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**Methodology for environmental impact assessment of information and communication technologies at city level**

Recommendation ITU-T L.1440

ITU-T

International Telecommunication Union

# Recommendation ITU-T L.1440

## Methodology for environmental impact assessment of information and communication technologies at city level


### Summary

Recommendation ITU-T L.1440 gives general guidance on city-level environmental assessments related to information and communication technologies (ICT) and provides a description of the methodologies to be used for the assessment of the environmental impact of ICT in cities.

In this first edition of this Recommendation, the assessment is limited to energy consumption and greenhouse gas (GHG) emissions.

This Recommendation is divided into two parts.

1) Part I relates to the first order effects from the use of ICT goods and networks in a city's organizations and households.

2) Part II relates to the first and second order effects from ICT projects and services applied in the city.

This Recommendation provides specific guidance on setting city boundaries, preparing and performing the assessment of ICT-related GHG emissions and energy consumption at city level.



### History

| Edition | Recommendation | Approval | Study Group | Unique ID* |
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### Keywords

Cities, energy consumption, environmental impact, GHG, greenhouse gas emissions, households, ICT, Information communication technologies, public administration.


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## Introduction

Cities, which are home to half the world's population, are growing rapidly and consume over two-thirds of the world's energy and account for more than 70 per cent of global $CO_2$ emissions. Nonetheless, cities are of the right scale and structure to deal with the challenges they face. As centres of cultural, political and economic leadership, cities can act on climate change, implementing bold steps to reduce greenhouse gas emissions so that others may follow. Due to this, the concept of smart sustainable cities (SSCs) is increasingly in focus.

Although the use of information and communication technologies (ICT) could reduce the environmental impact of cities, the deployment of ICT itself will consume increasing amounts of energy and resources. The positive as well as the negative impact of ICT has to be taken into account when assessing its impact.

The environmental impact of ICT in cities is the result of three orders of effects: The first order effect of ICT goods and networks in cities is related to their raw materials acquisition, production, use and end-of-life treatment. The impact of the whole life cycle is considered, both for goods, networks and services.

The second order effect refers to the environmental impact due to the use of ICT in other products or sectors in order to reduce their greenhouse gas (GHG) emissions or energy consumption. ICT can improve sustainability of urban infrastructure such as airports, harbours, buildings, public administration, sports venues, transport, street lighting, water management and security systems. ICT can also drive towards dematerialization and enhance optimization of other technologies, such as increasing the efficiency of power supply (e.g., to optimize smart grids).

Other effects of ICT in cities are systematic effects related to citizens' behaviours and behavioural changes, but also to structural changes linked to the use of ICT. In particular, so called rebound effects are included among other effects. Rebound effects refer to efficiency gains being offset by increased consumption.

NOTE 1 – This Recommendation uses both the terms "effects" and "impacts" where impact denotes the quantification of the effect.

NOTE 2 – In this Recommendation, energy consumption refers to the secondary energy used. GHG emissions also include the emissions related to energy generation and distribution. Furthermore, GHG emissions are included for assessment in ITU-T L.1410.

A number of methodologies have been developed in order to assess the environmental impact of cities. However, this Recommendation provides specific guidance on the assessment of the overall environmental impact of ICT at city level, as well as guidance on the assessment of city-level ICT projects and services.

This Recommendation is structured as follows: the initial clauses contain the general principles. Part I relates to the first order effects of the use of ICT goods and networks in a city's organizations and households and Part II relates to the first and second order effects of ICT projects and services applied in the city. Both parts are based on the existing ITU-T L.14xx-series of Recommendations (ITU-T L.1410, ITU-T L.1420 and ITU-T L.1430). In addition, examples are provided in the appendices.

Figure Int.0.1 shows an overview of the structure of this Recommendation. Part I is contained in clause 10 and Part II is contained in clause 11.

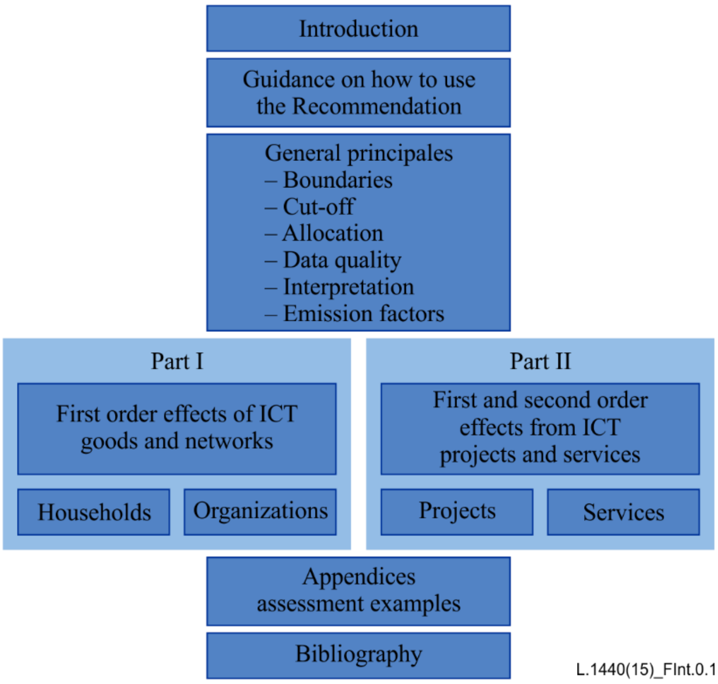


**Figure Int.0.1 – Overview of the structure of Recommendation ITU-T L.1440**

Although this Recommendation focuses on assessing the impact of ICT in cities, it is advisable that cities consider the first order impact of ICT in relation to the overall impact of ICT, in order to ensure that a balanced approach is adopted when tackling climate change and that ICT first order impact is co-optimized with its potential ability to enable GHG emissions reductions.

# Recommendation ITU-T L.1440

## Methodology for environmental impact assessment of information and communication technologies at city level

### 1 Scope

Based on other ITU-T L.14xx-series of Recommendations, this Recommendation aims at providing guidance for the assessment of ICT-related greenhouse gas (GHG) emissions and energy consumption at city level. This Recommendation provides a framework for the quantitative assessment at city level of first and second order effects of ICT. It also gives some guidance on how to qualitatively assess other effects.

More specifically, this Recommendation can be used to assess the first order effects of the use of ICT in organizations and households, as well as its first and second order effects when applied to different industrial sectors such as transport, buildings, utilities and waste management.

For the second order effects, it is not expected that the overall second order effects of all ICT at city level is assessed. Rather, this Recommendation provides guidance on how to assess the second order impact of one or more ICT projects or ICT services at the scale of the city.

This Recommendation, in line with [ITU-T L.1400], is focused on energy consumption and GHG emissions.

This Recommendation is intended for city authorities, policy-makers, environment and ICT experts and the industry and planning authorities, and can be used to guide the assessment of ICT-related GHG emissions and energy consumption at a city level.

### 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 stand-alone 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 sssessments of information and communication technology goods, networks and services*.

[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*.

[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*.

## 3 Definitions

### 3.1 Terms defined elsewhere:

This Recommendation uses the following terms defined elsewhere:

**3.1.1 ICT energy project** [ITU-T L.1430]: An ICT project that is designed to reduce energy consumption or enhance generation or storage of energy.

**3.1.2 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.

**3.1.3 ICT greenhouse gas (GHG) project** [ITU-T L.1430]: An ICT project that is designed to reduce GHG emissions or increase GHG removals.

**3.1.4 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.

**3.1.5 ICT organization** [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.

**3.1.6 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.

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

EXAMPLE: Teleconferencing, teleworking, e-ticketing, e-learning, e-healthcare, smart transport and logistics, procurement systems, supply chain management systems, music/film distribution over Internet or voice over IP, machine-to-machine systems.

### 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

**3.2.1 assessment boundary**: The assessment boundary defines what to assess and considers the project boundaries, services boundaries, city boundaries and system boundaries applicable to the assessment.

**3.2.2 city**: Any municipality incorporating one or several governments or planning authorities, which has defined geographical boundaries.

**3.2.3 city boundaries**: City boundaries denote the geographical boundaries of the city, city area or city district which is to be assessed.

**3.2.4 first order effect of ICT at city level**: The city level impact created by the physical existence of ICT and the processes involved, e.g., GHG emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.

NOTE – Based on [ITU-T L.1410].

**3.2.5 other effects of ICT at city level**: Effects of ICT at city level that are not first or second order effects; other effects can be related to changes of behaviour, of social, working or living habits and can include, e.g., rebound effects.

NOTE – Based on [ITU-T L.1410].

**3.2.6 project boundaries**: The project boundaries identifies the geographical boundaries of the project deployment and the ICT goods and networks that are part of the GHG and Energy ICT project.

**3.2.7 second order effect of ICT at city level**: The city level impacts and opportunities created by the use and application of ICT projects and services. This includes environmental load reduction effects which can be either actual or potential.

NOTE – Based on [ITU-T L.1410].

**3.2.8 service boundaries**: The service boundaries identifies the geographical boundaries of the service deployment and the ICT goods and networks that are part of the ICT service.

**3.2.9 tier 1 assessment**: An assessment of the impact of ICT where only the energy consumption and GHG emissions of the use phase of ICT are assessed.

NOTE – "energy consumption" refers to the secondary energy use in the use stage; "GHG emissions" due to this energy consumption also includes the emissions related to energy production.

**3.2.10 tier 2 assessmen**t: An assessment of the impact of ICT where the impacts of the energy consumption and GHG emissions for the whole life cycle of ICT are assessed, including those occurring outside city boundaries.

NOTE – "energy consumption" refers to the secondary energy use in the use stage; "GHG emissions" due to this energy consumption also include the emissions related to energy production.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AMI Advanced Metering Infrastructure

EoL End-of-Life

EoLT End-of-Life Treatment

GHG Greenhouse Gas

GNS Goods, Networks and Services

GWP Global Warming Potential

ICT Information and Communication Technology

LCA Life Cycle Assessment

LCI Life Cycle Inventory

LCIA Life Cycle Inventory Assessment

LTE Long Term Evolution

PC Personal Computer

RAN Radio Access Network

SME Small and Medium-sized Enterprises

SSC Smart Sustainable City

TV Television

## 5 Conventions

In the present Recommendation PC refers to a desktop personal computer while laptop refers to a laptop personal computer.

## 6 Guidance on how to use this Recommendation

This clause describes the intended use of this Recommendation.

Table 1 summarizes the different use cases for this Recommendation:

**Table 1 – Overview of use cases for this Recommendation**

| | Type of assessment | Scope | Purpose |
|---|---|---|---|
| Part I<br>(See clause 10) | Assessment of ICT related first order impacts of households<br>(Tier 1 and 2) | **ICT first order effects**:<br>ICT in households of the city | Understand the first order effects of the ICT used by households within the city boundaries.<br>Such results can serve as an input for assessments according to Part II of the methodology, or serve as a tool for the city stakeholders to monitor the impact of ICT used within the city boundaries. |
| | Assessment of ICT-related first order impacts of organizations<br>(Tier 1 and 2) | **ICT first order effects**:<br>ICT in organizations of the city | Understand the first order effects of the ICT of the organizations of the city. Such results can serve as a reference for assessments according to Part II of the methodology, or serve as a tool for the city stakeholders to monitor the impact of ICT used within the city boundaries. |
| Part II<br>(See clause 11) | Assessment of an ICT project's first and second order impacts<br>(Tier 1 and 2) | **ICT first and second order effects**:<br>One or more ICT projects with city level impact | Understand the first and second order effects of one or more ICT project(s). Such results can give a projection on how planned ICT projects will impact on the reduction of the GHG emissions and energy consumption of the city. Such assessments can also be used to monitor the impact of the actual project. |
| | Assessment of an ICT service's first and second order impacts | **ICT first and second order effects**:<br>One or more ICT services with city level impact | Understand the first and second order effects of one or more ICT service(s). Such results can give a projection on how planned ICT services will impact on the reduction of the GHG emissions and energy consumption of the city. Such assessments can also be used to monitor the impact of the actual service. |
| | Assessment of the expected impact of an ICT project or ICT service based on the experiences | **ICT first and second order effects**:<br>One or more ICT projects or ICT services with city level impact | Understand how assessment results of one city or a pilot project may be used to understand how an ICT project or service would impact another city. |

**Table 1 – Overview of use cases for this Recommendation**

| | Type of assessment | Scope | Purpose |
|---|---|---|---|
| | encountered in other cities | | |

Acknowledging that a city level assessment may be very challenging, both Tier 1 and Tier 2 assessments are described in this Recommendation for some of the use cases above as indicated in Table 1.

At the Tier 1 level, the assessment of the impact of ICT is limited to the operation of ICT in the use stage. A Tier 2 assessment is a more comprehensive assessment that provides more information about the impacts by including the full life cycle. It should be noted that Tier 2 level assessments often include impacts of activities occurring outside city boundaries.

The practitioner shall identify the most suitable approach in line with the scope and purpose of the assessment. Any intermediate level between Tier 1 and Tier 2 can be defined, provided that assumptions are transparently stated. As an example, Tier 1 may be combined with coarse estimates of other life cycle stages based on secondary data reflecting reference values from published sources.

A Tier 2 assessment should be preferred when possible for more representative results and stable conclusions. In both cases uncertainty analysis should be performed.

As an example, for a laptop or mobile phone, the production stage often represents a large portion of the life cycle impacts and an analysis of results based on only the use stage may therefore give the wrong conclusions from an environmental point of view. In the case where Tier 1 is adopted as a starting point it is recommended to prepare a plan to go all the way to Tier 2.

The tier concept is illustrated in Figure 6-1.

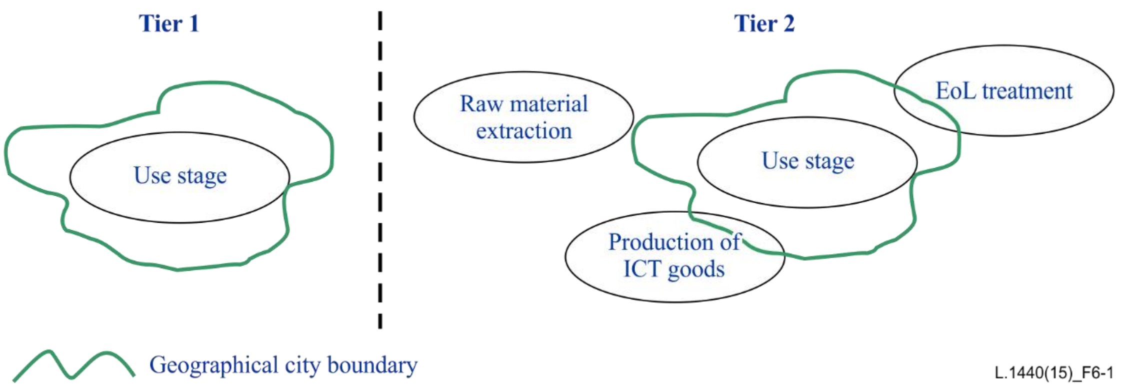


**Figure 6-1 – The tier concept**

NOTE – For both Tier 1 and Tier 2 assessments, all the emissions related to the energy supply shall be included even if the energy source is located outside the city boundaries.

# 7 General principles for impact assessment of ICT in cities

## 7.1 General

This Recommendation follows the guidelines of [ITU-T L.1400] for the environmental impact assessment of ICT, requiring that boundaries and a methodology are defined, that reliable data are used and that bias and uncertainty are addressed.

Practitioners shall strive for the assessments to be relevant, complete, accurate, consistent and transparent.

The practitioner shall adopt and document a consistent approach for all parts of the assessment. When combining the results of different parts of an assessment, the practitioner shall ensure that principles for data collection, data quality, boundary setting and cut-off, are consistent and documented in order to ensure that the best possible assessment quality is ensured.

## 7.2 Boundaries

Boundaries are defined to allow identifying what is "in" and what is "out" of the scope of the assessment of this Recommendation.

### 7.2.1 City boundaries

For all kinds of city level assessments, the city boundaries shall be identified, i.e., the geographical boundaries for a city, a part of a city or a city region, for which the ICT assessment shall be performed.

It is recommended that city boundaries identified and used for an overall city GHG emissions assessment are reused when performing an assessment of ICT-related emissions according to this Recommendation, especially for Part I (see clause 10).

### 7.2.2 Assessment boundaries

For the city level assessment, boundaries at different levels apply and need to be specified for the assessment boundaries to be well-defined.

Assessment boundaries shall be well defined in order to avoid the accounting of activities not directly concerning the city and to avoid double accounting.

#### 7.2.2.1 Assessment boundaries for Part 1

The assessment boundaries define the entities of the city that are taken into consideration in the assessment: which households and organizations are included. Furthermore, it defines which ICT goods and networks to consider and to what extent.

To define the assessment boundaries for a city level assessment according to Part I the following steps apply:

1 Identify the geographical boundaries of the city, city area or city region to be assessed (see clause 7.2.1).

2 Identify the households and/or organizations[1] located within those boundaries.

3 For these organizations and households, define the ICT goods and networks to include in the assessment, based on Annex A of [ITU-T L.1420] (this is referred to as operational boundaries in [ITU-T L.1420]).

4 For appointed ICT goods and networks, define the system boundaries to apply in accordance with clause 7.2.4 of [ITU-T L.1420] and the level of assessment chosen (Tier 1 or Tier 2). The system boundaries shall define the unit processes that should be taken into

[1] The Part I examples in this Recommendation are based on a statistical approach. If the assessment involves data collection from organizations the practitioner would also have to consider the boundaries between the organizations in order to ensure a consistent reporting approach to avoid double counting and gaps, i.e., the reporting should in this case be based on either operational control or ownership as further outlined in [ITU-T L.1420].

account in the assessment of ICT goods and networks[2]. Further guidance on system boundaries is given in [ITU-T L.1410].

a) For Tier 1 assessments, the system boundaries include only the use stage of ICT goods and networks.

b) For Tier 2 assessments, all life cycle unit processes including raw materials acquisition, production, use and end-of-life treatment (EoLT) apply.

NOTE – Ultimately, the practitioner would perform or have access to [ITU-T L.1410] compatible life cycle assessments (LCAs) for all included categories of ICT goods. If available, such data takes precedence over other data. In practice, other secondary data sources (including studies by ICT vendors and academia) may be used. The data and its quality need to be described as transparently as possible.

