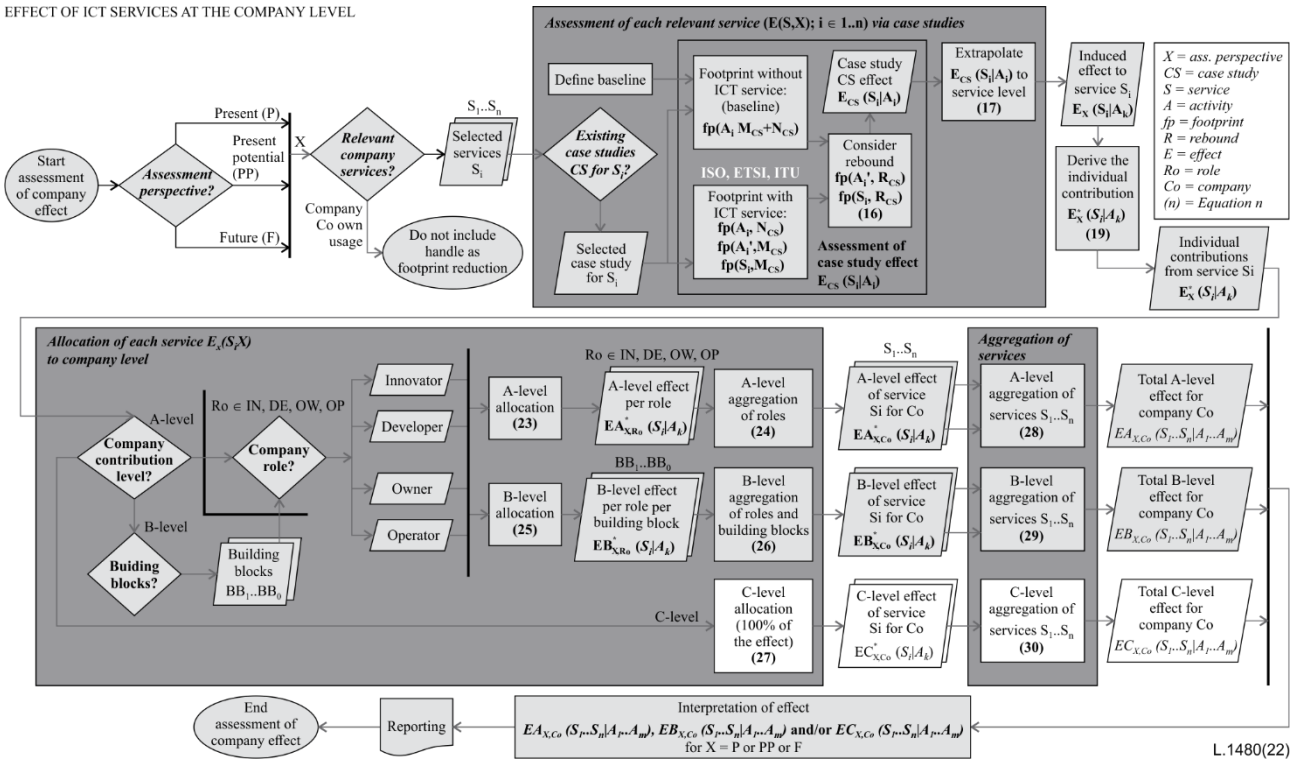


Figure V.2 – Assessing the effect of ICT solutions at a company level (Source: [b-B&C])

Bibliography

[b-ITU-T L.1420] Recommendation ITU-T L.1420 (2012), *Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations*.

[b-ITU-T Suppl. 54] Supplement 54 to the ITU-T L series Recommendations (2022), *Guidance for assessing the greenhouse gas emissions consequences of the financial effects generated by information and communication technology*.

[b-ADEME-1] ADEME (2016), *Quantifying the impact of an emission reduction action on GHGs, Methodological Guide – Version 2*.

[b-ADEME-2] ADEME (2014), *Guide sectoriel – 2014, Secteur financier, Réalisation d'un bilan des émissions de gaz à effet de serre*. <https://bilans-ges.ademe.fr/fr/ressource/guide-sectoriel-list/index/idElement/13/siGras/1>

[b-B&C] Pernilla Bergmark, Vlad C Coroamă, Mattias Höjer and Jens Malmodin (2020). *A methodology for assessing the environmental effects induced by ICT services – Part II: Multiple services and companies*, 7th International Conference on ICT for Sustainability (ICT4S2020), 21–26 June 2020, Bristol, United Kingdom, ACM, New York, NY, USA, 10 pp. <https://doi.org/10.1145/3401335.3401711>