NOTE – In case the practitioner performs a full LCA study of a specific ICT good (rather than reusing results from previous studies) the different activities composing the life cycle of an ICT good as defined in [ITU-T L.1410] should be identified and taken into account. All of the activities that are part of an ICT good have their own contribution to its overall environmental impact.

#### 7.2.2.2 Assessment boundaries for Part II

To define the assessment boundaries for a city level assessment of an ICT project or service according to Part II (clause 11) the following steps apply:

1 Identify the geographical boundaries of the city, city area or city region to be assessed (same as for Part I).

2 Define how the ICT project or ICT service is adopted within these boundaries and the corresponding use of ICT goods and networks needed to implement the project or service. Identify also the expected or actual second order effects of the project or service.

3 Define the reference scenario based on the selected geographical boundaries.

4 For both the ICT scenario and the reference scenario define the system boundaries to apply in accordance with [ITU-T L.1410] (for ICT services) and [ITU-T L.1430] (for ICT projects). For ICT projects indicate also the chosen level of assessment (Tier 1 or Tier 2).

a) For Tier 1 assessments, the system boundaries include only the use stage unit processes of ICT goods and networks.

b) For Tier 2 assessments, all life cycle unit processes including raw materials acquisition, production, use and end-of-life treatment apply.

c) For second order effects, the system boundaries of the reference product system also need to be defined as outlined in Part II of [ITU-T L.1410].

Further guidance on system boundaries of ICT goods is given in [ITU-T L.1410].

NOTE 1 – Ultimately, the practitioner would perform or have access to [ITU-T L.1410] compatible LCAs for all included categories of ICT goods. If available such data takes precedence over other data. In practice, other secondary data sources (including studies by ICT vendors and academia) may be used. The data and its quality need to be described as transparently as possible.

NOTE 2 – In case the practitioner performs a full LCA study of a specific ICT good (rather than reusing results from previous studies) the different activities composing the life cycle of an ICT good as defined in [ITU-T L.1410] should be identified and taken into account. All of the activities that are part of an ICT good have their own contribution to its overall environmental impact.

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2 As a Part I assessment may often reuse published LCA results the input data may not fully align with [ITU-T L.1410]; it may also not have enough documentation to see to what extent it does. If available, [ITU-T L.1410] compliant data takes precedence.

When assessing the impact of an ICT project or service, it is recommended that the geographical assessment boundaries equal the city boundaries applied for Part I if possible, so that the ICT project or service impact may be related to the first order impact of ICT in households and organizations

Particularly for the assessment of second order effects, the ICT project or service and the reference scenario shall address the same geographical boundaries and time span.

#### 7.2.3 Time boundaries

When assessing the ICT-related GHG emissions of a city in accordance with Part I, the recommended assessment period is one year.

For consistency, it is recommended that the assessment of the first order impact of ICT in households and in organizations, including the public administration, refers to the same year.

When assessing the GHG emissions related to the outcome of an ICT project or a service, the assessment timeframe depends on the duration of the project or on the lifetime of the service. However, it is recommended that results are presented as yearly values consistently with the overall timeframe of the assessment of the impact of ICT at city level.

### 7.3 Cut-off

Any cut-off shall follow the rules of [ITU-T L.1420] for the assessment of the first order impact of ICT at city level (Part I, see clause 10) and of [ITU-T L.1430] and [ITU-T L.1410] for the assessment of the second order impact of ICT at city level (Part II, see clause 11).

In particular, if the practitioner carries out an assessment at Tier 1 level, only unit processes of the use stage of ICT goods and networks are considered. Within this stage the practitioner shall document and justify the cut-offs.

For the Tier 2 level of assessment of all life cycle stages of all ICT goods and networks shall be considered. Accordingly, any cut-off applied with respect to life cycle emissions shall be justified and documented.

If the number of organizations within the city boundaries is too large, it might be preferable to establish the assessment gradually and proceed in different phases and some priority criteria can be set to initially restrict the assessment to, e.g., large organizations, organizations with large environmental impacts or organizations with a large presence of ICT. If so, the priority criteria shall be documented and motivated.

Any cut-off applied, shall be described and justified.

### 7.4 Allocation

If an ICT good is used by a household, but owned by an organization the impact shall be allocated to the household.

ICT goods and networks serving users both inside and outside the city boundaries shall be allocated according to the following:

– For Part I (clause 10), impact from ICT goods and networks located within the city boundaries and used inside and outside city boundaries shall be fully allocated to the city. Impact from ICT goods and networks located outside the city, but used by the city shall not be allocated to the city.

For example consider a data centre (or another ICT network good) located within the city boundaries but mainly used by households and organizations outside the city boundaries. In this case, the assessing city shall take into account all its impacts. In contrast, a data centre located outside the city boundaries but used by the citizens is not allocated to the city. For a more detailed approach refer to Appendix VII.

NOTE – Due to the ways data centres are used by users from many different locations and the high number of data centres accessed from one city, other allocation principles would be too complicated.

– For Part II (clause 11), impact from ICT goods and networks serving users inside and outside the city boundaries shall be allocated to the ICT service or project to the extent applicable to the ICT project or ICT service (proportional to parameters such as use time or amount of data). [ITU-T L.1410] gives detailed guidance on allocation.

### 7.5 Data quality and assessment

The practitioner shall ensure consistency in data collection, calculation and reporting.

In general, cities should use the most accurate and complete sets of data in order to perform the assessments.

The assessment of the impact of ICT at city level refers to [ITU-T L.1410], [ITU-T L.1420] and [ITU-T L.1430] respectively. Each of these Recommendations provides guidance on the quality of the input data and assessments, thus data quality requirements of [ITU-T L.1410], [ITU-T L.1420] and [ITU-T L.1430] apply. In addition, these Recommendations provide the principles for collection and reporting of data which shall be followed.

NOTE 1 – The most recent data is preferred due to the fast change of technologies.

NOTE 2 – If no [ITU-T L.1410] compatible data is available for Tier 2 assessments the breakdown of the life cycle stages may differ among goods, which could cause some difficulties when calculating and presenting results. How this is solved should be described in a transparent manner.

NOTE 3 – Data compliant with [ITU-T L.1410] take precedence over other data.

### 7.6 Interpretation of results

At city level, the practitioner shall adopt and document a consistent approach to perform the uncertainty analysis for all the assessments, including the assessment of ICT goods and networks for households and organizations and assessments of ICT projects and services.

The guidance for uncertainty analysis of related Recommendations applies as follows:

– [ITU-T L.1420] for Part I (clause 10) (for households and organizations);

– [ITU-T L.1430] for Part II (clause 11) (for projects);

– [ITU-T L.1410] for Part II (clause 11) (for services).

In addition, the interpretation phase should include a sensitivity analysis on the most relevant inputs, outputs, methodologies, allocations and scenarios, particularly addressing the boundary setting and choice of assessment approach (Tier 1 or Tier 2), in order to interpret the results.

The emission factors used demand special attention. As an example a city may assess its ICT impacts related to households and organizations based on Part I on a yearly basis. Between two years the emission factor used may change. If so, the practitioner must make sure to analyse to what extent changes in GHG emission level is due to the change in emission factor (reflecting mainly the changes in impacts of the energy supply system or new data) – and to what extent it actually reflects a change in the adoption or energy consumption of the ICT goods and networks.

For Part I, in some cases, an increase in impacts from ICT organizations within the city boundaries may correspond to a decrease in the impact in a wider region. As an example, a city may build a highly efficient data centre that replaces a number of less efficient data centres located outside the city boundaries. In this case the ICT-related GHG emissions of the cities' organizations may increase, but the overall GHG emissions may decrease. For further details refer to Appendix VII.

### 7.7 Emission factors

When selecting emission factors for the calculation of GHG emissions under this Recommendation the following guidance shall be followed:

Emission factors used should be the most up to date from publicly available sources. Where emission factors are sourced from non-public sources, or are not the most up to date ones, a justification for their use shall be provided.

For all life cycle stages, representative energy mixes are preferred in accordance with the goal and scope of the assessment.

For the use stage, the emission factor should reflect the energy mix of the city as closely as possible while also taking into account distribution and transport losses from electricity generation. When known, location-specific data on energy mixes for a given locality or region gives the most accurate results. In particular, the following emission factors shall be used for the energy consumed during the use phase:

- city-specific emission factors if available;
- country emission factors otherwise.

Consequently, cities that purchase or generate electricity from sources that are more sustainable than the national sources (like wind or solar power) may use emissions factors for these. Choice of emission factors should be transparently described and motivated.

NOTE – Different emission factors for electricity may or may not consider the energy supply and distribution. As complete emission factors as possible should be used and the comprehensiveness of those shall be transparently reported. Due to this, the most recent emission factors available may not be the preferred choice or may need to be complemented.

The specific global warming potential (GWP) values used shall be those taken from the latest UN IPCC reports. For further guidance see Appendix XI of [ITU-T L.1410].

## 8 Guidance for the assessment of other impacts of ICT at city level

Other impacts of ICT include those related to the behaviour and behavioural changes of citizens, but also to structural changes.

For Part I and Part II, among the other effects, particularly the rebound effect is of interest, i.e., there is a tendency that reduction in environmental impacts from increased efficiency is offset by increased consumption. The quantification of such effects is in most cases very challenging and could not be standardized at this stage. However, to understand the risks related to rebound and try to minimize them it is important when rolling out an ICT project or service to reduce or avoid the offset of its positive effects. Therefore, this Recommendation provides guidance for a subjective but systematic, qualitative assessment of other effects.

For Part II assessments, drivers and barriers for an ICT project or service will also impact its use, and thereby its potential positive second order effects. This Recommendation therefore provides similar guidance for those as for the rebound effect.

### 8.1 Inventory of other effects

To evaluate the other effects the following procedure may be applied:

- Try to identify, analyse and describe the potential other effects related to the assessed ICT service or project and what the potential effect would be, how and where it would occur and within what time frame. Do this for the following categories:
  - **Induction**:
    when an ICT application stimulates increased use of a product or service.

– **Direct economic rebound**:
when the increased efficiency in providing some products/services affects the price which leads to increased consumption of those products/services.

– **Indirect economic rebound**:
when the efficiency savings from specific good/services is spent on other goods/services.

– **Time rebound**:
when time savings are used in a way that increases emissions (may be direct or indirect).

– **Space rebound**:
when space savings are used in a way that increases emissions (may be direct or indirect).

– **Learning in production and consumption**:
when ICT is developing the 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 are happening 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**:
scale effect is when large-scale production has less environmental impacts than small-scale production.

– **Changed practices (behaviours and routines)**:
transforming the everyday practice of people due to using ICT devices and services in a way that either increases or decreases emissions (additional to intended changes).

– **Transformational impact**:
when changes in technology leads to changes in consumer preferences, alter social institutions and the organization of production.

• Once the other effects have been identified they could be categorized with respect to importance, probability and addressability based on qualified guesstimates.

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

## 8.2 Inventory of drivers and barriers for ICT projects and services

To evaluate the drivers and barriers for an ICT service or project the following procedure may be applied:

• Identify the stakeholders of the ICT service or project for the relevant categories such as:

  – end users;
  – ICT providers and vendors;
  – investors;
  – policy makers;
  – society.

• Use the following categories to try to identify the drivers and barriers related to the assessed ICT service or project and map them to different stakeholder categories and to different phases of the project or service (e.g., planning, execution, deployment and operation).

  – economic obstacles/incentives;

  - business obstacles/incentives;
  - structural obstacles/incentives;
  - social obstacles/incentives;
  - attitudes and behaviours.
- Once the drivers and barriers have been identified they could be categorized with respect to importance, probability and addressability.
- If possible, identify countermeasures against the barriers and supporting measures for the drivers to support that the full potential of positive second order effects is utilised.

# 9 Preparing a report on the environmental impact of ICT in cities

## 9.1 General

Reporting is an important step in ensuring accountability for the cities implementing this methodology. This clause specifies the reporting requirement and examples are provided in Appendices I and II.

If the city decides to assess both first and second order effects, the impact of ICT representing the first order effects of ICT in organizations and households (Part 1, see clause 10), and the enabling effect of ICT corresponding to the first and second order effects of selected ICT projects and services (Part II, see clause 11), shall be reported separately.

For Part I (clause 10), the reporting shall follow the guidelines stated in clause 9 of [ITU-T L.1410] and the contributions related to the life cycle stages: raw material acquisition, production, use and end-of-life treatment, shall be stated. It is also recommended that a breakdown into households, ICT organizations, non-ICT organizations and public administration is made.

For Part II (clause 11), in the case of ICT projects, reporting shall follow the guidelines stated in clause 13 of [ITU-T L.1430] for ICT GHG and energy projects. In the case of ICT services, reporting shall follow the guidelines stated in clause I.3.4 of [ITU-T L.1410].

For all assessments of ICT at a city level, the following information shall be included in the report:

- contact information;
- goal and scope of the study;
- type of assessment (i.e., the approach chosen, Tier 1 or Tier 2);
- a compliance statement with reference to this Recommendation and any deviations clearly stated;
- period for which the report is valid and frequency of the reporting;
- identification and justification of boundaries and timeframe chosen;
- identification and justification of cut-offs;
- identification of possible double counting situations;
- a description of the data collection method and quality with respect to energy data, GHG activity data and emission factors (how, where, when, why);
- emission factors used: the report shall include, for each reporting year, a list of the emission factors used and their origin and what they represent (e.g., the year they represent, to what extent the energy distribution and supply chain was included);
- other data, justifications and explanations as stated throughout this report.

## 9.2 Reporting of assessments based on Part I

When reporting the results of the assessment, households, ICT organizations, non-ICT organizations and public administrations should be reported separately.

Based on the relevant parts of the previous ITU_T L.14xx series of Recommendations, in particular [ITU-T L.1410], and in addition to what is listed in clause 9.1, the Part I (clause 10) report shall also contain:

- The results of the assessment:
  - energy consumption and GHG emissions of the use stage for Tier 1 assessments;
  - energy consumption and life cycle GHG emissions for Tier 2 assessments.
- The interpretation of the results and the outcome of the uncertainty analysis for energy consumption and GHG emissions.

Moreover, the following information shall be recorded by the city:

- organizations and/or households taken into account. Any exclusion of organizations and/or households within the city boundaries shall be documented and justified;
- number of people working in each organization and/or number of people living in the households;
- the data sources.

## 9.3 Reporting of Part II

### 9.3.1 Reporting the first and second order effects of an ICT project

The reporting of the first and second order effects of ICT projects at a city level shall consider the reporting as outlined in clause 12 of [ITU-T L.1430] and it shall include the following:

- information about any GHG programme to which the ICT project belongs;
- general market conditions, national regulations, requests of intended users, or internal policies, applicable to the ICT goods, networks or services incorporated in the project activities;
- short description of the ICT project;
- adoption of the ICT project, its use and effects;
- geographic boundaries of the ICT project, indicating whether the project involves activities or effects in more than one city. If so, also describe allocation between those cities involved;
- the operational lifetime of the ICT project;
- statement describing whether the GHG and energy assertions exist and have been validated and/or verified, including the type of validation or verification and level of assurance achieved;
- description of the project activity and the selected baseline scenarios;
- results covering the impacts of the project activities and the estimated baseline scenario;
- the interpretation of the results and the outcome of the uncertainty analysis for energy consumption and GHG emissions;
- monitoring plan.

### 9.3.2 Reporting the first and second order effects of ICT services

The reporting of the first and second order impacts of ICT services at a city level shall consider the reporting as outlined in clause 13 of [ITU-T L.1410] and it shall include the following:

- short description of the ICT service and its use and effects;
- adoption of the ICT service;
- geographic boundaries of the ICT service, indicating whether the service involves activities or effects in more than one city, and if so, the allocation between those cities involved;
- description of the baseline scenario;
- results covering the impacts of the ICT services and the selected baseline scenario;
- the interpretation of the results and the outcome of the uncertainty analysis for energy consumption and GHG emissions.

# 10 Part I: First order effects from the use of ICT goods and networks in a city's organizations and households

## 10.1 General description

Within the city, households and organizations, including the public administration, are identified as the main users of ICT for which the environmental impact of ICT can be assessed.

Thus, Part I aims at the assessment of the first order impacts of the ICT goods and networks used in households and organizations, public or private, ICT or non-ICT, within the city's boundaries.

The practitioner shall apply the non-ICT organizations' approach outlined in clause 7 of [ITU-T L.1420] for all the assessed main ICT users (households, organizations, including the ICT organizations and the public administration). If possible, data should be structured into the categories of households, ICT organizations, non-ICT organizations and Public Administration to enable that these are reported separately.

Building on [ITU-T L.1420], the present clause describes the steps to apply to assess the first order impacts of the ICT goods and networks used in a city. Although not specifically written for cities it is understood that [ITU-T L.1420] can be used also to estimate or follow-up on the impact of ICT in households and organizations at a city level. This Recommendation gives guidance on how the methodology should be applied.

Two different assessment approaches are considered in this clause: the Tier 1 assessment allowing for a simplified application of the methodology, and the Tier 2 assessment corresponding to a more complete evaluation as further outlined in clause 6.

NOTE – As a starting point, the assessment could be partial, for a reduced area of the city or a limited category of households or organizations. This should then be clarified and a roadmap should be provided towards the full assessment.

## 10.2 First order effect at city level of ICT goods and networks in households

This clause describes the assessment method to be applied for households. The practitioner shall apply clause 7 of [ITU-T L.1420], by considering all the households in the city as part of an organization. An example of a household assessment is available in Appendix I.

### 10.2.1 Boundaries

#### 10.2.1.1 Identification of city boundaries and households

As discussed in to clause 7.2, the city boundaries shall be identified as well as the households to be included in the assessment together with any selection criteria used.

#### 10.2.1.2 Identification of ICT goods and networks in households

The practitioner shall then define the ICT goods and networks present in the households as further outlined in 10.2.2. Any exclusion of ICT goods and networks shall be documented and justified.

Furthermore, the system boundaries should be outlined based on the assessment approach (Tier 1 or Tier 2) and the guidance given in [ITU-T L.1410].

Associated consumables, software and the impact of operation and maintenance activities may be excluded from the assessment.

### 10.2.2 Data collection and assessment

In accordance with [ITU-T L.1420] the environmental impact of the ICT goods and networks present in households shall be assessed according to the city boundaries. The data needed for the assessment of the impact of ICT, such as, the number of ICT goods and networks used per household, their use patterns and their energy consumption, may be collected with different approaches. The practitioner shall describe and document the data collection approach adopted as well as the data sources selected. For example, cities may use data collected from a sample of the households to model the average ICT usage of households, or they may rely on any other consistent data collection approach, including the use of secondary data. Alternative data collection approaches for user profiles include surveys, sampling and extrapolation, metering or census statistics.

In particular, the practitioner may rely on publicly available data for the embodied life cycle stages.

At a Tier 1 level of assessment only the use stage of ICT goods and networks shall be considered, whereas at a Tier 2 level the overall impact of ICT goods and networks, including all stages of the life cycle assessment, shall be considered.

NOTE – For each ICT good, the time of use in different modes (e.g., operation, idle state, deep sleep and off) is relevant for assessing the impact of the use stage. It is recommended to take into consideration the various modes of use. However, some simplifications could be made and then need to be transparently described.

It could also be practical to gather the ICT data collected into categories that reflects the use profiles. For a Tier 1 assessment, broad categories of ICT goods could be considered (information technologies, fixed communication technology, mobile communication technology, etc.) which could be associated with simple use profiles (for example a fixed percentage of time in operation/idle/deep sleep/off modes for each ICT categories).

## 10.3 First order impact at city level of ICT goods and networks in organizations

This clause describes the assessment method to be applied for organizations. To assess the impact of ICT used by organizations, clause 7 of [ITU-T L.1420] applies and should be used for both ICT and non-ICT organizations and for public as well as private organizations, as it is further described in this clause.

NOTE – As the intention of the city level assessment is not to assess the overall impact of ICT organizations but the use of ICT in any kind of organization, clause 8 of [ITU-T L.1420] does not apply.

The assessment and the documentation should distinguish between ICT organizations, non-ICT organizations and public administrations.

An assessment example for organizations is available in Appendix II.

### 10.3.1 Boundaries

#### 10.3.1.1 Identification of city boundaries and organizations

As referenced in clauses 7.3 and 7.4 of [ITU-T L.1420], the city boundaries as well as the organizations to be assessed shall be identified and the selection criteria used shall be documented together with information about the included organizations reflecting the granularity of the assessment. As an example, information about the total number of organizations per category and their estimated average number of employees is sufficient if a statistical approach is used, while more detailed information regarding the organizations applies for a more detailed approach.

For organizations with operations within and outside the city only the parts of the organization that are located within the city boundaries shall be considered.

The criteria adopted to include or exclude organizations in the inventory shall be justified.

#### 10.3.1.2 Identification of ICT goods and networks

As described in clause 7.4 of [ITU-T L.1420], the operational boundaries, i.e., the ICT goods and networks present in the organization, shall also be defined. Any exclusion of ICT goods and networks shall be documented and justified.

Furthermore, the system boundaries should be outlined based on the assessment approach (Tier 1 or Tier 2) and the guidance given in [ITU-T L.1410].

Associated consumables, software and the impact of staff directly related to ICT purchase, operation and maintenance activities may be excluded from the assessment.

### 10.3.2 Data collection and assessment

In accordance with [ITU-T L.1420], the environmental impact of the ICT goods and networks present in the organizations shall be assessed for the whole city. The data needed for the assessment of the impact of ICT, such as, e.g., the total number of ICT goods and networks used per organization, their use patterns and their energy consumption, may be collected with different approaches. The practitioner shall describe and document the data collection approach adopted as well as the data sources selected.

For example, cities may use data collected from a sample of the organizations to model the average ICT usage of organizations, or they may rely on any other consistent data collection approach, including the use of secondary data. In particular, the practitioner may rely on publicly available embodied life cycle data.

For the organizations that are subject to the assessment, clause 7.1 of [ITU-T L.1420], shall be applied to all operations identified according the boundaries defined in clause I.3.1.

At a Tier 1 level of assessment only the use stage of ICT goods and networks shall be considered, whereas at a Tier 2 level the overall impact of ICT goods and networks, including all stages of the life cycle assessment, shall be considered.

# 11 Part II: Methodological guidance for the assessment of the second order effect of ICT projects and services at city level

## 11.1 General description

The use of ICT in city transformation activities involving industry sectors other than ICT can have both positive and negative impacts on greenhouse gas emissions and energy consumption.

The effects of an ICT project can include more energy-efficient urban infrastructure such as: airports, harbours, buildings, public administration, sports venues, transport, street lighting, water management and security systems. ICT can also be used for process transformation such as home working to eliminate transport to central offices. ICT services may also include solutions that aim at improving existing city services, like teleconferencing, teleworking, e-ticketing, e-learning, e-healthcare, smart transport and logistics, procurement systems, supply chain management systems, music/film distribution over Internet or voice over IP and machine-to-machine systems.

A reduction in overall city emissions through such efficiency improvements is the desired outcome when an ICT project or ICT service is deployed. Such reduction would justify its own first order effects.

Part II (clause 11) introduces the methodology for assessing the impacts of city level ICT projects and ICT services based on the previous methodologies of the ITU-T L.14xx-series of Recommendations. The method to be used to assess the first and second order effects of ICT projects is based on [ITU-T L.1430]. The method to be used for assessment of ICT services at a city level is based on [ITU-T L.1410]. Though not specifically written for cities it is understood that these Recommendations can be used to estimate or follow-up on impacts of ICT projects and ICT at a city level. This Recommendation gives guidance on how these methodologies should be applied.

Besides the second order effects of ICT projects and services (environmental impacts in other sectors), their first order effects, i.e., the energy consumption and GHG emissions caused by the ICT projects or services have to be estimated to calculate their net impact. For an ICT project or service to be a positive contributor from an environmental impact point of view, the positive second order effect should outweigh the negative first order effects.

### 11.2 Environmental impact of ICT projects at city level

This clause provides guidance on how to apply [ITU-T L.1430] to assess the environmental impact of ICT projects at a city level. More specifically the focus is on GHG and energy projects but the shorter term ICT projects will be used in the text. An example of a city level assessment of an ICT project is provided in Appendix III.

ICT projects with expected impact on other sectors (such as energy, transport, buildings) can involve one single actor or several actors or organizations. In the case of more than one actor, the practitioner needs to get information from all actors or from a project coordinator.

In alignment with clause 7 of [ITU-T L.1430] (Introduction to ICT GHG and energy projects) this clause describes the general provisions that apply to the assessment of ICT projects including those specific to the city level. It also gives the specific provisions following clause 8 of [ITU-T L.1430] (Planning of ICT GHG and ICT energy projects). Practitioners should refer to those clauses to ensure compliance with [ITU-T L.1430].

As specified in clause 7.5 of [ITU-T L.1430] (Project cycle of an ICT GHG/ energy project), it is assumed that the ICT project applies best project management practices, including validation and verification steps. As specified in clause 7.2 of [ITU-T L.1430] (Adoption of a GHG programme) it is recommended that the organization or the project leader adopts a GHG programme in order to register and monitor the GHG emissions for all project activities and to allow for validation and verification of the project activities, thus originating in a more accurate and strict evaluation of all project activities.

In accordance with clause 8.1 of [ITU-T L.1430] (General requirements), it is recommended that "the project conforms to relevant requirements of the chosen GHG programme to which it subscribes" and that the project proponent uses "relevant good practice guidance".

#### 11.2.1 General provisions

Two different assessment approaches are presented in this clause: the Tier 1 assessment allowing for a simplified application of the methodology and the Tier 2 level corresponding to a more complete assessment as further outlined in clause 6. For a city ICT project, a Tier 1 assessment includes the most significant activities and their impacts and considers only the impact of the use phase of the ICT goods involved in the project. The Tier 2 assessment includes all project activities within the assessment boundaries and their impacts. It also includes the full life cycle for the goods, networks and services related to the ICT project, including those that occur outside the geographical boundaries. Preferably, the Tier 2 assessment should be applied in order to evaluate the full impact of a project.

In accordance with clause 7.4 of [ITU-T L.1430] (Consideration of life cycle assessment), it is recommended that a full assessment of the net second order effects of the project is performed, thus inherently including the first order effects of the project and of the reference scenario. This corresponds to a Tier 2 approach. However, a Tier 1 approach may also be applied.

The quantification units of GHG and energy effects shall comply with clause 7.3 of [ITU-T L.1430].

### 11.2.2 Specific provisions

According to clause 8.2 of [ITU-T L.1430] (Defining the boundary for assessment of an ICT GHG/energy project), the practitioner shall estimate the ICT project impact in relation to the functional unit, through specifying the ICT project and its activities, the second order effects, the baseline scenario and the assessment boundaries including the related GHG sources, sinks and storages and/or energy consumers, generators and storages.

#### 11.2.2.1 Identifying project activities

All project activities related to the GHG ICT project shall be identified.

#### 11.2.2.2 Identifying second order effects

As specified in [ITU-T L.1430], the second order effects of the ICT projects with the potential to reduce GHG emissions and energy consumption shall be identified and described. A list of possible second order effects is presented in table format in Appendix I of [ITU-T L.1430].

As described in Appendix V of [ITU-T L.1430], unintended changes shall also be taken into consideration if known.

#### 11.2.2.3 Boundaries

As Referred to in clause 7.2, the project boundaries, i.e., the geographical area where the ICT goods, networks or services are deployed, shall be identified (usually a city area, a city or a city region but it may also be a large building complex, etc.).

Next, the practitioner needs to define the geographical assessment boundaries; these boundaries can be within the city border (e.g., if the assessment is performed for a city district only) or they can be larger than the city border (e.g., if the assessment is made for a city region). Allocations are necessary if the geographical project boundaries are wider than the assessment boundaries.

If a project activity is deployed within multiple cities, each assessing city shall take into account only its own contribution. If so, the assessment boundaries of the city assessment will be different from the project boundaries and allocations are needed. Hence, an allocation principle shall be defined in order to quantify the impacts related to the city (based on the number of people involved, km travelled, area served, etc.). For example, in the case of a smart meter project rolled out in several cities, only the impact of the smart meter users located within the assessment boundaries would be included in the assessment. Another example is a real time navigation service where vehicles are moving across the boundaries and a principle has to be defined for handling of inbound and outbound traffic.

The practitioner shall also define the system boundaries, i.e., the life cycle activities and processes to assess the ICT goods, networks and services involved in the project and for the reference situation respectively. These activities may take place within or outside the city boundaries. In [ITU-T L.1430] this boundary setting is referred to as "Identifying GHG sources, sinks and storages and/or energy consumption sources, generators and storages". At Tier 1 level the assessment of the impacts can be limited to those within city boundaries. However, all emissions which come from the energy supply and distribution losses shall be taken into account even if they take place outside the city boundaries.

#### 11.2.2.4 Scenarios

Both the project scenario and the baseline scenario shall be defined.

The project scenario is given by the project activities, the second order effects and the boundaries described in clauses II.2.2.1 to II.2.2.3.

For the baseline scenario, [ITU-T L.1430] gives guidance as outlined below.

##### 11.2.2.4.1 Determining a baseline scenario for the ICT project

According to clause 8.3 of [ITU-T L.1430], two alternative procedures may be used for estimating the baseline impacts associated with the second order effects: a project-specific procedure, which is based on conditions specific to the project and a reference emission factor procedure, which may be based on secondary data.

At Tier 1 level, the practitioner may adopt a reference emission factor procedure for the assessment of the baseline scenario (e.g., a published value for typical emissions of a face-to-face meeting may serve as a reference to a telepresence project). At Tier 2 level, the more detailed project-specific procedure should be used. This requires quantifying more precisely the impact of the baseline scenario (e.g., the average emissions of face-to-face meetings applicable to the intended users of the telepresence solution based on measured data). For Tier 2, the reference emission factor procedure may be seen as a fall back approach.

As there may be several alternatives to the ICT project deployment, more than one baseline scenario may exist. As stated in [ITU-T L.1430] it is recommended that the practitioner identifies all baseline candidates that represent the possible alternative technologies or practices that could provide the same service or function as the project within the same geographical area and time frame.

#### 11.2.2.5 Data collection and assessment

It is recommended that a data quality management plan is defined as detailed in clause 8.4 of [ITU-T L.1430], (Designing data quality management).

The data needed for the assessment of the impact of the project and of the baseline scenarios, may be collected with different approaches. The practitioner shall describe and document the data collection approach adopted as well as the data sources selected. At a Tier 1 level of assessment only data for the use stage of ICT goods and networks shall be collected, whereas at the Tier 2 level, data for the overall impact of ICT goods and networks, including all stages of the life cycle, are needed.

### 11.3 Environmental impact of ICT services at city level

To support the city authorities, the ICT service vendors and the service operators in establishing a common understanding of the actual or potential enablement of specific ICT services, this section outlines how [ITU-T L.1410] should be applied on a city level to assess the environmental impact of one or more ICT services. An example is provided in Appendix IV. For more detailed guidance consult [ITU-T L.1410].

For the assessment of the impact of ICT services at city level, cities shall take into account the guidelines stated in Part II of [ITU-T L.1410], which allows for making a comparison between a reference product system and the ICT service. An ICT service is assessed by its first order effects and its second order effects and compared to a reference scenario. Part II of [ITU-T L.1410] details how to do this.

### 11.3.1 Assessment of the impact of ICT services at a city level

The assessment targets an ICT service which is either already in use, or a planned future implementation.

The following assessment steps, outlined in clauses II.3.1.1 to II.3.1.7 apply:

#### 11.3.1.1 Assessment scope

The practitioner shall define the scope of the assessment, i.e., what is the intended use of the service and what are the expected outcomes of the implementation of the service.

#### 11.3.1.2 Function and use of the ICT service

The practitioner shall identify and describe the main functions, use patterns, target users, main ICT goods and support goods required for the implementation of the service, etc.

#### 11.3.1.3 Expected effects due to the implementation of the service

The practitioner shall identify and describe the expected second order effects originating from the implementation of the ICT service, e.g., less need for transportation, less energy consumption in households and dematerialization. This forms the basis for the assessment of the second order effects together with the reference scenario.

#### 11.3.1.4 Reference units

For the identification of the reference unit for the assessment result, the city shall follow the guidelines stated in Part I of [ITU-T L.1410].

#### 11.3.1.5 Boundaries

The definition of boundaries for the impact assessment of ICT services shall follow the boundaries definition in clause 7.

Functions that are relevant to the second order effects of a service might be located outside geographical boundaries of the city (power plants, airports, etc.). For completeness, these functions could be covered by expanding the geographical boundary or as input/output to the considered system.

#### 11.3.1.6 Target systems for comparative analysis

In order to evaluate the second order effects of the ICT service, the city shall compare the business-as-usual case where no ICT service is applied or the ICT service already existing that is considered to be replaced by the newer ICT service. The principles stated in clause 11.3 of [ITU-T L.1410] shall be followed.

#### 11.3.1.7 Methodological framework

The methodological framework shall follow the guidelines stated in clause 12 of [ITU-T L.1410].

For the assessment of the impacts of the ICT service, the city shall follow the procedures outlined in Part I.2 of [ITU-T L.1410] in what concerns data quality requirements, calculations for life cycle inventory and life cycle assessment.

For the life cycle interpretation, the city shall also follow the guidelines stated in clause 12.5 of [ITU-T L.1410].

## 11.4 Guidance for estimating the impact of ICT projects or ICT services based on pilot implementations or experiences made by pilots or other cities

Cities may be interested in understanding the impact from a particular ICT service or project applied at a city level, based on small scale implementations of ICT services, pilot projects or experiences made in other cities. This clause gives guidance for how [ITU-T L.1410] (especially

Part II) and potentially also [ITU-T L.1430] could be applied for reuse of such results in city level assessments by detailing aspects like boundary setting, importance of the city profile, etc.

Many cities have already gained experiences from the use of ICT services and their impact on GHG emissions. Thus, it would be beneficial if experiences gained by one city could be used to help another city to better estimate its potential gains from adopting the same or similar services.

However, it is clear that all cities differ with respect to, e.g., population density, age distribution, development level, ICT maturity among citizens, ICT availability, geographic conditions and governance setup. All these are factors may impact the uptake of a solution and thereby its environmental impact. Thus, to be able to use a previous ICT city or pilot assessment scenario and obtained results to create an understanding of ICT's enablement potential in a specific city, without details on the use case being available, it is necessary to understand similarities and differences between the cities (or between the city and the pilot project) at a high level.

Steps included in interpreting scenarios and assessment results from one city (hereafter the reference city) or pilot project (hereafter the reference pilot project) for another city (hereafter the targeted city) are:

1 Identify the reference ICT service or project and the reference.

2 Analyse the estimated potential of the reference situation and how this potential was derived to ensure that it has sufficient quality to be used.

3 Identify the target city, city area or city region.

4 Define system boundaries for the target city and the reference.

5 Define a common reference unit.

6 Select relevant high-level profile data for the target city and the reference.

7 Compare the target city and the reference pilot study or reference city.

8 Compare solution specific parameters.

9 Build a use scenario (users, use profiles, ICT) for the targeted city also using the profile data.

10 Make a quantitative scaling for applicable parameters.

11 Make a qualitative analysis of other parameters.

12 Summarize and interpret the results.

The profile data for the targeted city and the reference city in general include data which are needed to make scenarios for the ICT service and to interpret results. This includes data such as population, geographical boundary, ICT development level, drivers and barriers and sector specific data. The intention is not to make complete environmental profiles for the cities as such.

The profile data for the target city and the reference city should be used to create a high-level understanding of the contexts and identification of similarities and differences. Data could be taken from different public databases.

At this stage parameters that could be directly used to quantitatively scale the assessment results from one city to another city, such as number of users, are quantitatively taken into account. Other parameters, like differences in incentives (or lack of them), are instead to be classified qualitatively (e.g., into groups denoted very favourable/favourable/neutral/negative/very negative or similar) indicating how the results of the reference are likely to be changed if the ICT service is applied in the target city. Although this classification generally has to be done on subjective grounds, it will give an indication on how results could differ between the cities.

For further guidance refer to the example in Appendix V.

# Appendix I

## Example of the assessment of the first order effect of ICT goods and networks in households at a city level

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

This appendix provides an example to show how the guidance given in Part I could be applied to assess the first order environmental impact of ICT in households at city level.

Some of the data used in this Appendix are fictitious. The non-fictitious data are based on best effort data collection and might not reflect the latest knowledge or information in areas such as energy consumption of the ICT goods or emission factors used.