[b-Bach] The Bach database of European companies accounts. <https://entreprises.banque-france.fr/etude/la-base-bach-des-comptes-dentreprises-europeennes> <https://www.bach.banque-france.fr/>

[b-C&B] Vlad C Coroamă, Pernilla Bergmark, Mattias Höjer and Jens Malmodin (2020), *A methodology for assessing the environmental effects induced by ICT services – Part I: Single services*, 7th International Conference on ICT for Sustainability (ICT4S2020), 21–26 June 2020, Bristol, United Kingdom, ACM, New York, NY, USA, 10 pp. <https://doi.org/10.1145/3401335.3401716>

[b-EC-1] European Commission (2011), *Addressing the rebound effect*. <https://ec.europa.eu/environment/eussd/pdf/rebound_effect_report.pdf>

[b-EC-2] European Commission (2010), *ILCD handbook – General guide for detailed LCA*. <https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf>

[b-ETSI TS 103 199] ETSI TS 103 199 (2011), *Environmental Engineering (EE); Life Cycle Assessment (LCA) of ICT equipment, networks and services: General methodology and common requirements*, V.1.1.1.

[b-GHG Protocol CS] Greenhouse Gas Protocol Corporate Standard (2004), *A Corporate Accounting and Reporting Standard.*

[b-GHGP-1] Greenhouse Gas Protocol (2014), *Policy and action accounting and reporting standard.* <http://ghgprotocol.org/policy-and-action-standard>

[b-GHGP-2] Greenhouse Gas Protocol (2013), *Technical guidance for calculating scope 3 emissions (version 1.0), Supplement to the corporate value chain (Scope 3) accounting and reporting standard*.

[b-GSMA] GSMA and Carbon Trust (2019), *The enablement effect, The impact of mobile communications technologies on carbon emission reductions.* <https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf>

[b-Hernnäs] H. Hernnäs (2018), *What is the impact of ICT on CO_2 emissions? A macro perspective.* <https://www.ericsson.com/49825a/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2018-09-helena-hernnas-m1-dissertation.pdf>

[b-ISIC] United Nations (2008), *International Standard Industrial Classification of All Economic Activities (ISIC)*, Rev.4 <*https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf*>

[b-ISO 14040] ISO 14040:2006, *Environmental management – Life cycle assessment – Principles and framework*.

[b-ISO/IEC 2382] ISO/IEC 2382:2015 (2015), *Information technology – Vocabulary*.

[b-MI] Andie Stephens and Veronica Thieme (2018), *Framework for assessing avoided emissions, Accelerating innovation and disruptive low- and zero-carbon solutions, Part 2: Draft methodology for calculating avoided emissions*, Mission Innovation Solution Framework. <https://www.misolutionframework.net/downloads/MI_Solutions_Framework_pt2_Draft_methodology_for_calculating_avoided_emissions_v2018-1.pdf>

[b-Net Zero Initiative] Net Zero initiative (2022), *A framework for collective carbon neutrality, Net Zero Initiative*. <https://www.net-zero-initiative.com/en>

[b-OECD] OECD, *Household savings*. <https://data.oecd.org/hha/household-savings.htm>

[b-ORSE] ORSE – ABC – ADEME (2015), *Guide sectorial – 2015, Bilan de gaz à effet de serre pour les activités financières, Analyse globale top-down des émissions induites par les financements et investissements*, Excel file <https://bilans-ges.ademe.fr/docutheque/docs/OUTIL%20EXCEL%20ORSE.xlsm>.

[b-Statista] Statista, *Gross savings rate of households in selected countries worldwide from 2010 to 2020*. <https://www.statista.com/statistics/246296/savings-rate-in-percent-of-disposable-income-worldwide/>

[b-UNFCCC-1] United Nations Framework Convention on Climate Change (2021), *Glasgow Climate Pact*. <https://unfccc.int/documents/310475>

[b-UNFCCC-2] United Nations Framework Convention on Climate Change (2015), Paris Agreement. <https://unfccc.int/sites/default/files/english_paris_agreement.pdf>

[b-World bank 1] The World Bank, *Gross savings*. <https://data.worldbank.org/indicator/NY.GNS.ICTR.ZS>

[b-World bank 2] The World Bank, *CO_2 emissions*. <https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD>

[b-WRI-1] Laura Draucker (2013), Do we need a standard to calculate "avoided emissions"? <https://www.wri.org/insights/do-we-need-standard-calculate-avoided-emissions>

[b-WRI-2] Stephen Russell (2019), *Estimating and reporting the comparative emissions impacts of products*, Working paper. World Resources Institute. <https://www.wri.org/research/estimating-and-reporting-comparative-emissions-impacts-products>

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant**
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems

Published in Switzerland
Geneva, 2022