NOTE – Practitioners should not use values of the examples without further review and graphs may not be reused.

This example assumes that a city with 77 500 inhabitants and 25 000 households and located in Italy is carrying out the assessment of the impact of ICT in households.

The two levels of assessment (Tier 1 and Tier 2) are described.

### I.1 Tier 1 assessment example

The present example illustrates the Tier 1 assessment of the impact of ICT in households within city boundaries in a reference year (2013).

#### I.1.1 Goal and scope definition

The goal of this assessment was to evaluate the environmental impact of ICT goods in households located in the city. This Tier 1 assessment took into consideration only the GHG emissions related to the use stage of ICT goods and networks.

For this Tier 1 level of assessment, a subset of ICT hardware was considered, which represented those items that were expected to be the most commonly used items in households: PCs, laptops, tablets, printers, mobile phones, modems, TVs and set-top boxes.

#### I.1.2 Boundaries

This assessment takes into consideration the households present within the city boundaries.

The city boundaries were identified based on XXX and the information regarding households within those boundaries was found in YYY.

NOTE – In a real assessment hypothetical references XXX and YYY would be replaced with specific references. The same approach is applied throughout these appendices.

#### I.1.3 Identifying the ICT goods and networks in households

To identify the ICT goods used in households a statistical approach was applied in order to estimate the average number of ICT items in households, as well as the typical time of use for each item and in each use mode (use pattern). See clause I.5 for details

#### I.1.4 Data collection

The statistical data for the average number of ICT items in households, as well as the typical time of use for each item and in each use mode (use pattern) were based on extrapolation of data collected from a representative set of households based on a research project carried out in a similar city. See ZZZ[3].

For the ICT goods only two use modes were taken into consideration in this study (ON and Standby) and the energy consumption values for the different modes were based on the preparatory studies for the European Union Eco-design and Energy Labelling legislation[4].

The energy mix and the corresponding emission factor were collected based on Italian conditions. The adopted emission factor was 0.708 kg $CO_2$eq/kWh[5]. This emission factor includes the full supply chain of electricity generation as well as the distribution losses. The emission factor represents Italian conditions for 2009 and the source of the data is the Covenant of Mayors guidebook.

### I.1.5 Data overview

Number of households: 25 000.

Members per household: 3.1.

Table I.1, Table I.2 and Table I.3 summarize the data used and some intermediate results:

**Table I.1 – Number of ICT items per household in the city (fictitious numbers)**

| | A | *B (=A*25 000)* |
|---|---|---|
| | Estimated average number of ICT items per household | *Total number of items in all households in the city* |
| PCs | 1.2 | *30 000* |
| Laptops | 1.3 | *32 500* |
| Tablets | 0.2 | *5 000* |
| Printers | 1 | *25 000* |
| Mobile phones | 2.5 | *62 500* |
| Modems/router | 1 | *25 000* |
| TVs | 1.2 | *30 000* |
| Set-top boxes | 1 | *25 000* |

3 In reality the numbers used here are fictitious numbers invented for this example.

4 https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp.

5 Covenant of Mayors Standard Emission Factors: www.covenantofmayors.eu/IMG/pdf/004_Part_II.pdf.

**Table I.2 – Time in ON and Standby mode per ICT item (daily and yearly) in household (data is a mix of real[6] and estimated data)**

| | ON mode | | Standby mode | |
|---|---|---|---|---|
| | **Hours per day** | **Hours per year (in 2013)** | **Hours per day** | **Hours per year (in 2013)** |
| Reference | C | D (=C*365) | E | F (=E*365) |
| PCs | 2 | 730 | 22 | 8 030 |
| Laptops | 5 | 1 825 | 19 | 6 935 |
| Tablets | 3 (charging) | 1 095 | 21 (non-charging) | 7 665 |
| Printers | 0.5 | 182.5 | 23.5 | 8 577.5 |
| Mobile phones | 2 (charging) | 730 | 22 (non-charging) | 8 030 |
| Modems | 14 | 5 110 | 10 | 3 650 |
| TVs | 3 | 1 095 | 21 | 7 665 |
| Set-top boxes | 4 | 1 460 | 20 | 7 300 |

**Table I.3 – Power need in ON mode and in Standby mode per item and energy consumption per year per item**

| | ON mode | | Standby mode | | TOTAL |
|---|---|---|---|---|---|
| | **Power need[7] (W)** | **Energy consumption per year per item (kWh/y)** | **Power need[8] (W)** | **Energy consumption per year per item (kWh)** | **Energy consumption per year per item (kWh)** |
| Reference | G | **H** (=G*D)/1 000 | I | **J** (=I*F)/1 000 | K (=H+J) |
| PCs | 100 | **73** | 3 | **24** | **97** |
| Laptops | 10 | **18** | 1 | **7** | **25** |
| Tablets | 10 (charging) | **11** | 0 (non-charging) | **0** | **11** |
| Printers | 4 | **1** | 1 | **9** | **9** |
| Mobile phones | 1 (charging) | **1** | 0 (non-charging) | **0** | **1** |
| Modems | 10 | **51** | 1 | **4** | **55** |

6 https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp.

7, 8 Sources: Preparatory studies for Eco-design and Energy Labelling legislation [http://ec.europa.eu/energy/efficiency/ecodesign/eco_design_en.htm], European Codes of Conduct for ICT [http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct] and experts' opinions.

**Table I.3 – Power need in ON mode and in Standby mode per item and energy consumption per year per item**

| | ON mode | | Standby mode | | TOTAL |
|---|---|---|---|---|---|
| | **Power need[7] (W)** | **Energy consumption per year per item (kWh/y)** | **Power need[8] (W)** | **Energy consumption per year per item (kWh)** | **Energy consumption per year per item (kWh)** |
| TVs | 60 | **66** | 1 | **8** | **73** |
| Set-top boxes | 30 | **44** | 4 | **29** | **73** |

### I.1.6 Results and conclusion

Table I.4 provides the assessment results per category of goods. Contributions from different ICT goods to the overall yearly GHG emissions related to ICT goods in households are shown in Figure I.1.

**Table I.4 – Overall CO2 emissions per ICT item (ON + Standby mode) per year per household and in all city's households**

| | #items/ house-hold | Energy consumption per year per household ON+STANDBY (kWh/y) | GHG emissions per year per household (kg $CO_2$e) | Total GHG emissions per year in all households in the city (tonnes $CO_2$e) | Share of total ICT emissions of households (%) |
|---|---|---|---|---|---|
| | A | K*A | L (=K*0.708) | M (= L*25 000/1 000) | **N (=M/Mtot*100)** |
| PCs | **1.2** | **116** | 82 | 2 060 | **31%** |
| Laptops | **1.3** | **33** | 23 | 575 | **9%** |
| Tablets | **0.2** | **2** | 2 | 39 | **1%** |
| Printers | **1** | **9** | 6 | 159 | **2%** |
| Mobile phones | **2.5** | **3** | 2 | 44 | **1%** |
| Modems | **1** | **55** | 39 | 974 | **15%** |
| TVs | **1.2** | **88** | 62 | 1 551 | **23%** |
| Set-top boxes | **1** | **73** | 52 | 1 292 | **19%** |
| | | **378** | **268** | **6 694** | **100%** |

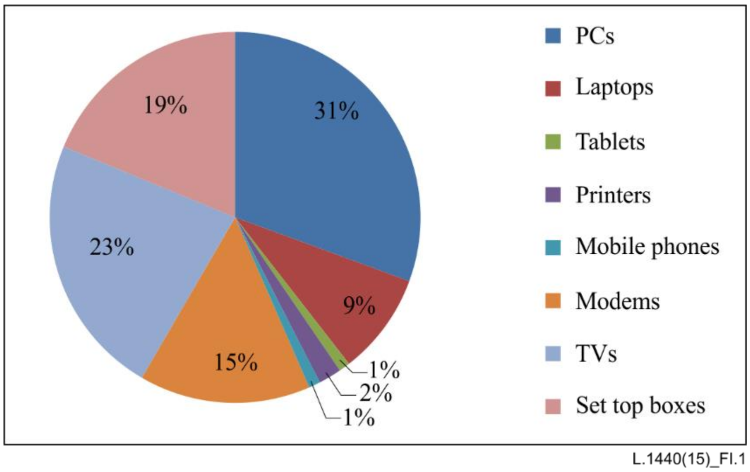


**Figure I.1 – Contributions from different ICT goods to the overall yearly GHG emissions related to ICT goods in households**

In summary, the amount of GHG emissions in the assessed city related to the use stage of ICT in households was estimated at 268 kg $CO_2$e per household and year, corresponding to 86 kg $CO_2$e per household member and year.

This corresponds to a total impact of the ICT goods in households in the assessed city of 6 700 tonnes $CO_2$e per year.

These values take into account the use stage only.

Based on these use stage results the main contribution to the ICT-related household emissions came from PCs (31%) followed by TVs (23%) and set-top boxes (19%).

### I.1.7 Interpretation of results

In this study results were mainly analysed through sensitivity analysis.

#### I.1.7.1 Sensitivity analysis

The Tier 1 assessment approach, from its conception, is an approach that does not take into account all life cycle impacts of the ICT goods. By only assessing the use stage of the ICT goods, the impacts associated with raw material acquisition, production and end-of-life treatment are not taken into consideration. In this sense the results are a giving a coarse approximation of the full impact of the ICT in households in the city. Particularly, for consumer goods with a relatively short lifetime, the other life cycle stages are known to have a significant contribution to the overall emissions.

A sensitivity analysis was performed to understand the impact on results and conclusions from assumptions and limitations in data.

The major uncertainty sources of the study were identified as those related to the limitations in access to actual data for use patterns, to the modelling of ICT goods used by households from a minor sample of households and to the lack of real data for power consumption. The fact that no distinction was made between the different models of the different ICT goods led to considerable uncertainty due to the difference in actual energy consumption between different models

NOTE – In a real study the sensitivity analysis should have been performed for all the above parameters (e.g., by doubling and halving the parameter value and recalculating the results with these values included) and the impact on the results and conclusions should have been transparently presented together with the results. This was not done for the sake of this example but is a fundamental activity for the interpretation of any life cycle assessment (LCA) study.

### I.2 Tier 2 Assessment example

This part of the example refers to a Tier 2 assessment where the full life cycle is evaluated.

#### I.2.1 Goal and scope definition

The goal of this assessment was to evaluate the environmental impact of ICT goods present in the households of the city taking into account GHG emissions related to their full life cycle, i.e., including the use stage as well as the raw materials acquisition, production and end-of-life treatment of goods.

For this Tier 2 level of assessment, a subset of ICT hardware was considered, which represented those items that were most commonly used in households: PCs, laptops, tablets, printers, mobile phones, modems, TVs, set-top boxes.

#### I.2.2 Boundaries

This assessment takes into consideration the households present within the city boundaries.

The city boundaries were identified based on XXX and the information regarding households within those boundaries was found in YYY.

The ICT goods used in households, as well as the typical time of use for each item and in each use mode (use pattern) were identified and modelled according to the same principles as in the Tier I example.

The system boundaries applicable to the assessed ICT goods are defined by the life cycle stages and activities defined in [ITU-T L.1410].

#### I.2.3 Data collection

When performing a life cycle assessment of the GHG emissions of the ICT goods used by households, the practitioner is expected to use the best available data, preferably adopting GHG emission values derived in accordance with [ITU-T L.1410].

After identifying the households within the city boundaries and their ICT goods and use, additional life cycle data are collected for each ICT good based on best available data sources. For example, if there are different models of televisions, data ideally, should be representative to each model. If no specific data are available for different models of ICT goods, reasonable estimations are acceptable (e.g., LCD TVs, plasma TVs). In this example data are mainly based on experts' estimations based on available tools like "Bilan Carbone" (carbon assessment) and approximations from LCA studies available in vendors' documentation[9].

NOTE 1 – Data collection can be a barrier to develop a Tier 2 assessment. However, ICT vendors sometimes provide LCA results including the embedded GHG emissions for their products. In this example the embedded LCA values (representing raw materials acquisition, production and end-of-life treatment stages) are estimated based on published data of varying quality. In general, data may be collected directly from manufacturer information or from published LCA studies, if available, or from other sources that allow for a reliable estimation of the life cycle GHG emissions of ICT goods.

The emission factors used for the different life cycle stages of the various ICT goods are in accordance with the adopted LCA results. This means that the emission factors used may represent different conditions and electricity mixes for different products.

NOTE 2 – In a real study the emissions factor of the use stage of all goods should be the same and representative of the city. If this is not possible the implications of applying different emission factors for different good categories need to be analysed as part of the interpretation phase.

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[9] In a real study the information about data sources and their application should be made more specific.

### I.2.4 Data overview

This clause summarizes the data used and some intermediate results:

Number of households: 25 000

Members per household: 3.1

Emission factors: The adopted emission factors were inherited as part of the LCA data and emerged from sources XXX, YYY and ZZZ.

NOTE – In a real study the emission factors adopted for different life cycle stages and goods needs to be aligned and transparently reported as far as possible.

See Tier 1 example for use stage. For other stages the emission factors were included in the input data and could not be transparently reported.

Table I.5 shows the number of ICT items per household and in the city.

**Table I.5 – Number of ICT items per household and in the city (see the Tier 1 example for details)**

| | Average number of items per household | Total number of items in households in the city |
|---|---|---|
| PCs | 1.2 | 30 000 |
| Laptops | 1.3 | 32 500 |
| Tablets | 0.2 | 5 000 |
| Printers | 1 | 25 000 |
| Mobile phones | 2.5 | 62 500 |
| Modems/router | 1 | 25 000 |
| TVs | 1.2 | 30 000 |
| Set-top boxes | 1 | 25 000 |

Table I.6 presents the data collected or derived for the overall life cycle GHG emissions and the breakdown of these emissions between life cycle stages for the different ICT goods assessed.

**Table I.6 – Life cycle impacts per ICT good**

| Overall GHG emissions per ICT good category and their breakdown between life cycle stages | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Operational lifetime (years) | Raw material acquisition (kg $CO_2$e) | Production (kg $CO_2$e) | Use stage | | End-of-life treatment (kg $CO_2$e) | Total Life cycle GHG emissions per ICT good (kg $CO_2$e) AA | Life cycle GHG emissions per ICT good and year of operation (kg $CO_2$e/ year) BB |
| | | | | Lifetime use (kg $CO_2$e) | Yearly use (kg $CO_2$e) | | | |
| PCs | 4 | 88.00 | 264.00 | *440.00* | *110.00* | 8 | **800** | **200** |
| Laptops | 4 | 74.00 | 200.00 | *125.00* | *31.25* | 1 | **400** | **100** |
| Tablets | 3 | 20.00 | 97.75 | *30.75* | *10.25* | 1.50 | **150** | **50** |
| Printers | 5 | 29.00 | 40.00 | *30.00* | *6.00* | 1 | **100** | **20** |
| Mobile phones | 3 | 3.25 | 48.75 | *12.35* | *4.12* | 0.65 | **65** | **22** |
| Modems/ router | 5 | 9.50 | 10.00 | *30.00* | *6.00* | 0.50 | **50** | **10** |
| TVs | 7 | 70.00 | 260.00 | *650.00* | *92.86* | 20 | **1 000** | **143** |
| Set-top boxes | 4 | 13.30 | 14.00 | *42.00* | *10.50* | 0.7 | **70** | **18** |

NOTE – The use stage values applied in the Tier 2 example are different from the ones applied in the Tier 1 example. For this reason no comparison could be made regarding the impact from other life cycle stages on the overall results. This illustrates a situation when the data sources have been changed between the Tier 1 and Tier 2 assessments. Preferably in such cases results should be calculated using both the original Tier 1 data and the new data for the use stage to understand how that impacts results. This is especially important when the city tries to understand how the GHG emissions develop over time.

### I.2.5 Results and conclusions

Taking into account the total number of ICT goods in the households in the city, Table I.7 summarizes their overall GHG emissions. The last column shows the overall yearly footprint.

**Table I.7 – Overall footprint of ICT goods in households**

| | #items/ household<br>CC | Operational lifetime (years) (YoL) | Total Raw material acquisition (tonnes $CO_2e$) (RMA) | Total Production (tonnes $CO_2e$) (P) | Total use stage (tonnes $CO_2e$) (Use) | Total End-of-life treatment (tonnes $CO_2e$) (EoL) | Life cycle GHG emissions for ICT goods per household (kg $CO_2e$/ year)<br>DD=AA* CC | Life cycle GHG emissions for ICT goods per household per year (kg $CO_2e$/ year)<br>EE=BB* CC | Total life cycle GHG emissions for the ICT goods of all households (Note) (tonnes $CO_2e$) (DD*#households/1 000) | Total life cycle GHG emissions for ICT goods of all households per year (tonnes $CO_2e$/ year) (EE* #households/1 000) | Share of total ICT emissions for all households per year (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PCs | 1.2 | 4 | 11% | 33% | 55% | 1% | **960** | 240 | 24 000 | **6 000** | 37% |
| Laptops | 1.3 | 4 | 19% | 50% | 31% | 0% | **520** | 130 | 13 000 | **3 250** | 20% |
| Tablet | 0.2 | 3 | 13% | 65% | 21% | 1% | **30** | 10 | 750 | **250** | 2% |
| Printers | 1 | 5 | 29% | 40% | 30% | 1% | **100** | 20 | 2 500 | **500** | 3% |
| Mobile phones | 2.5 | 3 | 5% | 75% | 19% | 1% | **163** | 54 | 4 063 | **1 354** | 8% |
| Modems/ router | 1 | 5 | 19% | 20% | 60% | 1% | **50** | 10 | 1 250 | **250** | 2% |
| TVs | 1.2 | 7 | 7% | 26% | 65% | 2% | **1 200** | 171 | 30 000 | **4 286** | 26% |
| Set-top boxes | 1 | 4 | 19% | 20% | 60% | 1% | **70** | 18 | 1 750 | **438** | 3% |
| | | | | | | | ***** | **653** | ***** | **16 327** | |
| NOTE – *Due to differences in life time these numbers cannot be added.* | | | | | | | | | | | |

In summary, the amount of GHG emissions in the assessed city related to the life cycle impact of ICT in households was estimated to 653 kg $CO_2e$ per household and year, corresponding to 211 kg $CO_2e$ per household member and year.

The corresponding total life cycle GHG emissions related to ICT goods in households was estimated to 16 300 tonnes $CO_2e$ per year.

Of this, the main contribution to the ICT related emissions came from PCs (37%) followed by TVs (26%) and laptops (20%).

NOTE – Note that even if the results of Tier 1 and Tier 2 assessment are expressed in the same units, these cannot be directly compared, since these results are obtained by applying two different approaches: the assessment of the impact of the use stage only and the assessment of the whole life cycle of ICT goods. In addition, different data sets were used even for the use stage.

However, it can be noted that the order of magnitude of Tier 1 and Tier 2 results are comparable, although results for the Tier 1 assessment are clearly lower than the results of the Tier 2 assessment.

In this example it appears clear that, while in the cases of PCs or TVs the use phase is the main contributor, in the case of tablets or mobile phones, the opposite occurs and the first stages of the life cycle are the main contributors.

When comparing the different kind of goods per item, it can be noted that the TV has the largest life cycle impact according to the used input data, while for the household, PCs seems to have the largest impact due to their shorter lifetime. To compare the relative contribution from various categories of goods, the yearly values are used as difference in lifetime must also be considered due to the probability that the households will replace the good with a similar good after its end-of-life. Also, the number of goods per category and household impacts.

Figure I.2 shows a graph representing the yearly overall impacts relating to the ICT goods in all households within city boundaries.

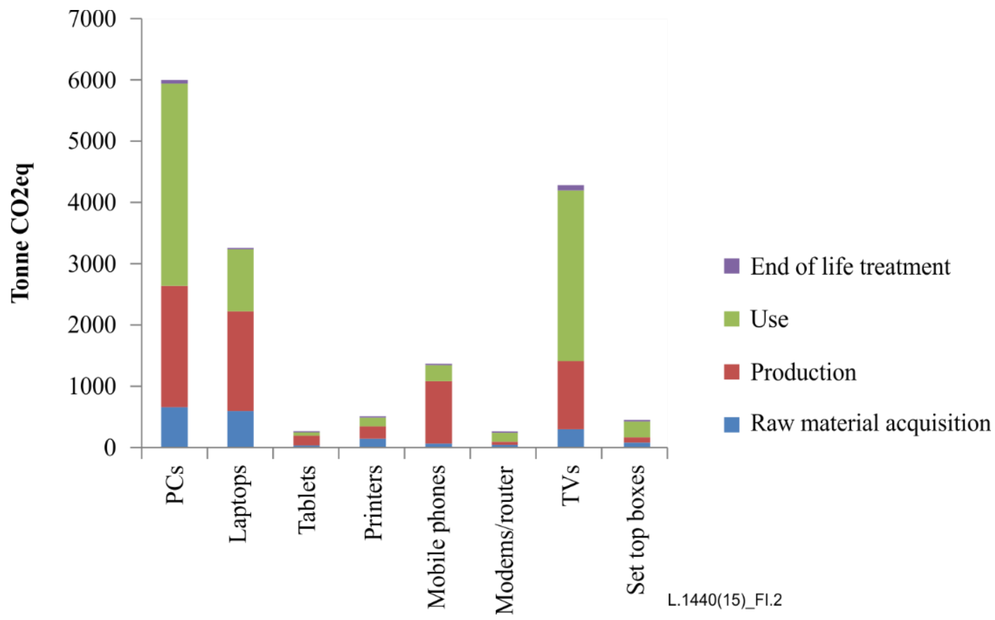


**Figure I.2 – Yearly city level life cycle GHG emissions related to ICT goods in all households**

### I.2.6 Interpretation

In this study results were mainly analysed through sensitivity analysis.

### I.2.7 Sensitivity analysis

In addition to the parameters to be considered in the sensitivity analysis according to the Tier 1 example, it is important to also consider data for all life cycle stages, as the modelling of embedded emissions is quite rough and the uncertainty is large. One way to understand what parameter values to use for the sensitivity analysis of different equipment would be to check the variations between different published LCAs

NOTE – As stated for the Tier 1 example, in a real study the sensitivity analysis should have been performed for all the identified parameters (e.g., by doubling and halving the parameter value and recalculating the results with these values included) and the impact on the results and conclusions should have been transparently presented together with the results. This was not done for the sake of this example but is a fundamental part of any LCA study.

## I.3 Reporting

In the reporting phase the results of the assessment are systematically presented. The reporting is common to a Tier 1 or a Tier 2 assessment. The report helps the city to identify the main impacts of ICT goods in the households within their boundaries. A clear reporting structure is needed in order to ensure a clear and comprehensive presentation of the results and their validity.

According to clause 9, the city will state in the common part of the report:

- Contact information:
  - City X, contact person N.N.
- Type of assessment:
  - The inventory was realized in accordance with [ITU-T L.1440] on ICT in cities.
  - The approach chosen was a Tier 1 assessment, assessing the impact of the use phase of ICT goods present within city boundaries (first example) and a Tier 2 assessment, assessing the impact of the full life cycle of the ICT goods present within city boundaries (second example).

- The ICT goods evaluated were PCs, laptops, tablets, printers, mobile phones, modems/routers, TVs, set-top boxes.
- The study was performed based on secondary data applying a statistical approach.

• Goals of the study:
  - The goals of this study were to evaluate the ICT footprint in the city in order to have an estimation of the environmental impact of ICT in households for the year of reference (2013). The evaluation of the results allows the city representatives to have a baseline scenario for XXX while projecting the cities pathways towards a more sustainable and smart future.

• Period for which the report is valid:
  - This report is valid for public city discussions for two years. At the end of these two years, there should be a revision with updated data.

• Identification of the number of inhabitants and households subject to the study
  - 77 500 inhabitants in 25 000 households.

• Identification and justification of boundaries and timeframe chosen:
  - The boundaries chosen are the cities geographical boundaries as defined in the urban plan boundaries definition (reference XXX).
  - The time frame is one year. The reference year is 2013. Results are presented as yearly values.
  - In example 1, a Tier 1 approach was applied and the assessment covered the use stage of PCs, laptops, tablets, printers, mobile phones, modems/routers, TVs, set-top boxes present in the households. In example 2, a Tier 2 approach was applied and the full life cycle of these ICT goods categories were included.

• Emission factors used:
  - The energy mix and the corresponding emission factor were collected based on Italian conditions. The adopted emission factor was 0.708 kg $CO_2$e/kWh[10]. This emission factor includes the full supply chain of electricity generation as well as the distribution losses. The emission factor represents Italian conditions for 2009 and the source of the data is the Covenant of Mayors guidebook.
  - The emission factors used for the different life cycle stages of the various ICT goods are in accordance with the adopted LCA results. This means that the emission factors used may represent different conditions and electricity mixes for different products.

• Sources of the LCA data of the ICT goods collected in the Tier 2 assessment:
  - Embodied life cycle stages were modelled based on publically available LCA data from ICT vendors (in a real report specific references are required).

• Justification of cut-offs:
  - Only hardware was taken into consideration in the assessment. Development of software and consumables used related to ICT goods were not taken into account in the study to reduce the work load and complexity.

• Identification of possible double accounting situations:
  - No double accounting situations were identified.

• Results for energy consumption and GHG emissions for the Tier 1 assessment:

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[10] Covenant of Mayors Standard Emission Factors www.covenantofmayors.eu/IMG/pdf/004_Part_II.pdf.

In summary, the amount of GHG emissions in the assessed city related to the life cycle impact of ICT in households was estimated to 268 kg $CO_2$e per household and year, corresponding to 86 kg $CO_2$e per household member and year.

The corresponding total GHG emissions related to ICT goods in households was estimated to 6 700 tonnes $CO_2$e per year. Of this, the main contribution to the ICT-related emissions came from PCs (31%) followed by TVs (23%) and set-top boxes (19%).

- Results for the energy consumption and GHG emissions for the Tier 2 assessment:

  In summary, the amount of GHG emissions in the assessed city related to the life cycle impact of ICT in households was estimated to 653 kg $CO_2$e per household and year, corresponding to 211 kg $CO_2$e per household member and year.

  The corresponding total life cycle GHG emissions related to ICT goods in households was estimated to 16 300 tonnes $CO_2$e per year. Of this, the main contribution to the ICT-related emissions came from PCs (37%) followed by TVs (26%) and laptops (20%).

  – At a city level the largest yearly environmental impacts can be ascribed to TVs, PCs, and laptops.

  – The importance of the production stage for some ICT goods has to be noted, representing a large portion of the overall impact. Even if these impacts primarily occur outside the city boundaries, these have a significant impact on the overall footprint.

NOTE 1 – A real study should also include comprehensive information regarding the interpretation of the results, for example the outcome of the sensitivity analysis, consequences of limitations in data etc.

NOTE 2 – For a combined results presentation of households and organizations see Appendix VI.

# Appendix II

## Example of the assessments of first order effect of ICT goods and networks in organizations at a city level

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

This appendix provides an example to show how the guidance given in Part I could be applied to perform a high level assessment of the first order environmental impact of ICT in organizations at city level.

Some of the data used in this Appendix are fictitious. The non-fictitious data are based on best effort data collection and might not reflect the latest knowledge or information in areas such as energy consumption of the ICT goods or emission factors used.

NOTE – Practitioners should not use values of the examples without further review and graphs may not be reused.

This example assumes that a city with 77 500 inhabitants and 25 000 households and located in Italy is carrying out the assessment of its impact of ICT in organizations.

The two levels of assessment (Tier 1 and Tier 2) are described.

### II.1 Tier 1 assessment example

The present example illustrates the assessment of the impact of ICT in organizations within city boundaries in a reference year (2013), at Tier 1 level of assessment.

### II.1.1 Goal and scope definition

The goal of this assessment was to evaluate the environmental impact of ICT goods in organizations located in the city. This Tier 1 level assessment took into consideration only the GHG emissions related to the use stage of ICT goods and networks.

For this Tier 1 level of assessment, a subset of ICT hardware was considered, which represented those items that were expected to be the most commonly used in organizations:

– PCs, laptops, tablets, printers, mobile phones, servers (enterprise servers), server rooms, base stations for cellular networks and ADSL/WiFi.

### II.1.2 Boundaries

This assessment takes into consideration the organizations present within the city boundaries.

The city boundaries were identified based on XXX and the information regarding the organizations within those boundaries was found in YYY.

NOTE – In a real assessment references XXX and YYY would be replaced with specific references. The same approach is applied throughout this appendix.

The assessment includes only organizations that are located within city boundaries and activities outside city boundaries are not taken into account.
The following organizations were identified:

– 7 000 small and medium enterprises in different sectors including private companies, with less than 250 employees (20 employees in average assumed); 2 000 of them assumed to be ICT companies.

– 70 large companies, all private, with 500 employees on average, belonging to various sectors. 20 of them assumed to be ICT companies (e.g., one mobile phone service operator).

– the public administration, with 30 sites (including schools, hospitals, etc.) within the city boundaries.

### II.1.3 Identifying the ICT goods and networks in organizations

To identify the ICT goods used in organizations a statistical approach was applied in order to estimate the average number of ICT items in organizations, as well as the typical time of use for each item and in each use mode (use pattern).

### II.1.4 Data collection

The statistical data for the average number of ICT items in organizations, as well as the typical time of use for each item and in each use mode (use pattern) were based on extrapolation of data collected from a representative set of organizations based on a research project carried out in a similar city. See ZZZ[11].

For the ICT goods only two use modes were taken into consideration in this study (ON and Standby) and the energy consumption values for the different modes were based on the preparatory studies for the European Union Eco-design and Energy Labelling legislation[12].

The energy mix and the corresponding emission factor applied were based on Italian conditions. The adopted emission factor was 0.708 kg $CO_2$e/kWh[13]. This emission factor includes the full supply chain of electricity generation as well as the distribution losses. The emission factor represents Italian conditions for 2009 and the source of the data is the Covenant of Mayors guidebook.

### II.1.5 Data overview

Number of organizations and number of employees per organization:

– 7 000 small and medium enterprises in different sectors including private companies, with less than 250 employees (20 employees in average assumed); 2 000 of them assumed to be ICT companies.

– 70 large companies, all private, with 500 employees on average, belonging to various sectors. 20 of them assumed to be ICT companies (e.g., one mobile phone service operator).

– the public administration, with 30 sites (including schools, hospitals, etc.) within the city boundaries.

Table II.1 and Table II.2 summarize the other data used and some intermediate results.

**Table II.1 – Number of ICT goods in organizations in the city (experts' assumptions)**

| | ***SME (7 000 enterprises)*** | | | ***Large companies (70 companies)*** | | | ***Public Administration (PA) (30 sites)*** | |
|---|---|---|---|---|---|---|---|---|
| | **Average number of goods per SME** | **Overall number of ICT goods in non-ICT SME (5 000)** | **Overall number of ICT goods in ICT SME (2 000)** | **Average number of goods** | **Overall number of ICT goods in non-ICT organizations (50)** | **Overall number of ICT goods in ICT organizations (20)** | **Overall number of ICT goods** | ***Total number of goods in all organizations*** |
| PCs | *15* | 75 000 | 30 000 | *100* | 5 000 | 2 000 | *3 000* | **115 000** |
| Laptops | *12* | 60 000 | 24000 | *100* | 5 000 | 2 000 | *1 000* | **92 000** |

[11] In reality the numbers used here are fictitious numbers invented for this example.

[12] https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp.

[13] Covenant of Mayors Standard Emission Factors www.covenantofmayors.eu/IMG/pdf/004_Part_II.pdf.

**Table II.1 – Number of ICT goods in organizations in the city (experts' assumptions)**

| | *SME (7 000 enterprises)* | | | *Large companies (70 companies)* | | | *Public Administration (PA) (30 sites)* | |
|---|---|---|---|---|---|---|---|---|
| | **Average number of goods per SME** | **Overall number of ICT goods in non-ICT SME (5 000)** | **Overall number of ICT goods in ICT SME (2 000)** | **Average number of goods** | **Overall number of ICT goods in non-ICT organiza-tions (50)** | **Overall number of ICT goods in ICT organiza-tions (20)** | **Overall number of ICT goods** | ***Total number of goods in all organiza-tions*** |
| Tablets | *10* | 50 000 | 20 000 | *70* | 3 500 | 1 400 | *1 000* | **75 900** |
| Printers | *5* | 25 000 | 10 000 | *80* | 4 000 | 1 600 | *600* | **41 200** |
| Mobile phones | *6* | 30 000 | 12 000 | *120* | 6 000 | 2 400 | *1 000* | **51 400** |
| Servers | *0.7* | 3 500 | 1 400 | *4* | 200 | 80 | *50* | **5 230** |
| Server rooms | *0* | 0 | 0 | *0.6* | 30 | 12 | *7* | **49** |
| Base stations for cellular networks | *0* | 0 | 0 | *0.2* | 10 | 4 | *1* | **15** |
| ADSL +WiFi | *1* | 5 000 | 2 000 | *10* | 500 | 200 | *50* | **7 750** |

**Table II.2 – Time of use of ICT goods: hours per day in ON and Standby mode and the derived yearly energy consumption per item (expert's assumptions)**

| | **Time** | | **ON mode** | | **Standby mode** | | **Total** |
|---|---|---|---|---|---|---|---|
| | ***h* per day ON** | ***h* per day STD BY** | **Power need per item ON (W)** | **Yearly energy cons per item ON (kWh/y)** | **Power need per item STD BY (W)** | **Yearly energy cons per item STD BY (kWh/y)** | **TOT energy cons per item per year (kWh/y)** |
| PCs | 10 | 14 | 100 | 365 | 8 | 41 | 406 |
| Laptops | 12 | 12 | 10 | 44 | 2 | 9 | 53 |
| Tablets | 3 | 21 | 10 | 11 | 0 | 0 | 11 |
| Printers | 0.5 | 23.5 | 4 | 1 | 1 | 9 | 10 |
| Mobile phones | 3 | 21 | 5 | 5 | 0 | 0 | 5 |
| Servers | 24 | 0 | 200 | 1 752 | Na | 0 | 1 752 |
| Server rooms | 24 | 0 | 1 000 | 8 760 | Na | 0 | 8 760 |
| Base stations for cellular networks | 24 | 0 | 700 | 6 132 | Na | 0 | 6 132 |
| ADSL +WiFi | 24 | 0 | 8 | 70 | Na | 0 | 70 |

This is a simplified example considering only a Tier 1 assessment and considering that all ICT goods have the same consuming patterns (i.e., all PCs are ON for the same number of hours). While performing the assessment it is recommended that the most approximate data are collected.

Table II.3 shows the $CO_2e$ emissions of the ICT goods in the use phase for all organizations in the city. The $CO_2$ emissions are calculated by multiplying the power consumption by this emission factor of 0.708 kg $CO_2e$/kWh, corresponding to GHG emission factor for the Italian power mix.

**Table II.3 – GHG emissions (in tonnes of $CO_2$ equivalent) by ICT per year in organizations**

| | **$CO_2e$ emissions (all org) use phase** | | | | |
|---|---|---|---|---|---|
| | **Emissions per year per item (kg $CO_2e$)** | **non-ICT (tonnes $CO_2e$)** | **ICT (tonnes $CO_2e$)** | **Public Administration (tonnes $CO_2e$)** | **TOT all items (tonnes $CO_2e$)** |
| PCs | 287 | 22 989 | 9 196 | 862 | 33 047 |
| Laptops | 37 | 2 419 | 968 | 37 | 3 424 |
| Tablets | 8 | 415 | 166 | 8 | 588 |
| Printers | 7 | 191 | 76 | 4 | 272 |
| Mobile phones | 4 | 140 | 56 | 4 | 199 |
| Servers | 1 240 | 4 590 | 1 836 | 62 | 6 487 |
| Server rooms | 6 202 | 186 | 74 | 43 | 304 |
| Base stations for cellular networks | 4 341 | 43 | 17 | 4 | 65 |
| ADSL +WiFi | 50 | 273 | 109 | 2 | 385 |

### II.1.7 Results and conclusion

Figure II.1, Figure II.2 and Figure II.3 show the results of the assessment

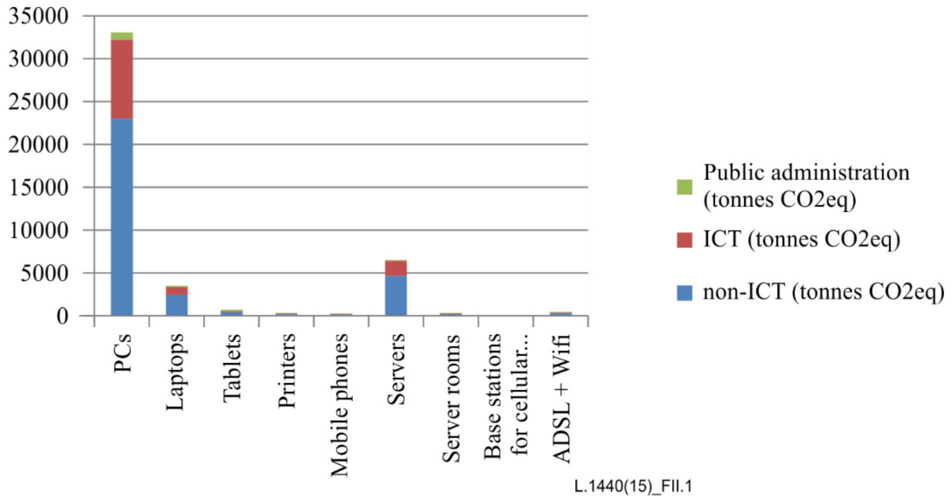


**Figure II.1 – Yearly GHG emissions related to ICT goods in organizations – presented per good type**

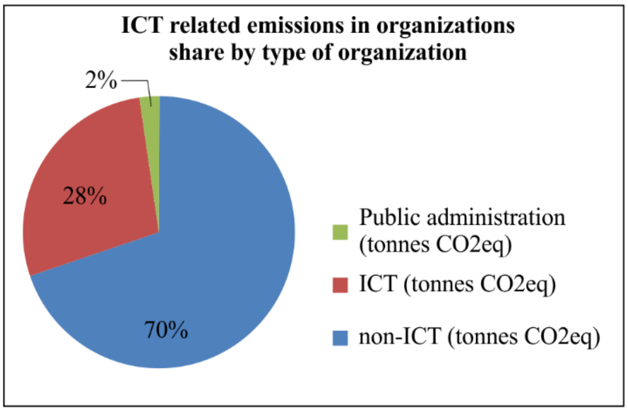


**Figure II.2 – Yearly GHG emissions related to ICT goods in organizations – presented per organization type**

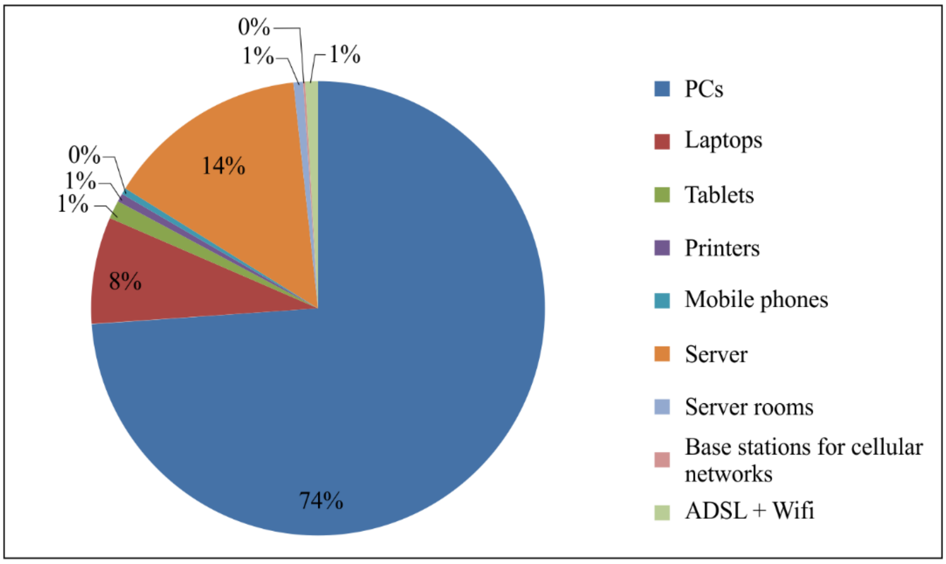


**Figure II.3 – Yearly GHG emissions related to ICT goods in organizations – presented per goods category**

In summary, the amount of GHG emissions in the assessed city related to the use stage of ICT in organizations was estimated to around 31 ktonnes $CO_2e$ per year for ICT organizations, 12 ktonnes $CO_2e$ per year for ICT organizations and 1 ktonne $CO_2e$ per year for the public administration.

This corresponds to a total impact of the ICT goods in organizations in the assessed city of 44 ktonnes $CO_2e$ per year.

These figures take into account the use stage only.

Based on these use stage results the main contribution to the ICT related organization emissions came from PCs followed by servers.

### II.1.8 Interpretation of results

In this study results were mainly analysed through sensitivity analysis.

#### II.1.8.1 Sensitivity analysis

The Tier 1 assessment approach, from its conception, is an approach that does not take into account all life cycle impacts of the ICT goods. By only assessing the use stage of the ICT goods, the impacts associated with raw material acquisition, production and end-of-life treatment are not taken into consideration. In this sense the results are giving a coarse approximation of the full impact of the ICT in organizations in the city. Particularly, for consumer goods with a relatively short lifetime, the other life cycle stages are known to have a significant contribution to the overall emissions.

A sensitivity analysis was performed to understand the impact on results and conclusions from assumptions and limitations in data.

The major uncertainty sources of the study were identified as those related to the limitations in access to actual data for use patterns, to the modelling of ICT goods used by organizations from a minor sample of organizations and to the lack of real data for power consumption. The fact that no distinction was made between the different models of the different ICT goods led to considerable uncertainty due to the difference in actual energy consumption between different models

NOTE – In a real study the sensitivity analysis should have been performed for all the above parameters (e.g., by doubling and halving the parameter value and recalculating the results with these values included) and the impact on the results and conclusions should have been transparently presented together with the results. This was not done for the sake of this example but is a fundamental activity for the interpretation of any LCA study.

NOTE – For the sake of this example, no results per employee were derived. In a real study such values would give a better understanding of how the efficiency of the ICT goods used by organizations evolves over time.

## II.2 Tier 2 assessment

This part of the example refers to a Tier 2 assessment where the full life cycle is evaluated.

### II.2.1 Goal and scope definition

The goal of this assessment was to evaluate the environmental impact of ICT goods present in the organizations of the city taking into account GHG emissions related to their full life cycle, i.e., including the use stage as well as the raw materials acquisition, production and end-of-life treatment of goods.

For this Tier 2 level of assessment, a subset of ICT good were considered, which represented those items that were the most commonly used items in organizations: PCs, laptops, tablets, printers, mobile phones, servers (enterprise servers), server rooms, base stations for cellular networks and ADSL/WiFi.

### II.2.2 Boundaries

This assessment takes into consideration the organizations present within the city boundaries.

In this example the organizations are categorized into Public Administration, ICT organizations and non-ICT organizations which are then subdivided in small and medium-sized enterprises (SMEs) and large companies.

The city boundaries were identified based on XXX and the information regarding organizations within those boundaries was found in YYY.

The ICT goods used in organizations, as well as the typical time of use for each item and in each use mode (use pattern) were identified and modelled according to the same principles as in the Tier I example.

The system boundaries applicable to the assessed ICT goods are defined by the life cycle stages and activities defined in [ITU-T L.1410].

### II.2.3 Data collection

When performing a life cycle assessment of the GHG emissions of the ICT goods used by organizations, the practitioner is expected to use the best available data, preferably adopting GHG emission values derived in accordance with [ITU-T L.1410].

After identifying the organizations within the city boundaries and their ICT goods and use, additional life cycle data are collected for each ICT good based on best available data sources. For example, as there are different models of televisions, data ideally, should be representative to each model. If no specific data are available for different models of ICT goods, reasonable estimations are acceptable (e.g., LCD TVs, plasma TVs, etc.). In this example data are mainly based on experts' estimations based on available tools like "Bilan Carbone" (carbon assessment) and approximations from LCA studies available in vendors' documentation[14].

NOTE – Data collection can be a barrier to develop a Tier 2 assessment. However, ICT vendors sometimes provide LCA results including the embedded GHG emissions for their products. In this example the embedded LCA values (representing raw materials acquisition, production and end-of-life treatment stages) are estimated based on published data of varying quality. In general, data may be collected directly from manufacturer information or from published LCA studies, if available, or from other sources that allow for a reliable estimation of the life cycle GHG emissions of ICT goods.

The emission factors used for the different life cycle stages of the various ICT goods are in accordance with the adopted LCA results. This means that the emission factors used may represent different conditions and electricity mixes for different goods.

NOTE – In a real study the emissions factor of the use stage of all goods should be the same and representative to the city. If this is not possible the implications of applying different emission factors for different good categories need to be analysed as part of the interpretation phase.

### II.2.4 Data overview

This clause summarizes the data used and some intermediate results:

Number of organizations and number of employees per organization:

– 7 000 small and medium enterprises in different sectors including private companies, with less than 250 employees (20 employees in average assumed); 2 000 of them assumed to be ICT companies.
– 70 large companies, all private, with 500 employees on average, belonging to various sectors. 20 of them assumed to be ICT companies (e.g., one mobile phone service operator).
– the public administration, with 30 sites (including schools, hospitals, etc.) within the city boundaries.

The emission factors used for the different life cycle stages of the various ICT goods are in accordance with the adopted LCA results and are based on XXX, YYY and ZZZ.

NOTE – In a real study the emission factors adopted for different life cycle stages and goods needs to be aligned and transparently reported as far as possible.

The calculations for this Tier 2 example of assessment are reported in Table II.4 and Table II.5.

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[14] In a real study the information about data sources and their application should be made more specific.

**Table II.4 – Number of ICT items per organization category and in the city**

| | ***SME (7 000 enterprises)*** | | | ***Large companies (70 companies)*** | | | ***Public Administration (30 sites)*** | ***A*** |
|---|---|---|---|---|---|---|---|---|
| | **Average Number of goods per SME** | **Overall number of ICT goods in non-ICT SME (5 000)** | **Overall number of ICT goods in ICT SME (2 000)** | **Average number of goods** | **Overall number of ICT goods in non-ICT organiza-tions (50)** | **Overall number of ICT goods in ICT organiza-tions (20)** | **Overall number of ICT goods** | ***Total number of goods in all organiza-tions*** |
| PCs | *15* | 75 000 | 30 000 | *100* | 5 000 | 2 000 | *3 000* | **115 000** |
| Laptops | *12* | 60 000 | 24 000 | *100* | 5 000 | 2 000 | *1 000* | **92 000** |
| Tablets | *10* | 50 000 | 20 000 | *70* | 3 500 | 1 400 | *1 000* | **75 900** |
| Printers | *5* | 25 000 | 10 000 | *80* | 4 000 | 1 600 | *600* | **41 200** |
| Mobile phones | *6* | 30 000 | 12 000 | *120* | 6 000 | 2 400 | *1 000* | **51 400** |
| Servers | *0.7* | 3 500 | 1 400 | *4* | 200 | 80 | *50* | **5 230** |
| Server rooms | *0* | 0 | 0 | *0.6* | 30 | 12 | *7* | **49** |
| Base stations for cellular networks | *0* | 0 | 0 | *0.2* | 10 | 4 | *1* | **15** |
| ADSL +Wifi | *1* | 5 000 | 2 000 | *10* | 500 | 200 | *50* | **7 750** |

Table II.5 presents the data collected or derived for the overall life cycle GHG emissions and the breakdown of the emission between life cycle stages for the different ICT goods assessed.

NOTE – The use stage values applied in the Tier 2 example are different from the ones applied in the Tier 1 example. For this reason no comparison could be made regarding the impact from other life cycle stages on the overall results. This illustrates a situation when the data sources have been changed between the Tier 1 and Tier 2 assessments. Preferably in such cases results should be calculated using both the original Tier 1 data and the new data for the use stage to understand how that impacts results. Especially, this is important when the city tries to understand how the GHG emissions develop over time.

**Table II.5 – Life cycle GHG emissions per item**

| | Life cycle GHG emission ($CO_2e$) per item | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Operational lifetime (years)** | **Raw materials acquisition (kg $CO_2e$)** | **Production (kg $CO_2e$)** | **Full life cycle use (kg $CO_2e$)** | **Yearly use (kg $CO_2e$)** | **EoL treatment (kg $CO_2e$)** | **Total life cycle GHG emissions per item (kg $CO_2e$)** |
| PCs | 4 | 88 | 264 | 440 | 110 | 8 | **800** |
| Laptops | 4 | 74 | 200 | 125 | 31 | 1 | **400** |
| Tablets | 3 | 20 | 98 | 31 | 10 | 2 | **150** |
| Printers | 5 | 29 | 40 | 30 | 6 | 1 | **100** |
| Mobile phones | 3 | 3 | 49 | 12 | 4 | 1 | **65** |
| Servers | 7 | 100 | 400 | 10 500 | 1 500 | 80 | **11 080** |
| Server rooms | 7 | 36 720 | 36 720 | 331 360 | 46 628 | 3 200 | **408 000** |
| Base stations for cellular networks | 10 | 9 000 | 3 000 | 70 000 | 7 000 | 200 | **82 200** |
| ADSL +Wifi | 5 | 15 | 60 | 550 | 110 | 2 | **627** |

### II.2.5 Results and conclusions

Table II.6 and Table II.7 present the overall results of the assessment of the impacts of ICT goods in organizations within city boundaries. Table 14 shows the impact of all organizations and Table 15 shows the breakdown per type of organization.

**Table II.6 – Life cycle GHG emissions for all items**

| | **Total life cycle GHG emissions per item (kg $CO_2e$)** | **Total life cycle GHG emission for all items (tonnes $CO_2e$)** | **Total life cycle GHG emissions for all items per year (tonnes $CO_2e$)** |
|---|---|---|---|
| PCs | **800** | **92 000** | 23 000 |
| Laptops | **400** | **36 800** | 9 200 |
| Tablets | **150** | **11 385** | 3 795 |
| Printers | **100** | **4 120** | 824 |
| Mobile phones | **65** | **3 341** | 1 114 |
| Servers | **11 080** | **57 948** | 8 278 |
| Server rooms | **408 000** | **19 992** | 2 856 |
| Base stations for cellular networks | **82 200** | **1 233** | 123 |
| ADSL +Wifi | **627** | **4 855** | 971 |

**Table II.7 – Overall life cycle GHG emissions (tonnes of $CO_2e$) of city organizations**

| | GHG emissions Tier 2 ALL ORGANIZATIONS (tonnes CO2e) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Non-ICT org** | | **ICT org** | | **Public Administration** | | **Life cycle GHG emission all organizations** | | |
| | **Total lifetime** | **Yearly** | **Total lifetime** | **Yearly** | **Total lifetime** | **Yearly** | **Total lifetime** | **Yearly** | **Yearly relative % over all items** |
| PCs | **64 000** | **16 000** | **25 600** | **6 400** | **2 400** | **600** | **92 000** | **23 000** | 45.9% |
| Laptops | **26 000** | **6 500** | **10 400** | **2 600** | **400** | **100** | **36 800** | **9 200** | 18.3% |
| Tablets | **8 025** | **2 675** | **3 210** | **1 070** | **150** | **50** | **11 385** | **3 795** | 7.6% |
| Printers | **2 900** | **580** | **1 160** | **232** | **60** | **12** | **4 120** | **824** | 1.6% |
| Mobile phones | **2 340** | **780** | **936** | **312** | **65** | **22** | **3 341** | **1 114** | 2.2% |
| Servers | **40 969** | **5 853** | **16 399** | **2 343** | **551** | **79** | **57 948** | **8 278** | 16.5% |
| Server rooms | **12 235** | **1 748** | **4 896** | **699** | **2 857** | **408** | **19 992** | **2 856** | 5.7% |
| Base stations for cellular networks | **822** | **82** | **329** | **33** | **82** | **8** | **1 233** | **123** | 0.2% |
| ADSL +Wifi | **3 446** | **689** | **1 378** | **276** | **31** | **6** | **4 855** | **971** | 1.9% |
| | | **34 906 (Note)** | | **13 965 (Note)** | | **1 285 (Note)** | | **50 161 (Note)** | |
| NOTE – *Due to differences in lifetime only yearly figures may be summed up to an overall value (as per principles of LCA assessment).* | | | | | | | | | |

The emissions are distributed based on type of organization according to the following: around 35 ktonnes $CO_2e$ per year for non-ICT organizations, 14 ktonnes $CO_2e$ per year for ICT organizations and 1 ktonne $CO_2e$ for the public administration. This corresponds to a total impact of the ICT goods in organizations in the assessed city of 50 ktonnes $CO_2e$ per year.

Figure II.4 shows ICT-related emissions by type of organization and Figure II.5 shows relative ICT-related emissions per type of equipment.

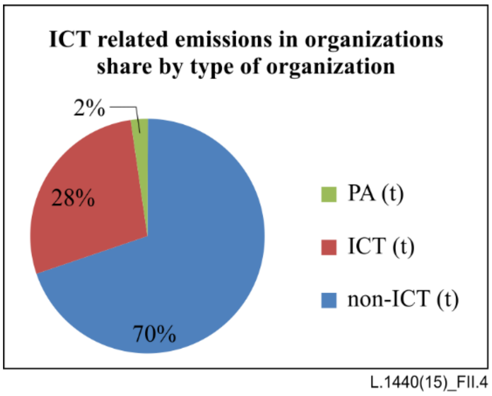


**Figure II.4 – ICT-related emissions by type of organization**

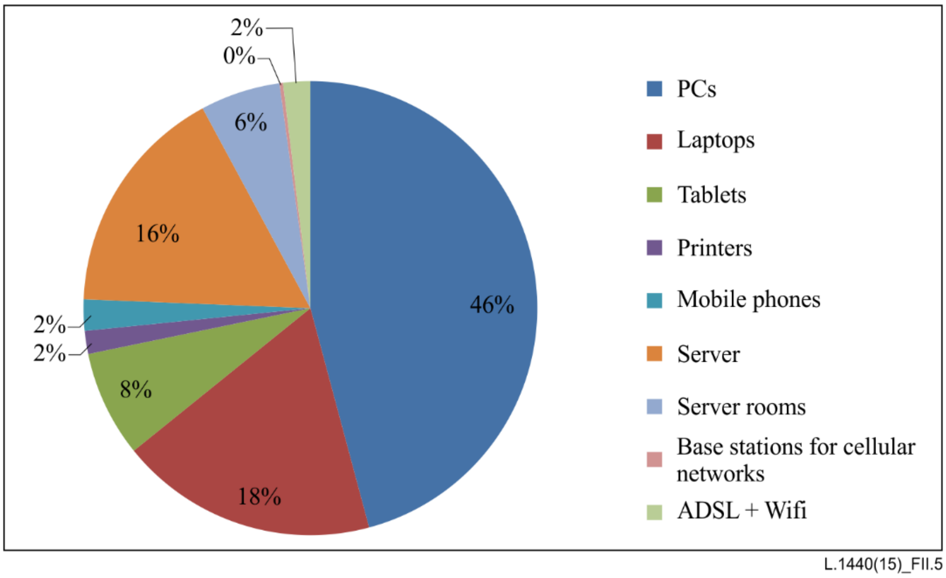


**Figure II.5 – Relative ICT-related emissions per type of equipment**

Based on these results the main contribution to the ICT-related organization emissions came from PCs followed by laptops and servers (enterprise servers).

NOTE – Note that even if the results of Tier 1 and Tier 2 assessment are expressed in the same units, these cannot be directly compared, since these results are obtained by applying two different approaches: the assessment of the impact of the use stage only and the assessment of the whole life cycle of ICT goods. In addition, different data sets were used even for the use stage.

### II.2.6 Interpretation

In this study results were mainly analysed through sensitivity analysis.

#### II.2.6.1 Sensitivity analysis

In addition to the parameters to be considered in the sensitivity analysis according to the Tier 1 example it is important to also consider data for all life cycle stages, as the modelling of embedded emissions is quite rough and the uncertainty is large. One way to understand what parameter values to use for the sensitivity analysis of different equipment would be to check the variations between different published LCAs.

NOTE – As stated for the Tier 2 example, in a real study the sensitivity analysis should have been performed for all the identified parameters (e.g., by doubling and halving the parameter value and recalculating the results with these values included) and the impact on the results and conclusions should have been transparently presented together with the results. This was not done for the sake of this example but is a fundamental part of any LCA study.

## II.3 Reporting

The reporting is common to a Tier 1 or a Tier 2 assessment. In the reporting phase the results achieved through the assessment are systematically presented so that a city may be able to identify where the impacts of ICT goods within their boundaries.

According to clause 9 on reporting, the city will report in the common part of the report:

- Contact information:
  - City X, Contact person N.N
- Type of assessment:
  - The inventory was realized according to the ITU-T L.14xx-series methodologies, according to the ITU-T L.14xx-series of Recommendations for ICT in cities.

- The approach chosen was a Tier 1 assessment, assessing the impact of the use phase of ICT goods present within city boundaries (first example) and a Tier 2 assessment, assessing the impact of the full life cycle of the ICT goods present within city boundaries (second example).
- The ICT goods evaluated were: PCs, laptops, tablets, printers, mobile phones, servers, server rooms, base stations for cellular networks and ADSL +Wifi.
- The study was performed based on secondary data applying a statistical approach.

• Goals of the study:
  - The goals of this study are to evaluate the ICT footprint in the city in order to have a estimation of the environmental impact of ICT in organizations for the year of reference (2013). The evaluation of the results allows the city representatives to have a baseline scenario for XXX while projecting the cities pathways towards a more sustainable and smart future.

• Period for which the report is valid:
  - This report is valid for two years. At the end of these two years, there should be a revision with updated data.

• Identification of number and types of organizations subject to the study:
  - 7 000 small and medium enterprises from which 2000 are ICT companies.
  - 70 large companies from which 20 are ICT companies.
  - 30 sites of the Public Administration.
  - Identification and justification of boundaries and timeframe chosen.
    • The boundaries chosen are the cities geographical boundaries as defined in the Urban Plan boundaries definition (reference XXX).
    • The time frame is one year. The reference year is 2013. Results are presented as yearly values.
    • In example 1, a Tier 1 approach was applied and the assessment covered the use stage of PCs, laptops, tablets, printers, mobile phones, servers, server rooms, base stations for cellular networks and ADSL +Wifi. In example 2, a Tier 2 approach was applied and the full life cycle of these ICT good categories were included.

• Emission factors used:
  - For Tier 1: The energy mix and the corresponding emission factor were based on Italian conditions. The adopted emission factor was 0.708 kg $CO_2$e/kWh[15]. This emission factor includes the full supply chain of electricity generation as well as the distribution losses. The emission factor represents Italian conditions for 2009 and the source of the data is the Covenant of Mayors guidebook.
  - The emission factors relating to embodied emissions of the Tier 2 assessment are not available since the companies disclosing the LCA results do not make these values available which are diverse, depending where the different life cycle stages occur.

• Sources of the LCA data of the ICT goods collected in the Tier 2 assessment:
  - Embodied life cycle stages were modelled based on publically available LCA data from ICT vendors (in a real report specific references are required).

[15] Covenant of Mayors Standard Emission Factors www.covenantofmayors.eu/IMG/pdf/004_Part_II.pdf.

- Justification of cut-offs:
  - Only hardware was taken into consideration in the assessment. Development of software and consumables used related to ICT goods were not taken into account in the study to reduce the work load and complexity.
- Identification of possible double accounting situations:
  - No double accounting situations identified.
- Identification and interpretation of the results of energy consumption assessment and GHG emissions assessment in case of a Tier 1, use stage only, assessment 44 ktonnes $CO_2$e:
  - 44 ktonnes $CO_2$e of yearly impact.
- Identification and interpretation of the results of the embedded footprint arising from the LCA of the ICT goods in case of a Tier 2 assessment:
  - 50 ktonnes of yearly impact.
  - 70% coming from non-ICT organizations, 28% from ICT Organizations and 2% from the Public Administration.
  - At a city level the largest environmental impacts can be ascribed to PCs followed by laptops and servers (enterprise servers).
  - The most significant life cycle stage is the use phase, which actually occurs within city boundaries.
  - The importance of the production stage has to be noted, representing a large portion of the overall impact. Even if it is not clear if these impacts occur within city boundaries, these have to be considered.

Based on the background calculations it can be seen that the Tier 1 assessment, use stage only, gives a result of 44 Ktonnes while the use stage as calculated in Tier 2 corresponds to 35 ktonnes only. This is a difference of about 20% which is due to the use of different input data.

As shown in this example using different sets of data, LCA studies with non-transparent assumptions or best effort estimates, can produce different results.

NOTE – For a combined results presentation of households and organizations see Appendix VI.

# Appendix III

## Examples on how to apply this Recommendation to an ICT project at city level

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

This appendix describes a hypothetical example of an ICT GHG and/or energy project in order to illustrate the use of this Recommendation to evaluate the GHG impacts of an ICT project. This example shows how this Recommendation could be applied at a city level. This example is not a comprehensive application of this Recommendation, rather it gives a practical application of clause 8.5 of [ITU-T L.1430].

The chosen example describes the assessment of a project for a real-time traffic monitoring system in a public bus line. In the bus a meter is installed and collects real-time data (e.g., speed, consumption and time between stops). Data is sent to a server located inside the city boundaries. From that data centre, information about the schedules of bus arrivals is sent to a mobile application accessible to the citizens and at the bus stops throughout the city. It is also possible for the bus driver to receive traffic information in order to manage the bus speed according to predetermined schedules and the traffic situation, thus allowing for a better performance on fuel consumption and on reducing the GHG emissions.

This service might increase the public transport use due to the improvement of its efficiency and therefore displace private transport and correspondingly GHG emissions.

### a) Title of ICT GHG and/or energy project

Pilot implementation of a real-time traffic monitoring system in a city bus line.

### b) Purpose(s) and objective(s) of ICT GHG and/or energy project

The purpose of the pilot project is to monitor traffic conditions in a bus line, by installing performance and consumption meters in the buses that communicate with the rest of the buses in the line through a common framework that subsequently communicate with the bus driver, informing about the fuel consumption and expected times of arrival. This system may also be able to send expected times of arrival to the bus stops and to a smartphone application accessible to the passengers.

This project may allow a more efficient management of the buses in the city, leading to reduction of the direct GHG emissions of the buses and an indirect reduction of the GHG emissions of private cars, due to an expected increase in public transport users.

This is a Tier 1 example.

### c) Type of ICT GHG and/or energy project (according to Appendix I of [ITU-T L.1430])

– Smart logistics and transport;

– Fleet management;

– Real-time traffic-flow optimization.

### d) Project participants

– Municipal administration;

– City transport companies;

– ICT GNS developers;

– Telecommunication companies;

– Project proponents.

**e) Location of the ICT GHG and/or energy project**

The project will be deployed within the assessed city boundaries.

Data centre and control will be located inside city boundaries.

Life cycle activities other than the use stage (i.e., raw materials acquisition, production and end-of-life treatment) may occur outside city boundaries.

**f) Conditions prior to project initiation:**

There are no major conditions that might affect the project or its initiation besides the fact that the transport system has to be effectively in the city, but a precondition is that the transport system's efficiency is not deteriorated.

**g) Description of an ICT GHG and/or energy project:**

This project may achieve energy consumption and GHG emissions reduction through the optimization of the timetables of the buses, providing real-time information to the bus drivers to raise their awareness regarding fuel usage and traffic congestion to trigger suitable actions. The citizens will get access to real-time information on their smartphones where they could check the updated timetables of the buses and choose the means of transport that best suits their needs.

Through a more efficient service, the public transport services could attract more passengers, thereby reducing the GHG emissions associated with private cars use. The latter however is not assessed in this example.

The activities considered in this example are:

A – Driving the bus (impacted activity): fuel consumption and GHG emissions;

B – Operating the bus meters (hardware, software): electric energy consumption and GHG emissions;

C – Data analysis: electric energy consumption and GHG emissions in the data centre;

D – Network communication to users and buses: electric energy consumption and GHG emissions.

**h) ICT GNS product systems to be employed by the ICT GHG and/or energy project**

– Hardware: on-board meters with commercial GPS software and antennas on buses, data centres;

– Software: customized mobile application, customized software for the management of the system;

– Networks: Mobile cellular connection between meters and the control room. Connection between the control room and the bus display, bus stops and mobile application.

**i) Estimated amount of GHG and energy effects over the chosen crediting period, stated in tonnes of $CO_{2e}$, toe and/or MWh**

Here fictitious data illustrate the hypothetical impacts of the activities foreseen. This evaluation considers the use stage only and does not take into account all life cycle assessments of the whole project and its constituents.

Electricity emission factor:

The energy mix and the corresponding emission factors were collected, based on Italian conditions. The adopted emission factor was 0.708 kg $CO_2$e/kWh[16]. This emission factor includes the full

[16] Covenant of Mayors Standard Emission Factors www.covenantofmayors.eu/IMG/pdf/004_Part_II.pdf.

supply chain of electricity generation as well as the distribution losses. The emission factor represents Italian conditions for 2009 and the source of the data is the Covenant of Mayors guidebook.

Diesel emission factor:

Emission factor is 3.1 kg $CO_{2e}$/litre diesel

Activity A, the actual transport, is related to the fuel consumption of the bus, expressed in tonne of oil equivalent (toe) and consequently in tonnes of $CO_2$e. Here, this value would represent the difference between the baseline scenario (i.e., without the introduction of ICT in the bus line system) and the project scenario (i.e., after the project fully is implemented).

Before implementing the project and considering that the 40 buses would each drive 200 km per day, with a consumption of 100 L of diesel per 100km, the fuel consumption would add up to 240 000 litres of diesel consumed per month.

Considering the emission factor of 3.1 kg $CO_{2e}$/litre diesel the corresponding emissions are 738 tonnes of $CO_{2e}$.

The project resulted in a fuel consumption reduction of 5% thus, the obtained GHG emissions reduction is of about 37 tonnes of $CO_{2e}$.

Activity B, the operation of the bus meters (hardware components and software/firmware), would cause energy consumption expressed in MWh and consequent GHG emissions, expressed in tonnes of $CO_{2e}$.

The project involves 40 buses, with 1 meter each. Table III.1 shows energy consumption per smart meter per day.

**Table III.1 – Energy consumption per smart meter per day**

| Per meter | ON | Standby | OFF | TOTAL |
|---|---|---|---|---|
| Time (hours) | 10 | 10 | 4 | |
| Power (watt) | 20 | 0.5 | 0 | |
| Energy (Wh/day) | 200 | 5 | 0 | 205 |

For 40 buses this results in an energy consumption of 246 kWh per month and emissions of 174 kg $CO_{2e}$.

Activity C, the data analysis, would lead to energy consumption in the data centre where data received from the on-board metering systems, would be analysed and sent back to the bus drivers, bus stops and mobile application.

Assuming that the data centre consumes 5 kW of power for this project and operates 24 hours/day, the data centre would have a daily electric energy consumption of 120 kWh.

This equals around 3 600 kWh or 2.5 tonnes $CO_{2e}$ emitted per month.

Activity D, network communication, would represent the networks needed to link the bus meters and the data centre and then send back information to the buses, bus stops and to the smartphone application. The networks within the data centre would not be taken into account as they would be considered in Activity C.

Considering that the networks would represent 1 kW of installed power for 20 hours per day, the networks' electric energy consumption would be of 20 kWh per working day.

This equals around 600 kWh or 0.4 tonnes $CO_{2e}$ emitted per month.

In conclusion, the effect of the project would be the sum of the negative impacts and of the positive impacts. In this example, since in the baseline scenario no activities would be taking place other than the regular bus energy consumption, the overall impact could be calculated as the balance of the energy savings in the fuel consumptions of the buses, minus the energy consumption of the ICT equipment installed and running for the project.

In total the project saved 37 tonnes due to fuel usage reduction and added 3.07 tonnes of $CO_{2e}$ for the ICT solution. This means, that by implementing the project a reduction of around 34 tonnes $CO_{2e}$ per month was achieved in the city for a 5% reduction in bus fuel use.

On a city scale for a fleet of 4 000 buses, assuming that the fuel reduction stays the same (5%) and the ICT consumption is directly proportional to the number of buses, the savings would be around 3 400 tonnes of $CO_{2e}$ per month.

**j) Identification of risks that may substantially affect GHG and energy effects of the project**

Incentives for bus drivers to adopt their driving behaviour towards lower fuel consumption

**k) Information about stakeholders**

– Municipal administration;
– City transport regulatory entities;
– National energy and transport entities;
– ICT GNS developers;
– Telecommunication companies;
– Groups of citizens;
– GHG programme promoters;
– External consultants;
– Third-party validators/ verifiers.

**l) Chronological plan**

This project would take place in a timeframe of 11 years, starting from the year 0, with implementation in Year 1 and completion in Year 10.

The monitoring frequency should be biannual, as should the reporting period.

**m) Sampling plan for validation and/or verification**

No sampling is needed for fuel data since real data on per bus consumption is available.

For every reporting period, assumptions for energy consumption for all activities shall be reassessed to consider changes in equipment and operating conditions.

# Appendix IV

## Example on how to apply this Recommendation to an ICT service at city level

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

NOTE – Practitioners should not use values of the examples without further review. Data are based on best effort data collection in areas such as energy consumption of the ICT goods or emission factors used and are only representative for the conditions of this example.

**Assessment scope and purpose**

The assessment targets a smart meter service for 30,000 users in a city area in country X.

The assessment was performed to understand the reduction in energy use needed to compensate for the first order life cycle impacts of the ICT service.

**The ICT service**

This example is based on the deployment of a smart metering service in a city area in country X. Smart meters enable users to better manage their energy use through continuous information about the amount of energy being used and the associated costs, thus enabling a reduction in the carbon emissions of energy users.

This example uses a life cycle assessment to calculate the GHG emissions related to the first and second order effects of the service.

In this example it is assumed that the service hardware consists of the following goods: the smart meters; a dedicated long term evolution (LTE) radio access network (RAN) with related site infrastructure; a corresponding LTE core network and a dedicated data centre. The smart meter includes the meter, a communication modem and a remotely operated switch. The private LTE RAN includes a radio base station site with radio units, digital units, antennas, peripherals and a cabinet. New antenna towers are included for half of the sites. In addition, the related LTE core network includes the servers and mechanics used to house the evolved packet core that handles the LTE air interface. The data centre houses the servers, mechanics and peripherals.

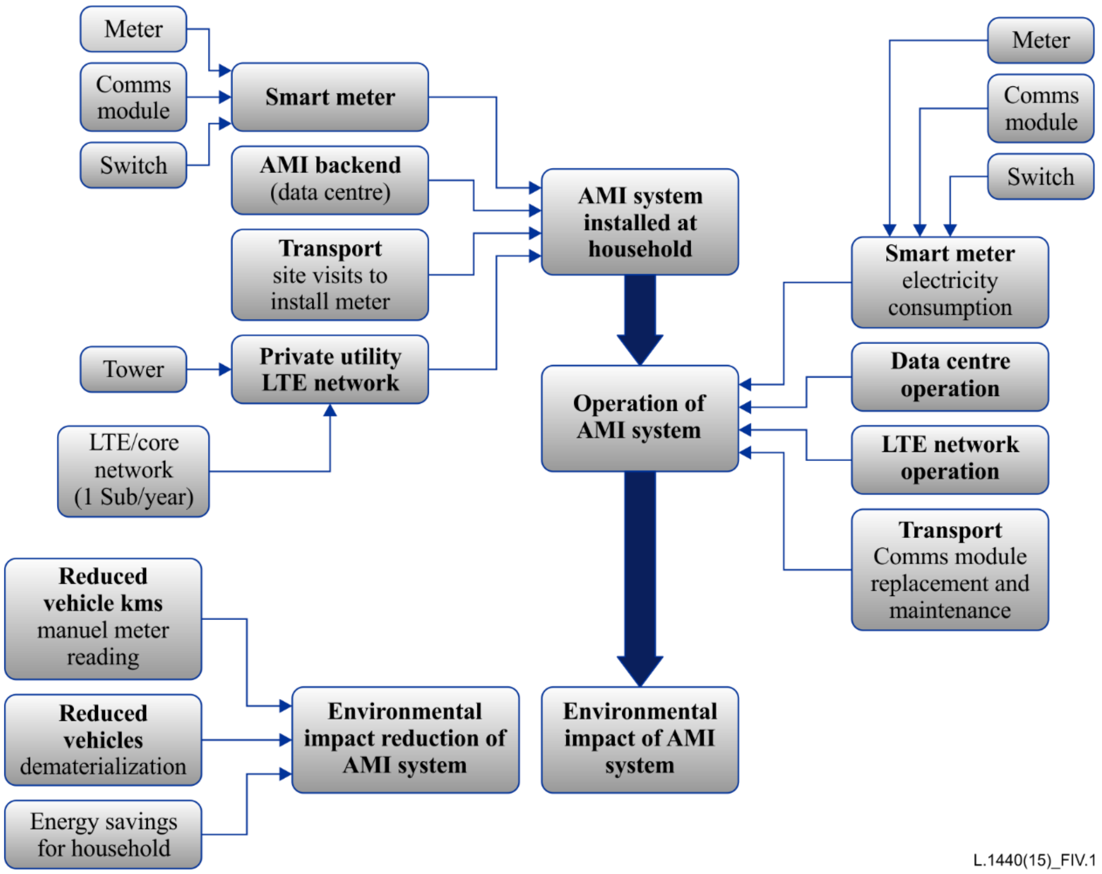


**Figure IV.1 – System flow chart of the LCA models**

For all goods of the flow chart shown in Figure IV.1, both embodied and operational GHG emissions are considered based on previous studies (in a real report references are required) which were to a large extent aligned with [ITU-T L.1410][17].

An operational lifetime of 20 years is assumed[18].

The assessment also includes emissions related to transportation for installation and maintenance purposes. The assessment does not include end-of-life (EoL) treatment neither for the new meters nor for the replaced ones. The justification is that previous studies show that the GHG emissions of the EoLT stage are marginal.

**Expected second order effects**

The smart metering service has three main benefits: the elimination of manual meter reading, a reduced number of vehicles used and a reduction of energy used in the home.

Based on previous research, we estimate that an average distance of 4.35 km per year per smart meter is avoided through automated meter reading instead of a technician travelling to each site for manual reading (reference YYY).

The elimination of manual meter reading is also assumed to lead to a reduction in the number of vehicles needed for field operations by one vehicle per year. Home energy management is expected to lead to a decrease in power used by households. At the time of the assessments the study was not

[17] In a real study report details about each good would be provided as well as details regarding any L.1410 deviations

[18] In a real study report more details would be provided regarding lifetime assumptions for all goods.

yet in operation so actual energy data were not available, instead GHG emissions reduction scenarios for 1%, 2% and 4% energy reduction were applied. Studies from other trials indicate an average saving of 4 per cent (reference YYY).

**Reference unit**

Annual impact per customer.

**Scenario descriptions**

ICT scenario:

The smart metering scenario includes 30 000 customers within the city boundaries for which new and smart meters are introduced. The assessed solution offers services that include remote meter reading and updates, as well as access to real-time power consumption information for customers.

Reference scenario:

Studies conducted by the State Government show that the average electricity usage rate for the residents was 7 300 kWh per year before the deployment of the smart meter service (reference XXX), and this figure is used in the present example as a reference level.

The assessment targets the meters as well as the communications network, and their overall GHG emissions from raw material acquisition, production and use are compared with a potential reduction in emissions due to reduced fuel consumption caused by fewer vehicle journeys and lower energy use in the home.

Emission factors for the electricity mix of embodied emissions are inherited from references (in a real report specific references are required). The emission factor for operation is based on country X conditions and set to 1.07 kg of $CO_{2e}$/kWh based on (reference YYY). This figure represents year Y and includes energy supply chain and distribution losses.

**Results and interpretation**

The results show that the annual life cycle impact per user of the ICT solution (with one meter per household), is about 65 kg $CO_{2e}$, 80% of which comes from the use stage.

The figures take into account the life cycle impacts of the whole technical system and the largest proportion is due to the dedicated LTE network followed by the meter itself, together representing 80% of the emissions.

Table IV.1 shows the first and second order impacts of the ICT service.

**Table IV.1 – First and second order impacts of the ICT service**

| | GHG emissions (kg $CO_{2e}$) | Net reduction (kg $CO_{2e}$) | Net saving for 30 000 end user (tonnes $CO_{2e}$) |
|---|---|---|---|
| First order impacts | 65 | | |
| Second order impacts at 1% saving | 80 | 15 | 450 |
| Second order impacts at 2% saving | 160 | 95 | 2 850 |
| Second order impacts at 4% saving [kg $CO_{2e}$] | 315 | 250 | 7 500 |

Taking into account the three main benefits of the smart metering service, as shown in Figure IV.1, namely the elimination of manual meter reading, a reduced number of vehicles used and reduction in energy used in the home, a positive net effect on emissions is achieved already at the 1% energy savings scenario. Net reductions in GHG emissions would be substantial at 2-4% energy saving[19].

The results above are only relevant for the conditions of the study such as the operational lifetime, the system architecture and the dimensioning and emission factors applied. One way to understand what parameter values to use for the sensitivity analysis of different items of equipment would be to check the variations between different published LCAs.

NOTE – In a real study a sensitivity analysis should have been performed for all the identified parameters (e.g., by doubling and halving the parameter value and recalculating the results with these values included) and the impact on the results and conclusions should have been transparently presented together with the results. This was not done for the sake of this example but is a fundamental part of any LCA study.

This comparison is relevant for country X, where the emissions per kilowatt hour are very high (in this scenario at 1.07 kg of $CO_{2e}$/kWh). Using a world average electricity mix, breakeven occurs at approximately 2 per cent home energy savings.

However, the assessed service is based on a dedicated LTE network. If a shared network was used the first order effects of the ICT service would be reduced considerably. Consequently, the demanded savings are a bit higher than what would typically be needed to outbalance the first order effects of the service.

[19] This example is based on a real study. For further details refer to www.ericsson.com/res/thecompany/docs/corporate-responsibility/2012/smart-metering.pdf.

# Appendix V

## Example regarding how to estimate effects of ICT projects or ICT services based on pilots or experiences made by other cities

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

NOTE – Practitioners should not use values of the examples without further review. Some of the data used in this Appendix are fictitious. The non-fictitious data is based on best effort data collection and might not reflect the latest knowledge or information in areas such as energy consumption of the ICT goods or emission factors used.

### Background

This example outlines a simplified (fictive) study seeking to understand how a pilot ICT project for smart work performed for one large company could be used to estimate the potential changes in GHG emissions if applied on a city scale.

NOTE – The example is considered as simplified, as parameters other than those outlined in the example could also need consideration.

### Identification of the reference ICT service or project and the reference situation

In this example the reference pilot project studied refers to the use of various ICT services to reduce the need for business travelling and commuting. The reference pilot was based on the experiences made by a large Swedish company while running a smart work programme to reduce commuting.

As shown in the Table V.1, the studied solution was calculated to have the described enablement potential.

**Table V.1 – Example pilot ICT project enablement potential**

| ICT project | ICT life cycle impacts | Reductions | Comment |
|---|---|---|---|
| Smart work | N/A (Note 1) | –66 kg $CO_{2e}$ per office employee and year (Note 2) | Reduction in car commuting. |
| NOTE 1 – *This study focused on a situation where already existing ICT goods, networks and services were used to change travel patterns. No dedicated ICT products and services were used. A more detailed study would also look into how use patterns and thus the life cycle impacts of ICT would change due to the programme. However, such impacts are not expected to change the conclusion that the enablement potential is significant for this kind of programme.*<br>NOTE 2 – *Since this example is about using these results to understand the potential impact reductions for the target city and not about the original assessments for the reference situation no further details are given on how these numbers were derived. However, these numbers depend fully on the assessment scenarios and assumptions behind these numbers and they could not be used to give any general indication regarding the potential of this kind of solution.* | | | |

### Identification of the target city, city area or city region

For this example, Stockholm, the capital of Sweden, was chosen as the target city.

The system boundary for Stockholm was set to Stockholm county as the suburbs need to be included when looking at commuting patterns.

**Definition of system boundaries for the pilot project and the targeted city**

The boundaries of the reference project were set in accordance with the company and project boundaries as outlined in (reference XXX)[20] and the geographical boundaries of the city was set to Stockholm county and defined in accordance with publically available data sources (reference XXX) and (reference YYY)[21] published by the authorities.

**Definition of the reference unit**

Reduction in GHG emissions per office employee and year

**Selection of high-level profile data for the two cities**

The city profile data for Stockholm and the reference pilot project were used to create a high-level understanding of the contextual factors and identification of similarities and differences with respect to car commuting. Data was taken from different public databases like Statistics Sweden, European statistics database and ITU[22].

**Comparison of the target city and the reference pilot study**

Except for the total population setting the addressable number of users, no differences in profile data (including demographic and ICT maturity factors) were identified as parameters which would influence the applicability of the company based results for Stockholm county.

The numbers of employees of the Swedish company decreased from 12 593 to 10 974 during the assessment period.

As shown in Table V.2, the addressable number of users in Stockholm was calculated taking into account different solution-specific parameters and data sources.

**Table V.2 – Addressable number of users in Stockholm calculation**

| ICT solution | Addressable number of users | Specification |
|---|---|---|
| Smart work | 322 790 office workers | Number of office employees estimated based on the total number of employees in different industry sectors in Stockholm county, from public statistics, and an assumed fraction of these being office workers. |
| | 200 130 car commuting office workers (Note) | 62% of office workers are commuting by car according to (reference XXX) |
| NOTE – *In reality the tendency to e-commute may be higher among those who are car commuting as the preference for going by car (and to e-commute) may be higher among those who are living far from the work place. In a more detailed study such dependencies should be looked into.* | | |

[20] In a real case this reference would be official information from the studied company

[21] As this is an example no real data sources are listed as they would be in a real study.
This principle applies throughout the appendix.

[22] Statistics Sweden (SCB): <http://www.scb.se>
European statistics database: <http://epp.eurostat.ec.europa.eu/>
International Telecommunications Union: "Measuring the Information Society – the ICT development index", revision 1. 2009.

**Comparison of solution specific parameters**

As shown in Table V.3, the identified solution specific parameters considered to influence the transfer of the ICT solution scenario and impact are listed. When necessary, secondary data have been used to bridge data gaps.

**Table V.3 – Solution specific parameters considered to influence the ICT scenarios and their impact**

| Parameter | Comparison of solution specific cases between the pilot project and the target city | |
|---|---|---|
| | ***Parameter value in the targeted city ($P_{target}$)*** | ***Parameter value in the pilot ($P_{ref}$)*** |
| Average time of journey to work (hour) | 0.58 | 0.45 |
| Average distance to work | X | 0,9X |
| Percentage of commuting performed by car | 48% | 62% |
| Average $CO_{2e}$ emission from car (g/km) | 153 | 150 |
| Existence of a smart work programme | Not decided | A smart work programme was set up within the company |
| NOTE – *References:XXX,YYY, ZZZ* | | |

**Building a use scenario (users, use profiles, ICT) for the targeted city also using the profile data**

In this study the conditions of the reference pilot seem to be applicable for the target city with respect to ICT maturity, except for some difference in the parameters listed in the previous table (average time and distance to work, percentage of commuting performed by car and the average emissions per car differs slightly). The addressable number of users, i.e., the number of office employees in Stockholm county who could use the smart work solutions, forms part of the scenario.

A main difference between the city and the pilot is that the pilot was based on a shift in travelling policy which was made possible due to the ICT service. In this example, no such policy is planned for the city.

NOTE – In the pilot scenario no extra heating of homes was assumed. This is in accordance with Stockholm conditions where heating is normally on during day time independently of people being home or not.

NOTE – In a more detailed study it is necessary to consider the GHG emissions related to the potential expansion of the ICT network due to an increase of the data traffic originating from the higher number of users at a city level compared to the pilot. However, due to the relatively small footprint of ICT compared to transport activities such refinements are not expected to change conclusions significantly.

**Making a quantitative scaling for applicable parameters**

Starting from the pilot saving potential of 66 kg $CO_{2e}$ per office employee and year, these numbers should be modified in accordance with the differences in the parameters for which the company results could be recalculated in terms of actual saving per saved trip.

Thus, considering that the emissions per km are d*e, as shown in Table V.4 below, the estimated saving in GHG per commuting trip would be changed by a factor (0.9*0.98) compared to the pilot case, resulting in a saving potential of 58 kg $CO_{2e}$ per employee and year (i.e., slightly lower than the potential per employee in the pilot project).

**Table V.4 – Estimated saving in GHG per commuting trip**

| Parameter | *Parameter value in targeted city* ($P_{target}$) | *Parameter value in reference scenario* ($P_{ref}$) | *Difference* |
|---|---|---|---|
| Average distance to work (d) | x | 0.9x | –10% |
| Average $CO_{2e}$ emission from car (g) | 153 | 150 | –2% |

**Making a qualitative analysis of other parameters**

According to the assumptions of this example the lack of incentives or programmes to deploy the smart work package on a wide scale is likely to reduce its use. However, this effect could not be quantified due to lack of data.

The difference in the factors used for recalculating the potential as outlined above may also impact the probability of users to adopt the smart work solution. This was looked into qualitatively as shown in Table V.5.

**Table V.5 – Qualitative analysis of other parameters**

| Parameter | *Parameter value in targeted city* ($P_{target}$) | *Parameter value in reference scenario* ($P_{ref}$) | *Difference (Note)* | *Assumed importance (Note)* |
|---|---|---|---|---|
| Share of journey to work by car | 48% | 62% | Minor to significant | Somewhat |
| Average time of journey to work (hour) | 0.58 | 0.45 | Minor | Minor |
| Average $CO_{2e}$ emission from car (g) | 153 | 150 | Minor | None |
| NOTE – *In this example these values are based on subjective judgments. Such judgments should preferably be based on previous experience and research.* | | | | |

**Summarize and interpret the results**

Based on the pilot study and the assumptions of this example a reduction potential of 58 kg $CO_{2e}$ per office employee and year was calculated (to be compared with 66 kg per employee and year in the pilot project), corresponding to a yearly overall saving potential of 11 ktonnes $CO_{2e}$ for Stockholm county. For the approximately 200 000 car commuting office workers of Stockholm, the overall reduction potential adds up to 12 ktonnes of $CO_{2e}$. This assumes that e-commuting is applied to the same extent as for the assessed company.

The overall saving potential is proportional to the number of users which is expected to be sensitive to the existence of a programme or incentives.

Also the difference in commuting conditions may impact the adoption of the ICT solutions. However, as shown in Table V.6, this example finds only limited difference in factors that could potentially impact citizens' interest in adopting the solution. As the pilot was deployed within the city this seems like a reasonable result but further studies are needed for more stable conclusions.

**Table V.6 –Commuting conditions impact on the adoption of the ICT solutions**

| **Parameter** | ***Parameter value in targeted city ($P_{target}$)*** | ***Parameter value in reference scenario ($P_{ref}$)*** | ***Difference (Note)*** | ***Assumed importance (Note)*** |
|---|---|---|---|---|
| Average time of journey to work (hour) | 0.58 | 0.45 | Minor to significant | Minor |
| Share of journey to work by car | 48% | 62% | Minor-significant | Somewhat |
| Average $CO_{2e}$ emission from car (g) | 153 | 150 | Minor | None |
| NOTE – *In this example these values are based on subjective judgments.* | | | | |

# Appendix VI

## Example of combined results for households and organizations

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

NOTE – Practitioners should not use values of the examples without further review. Some of the data used in this Appendix is fictitious. The non-fictitious data is based on best effort data collection and might not reflect the latest knowledge or information in areas such as energy consumption of the ICT goods or emission factors used.

This Appendix aims at providing an example of combined results for households and organizations. For detailed reporting on households and organizations refer to Appendix I and Appendix II respectively.

Table VI.1 shows Tier 1 yearly GHG emissions for households and organizations and Figure VI.1 shows the same information in pie chart form.

**Table VI.1 – Yearly GHG emissions (tonnes $CO_2$e) Tier 1**

| Yearly GHG emissions (tonnes $CO_2$e) Tier 1 | | | | |
|---|---|---|---|---|
| **Households** | **non-ICT organizations** | **ICT organizations** | **Public Administration** | **TOTAL** |
| 6 694 | 31 246 | 12 498 | 1 026 | 51 464 |
| 13% | 61% | 24% | 2% | 100% |

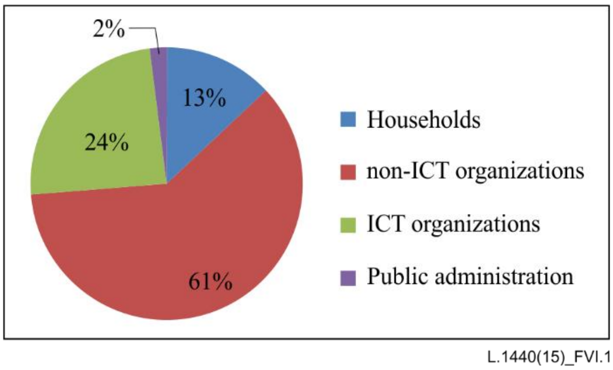


**Figure VI.1 – Yearly GHG emissions (tonnes $CO_2$e) Tier 1**

Table VI.2 shows Tier 2 yearly GHG emissions for households and organizations and Figure VI.2 shows the same information in pie chart form.

**Table VI.2 – Yearly GHG emissions (tonnes $CO_2$e) Tier 2**

| Yearly GHG emissions (tonnes $CO_2$e) Tier 2 | | | | |
|---|---|---|---|---|
| **Households** | **non-ICT organizations** | **ICT organizations** | **Public administration** | **TOTAL** |
| 16 327 | 34 025 | 13 610 | 1 281 | 65 243 |
| 25% | 52% | 21% | 2% | 100% |

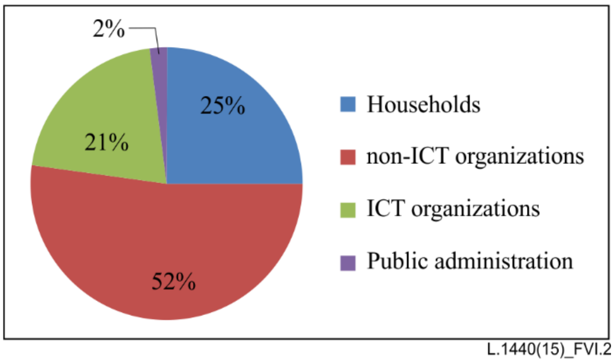


**Figure VI.2 – Yearly GHG emissions (tonnes $CO_2e$) Tier 2**

# Appendix VII

## Example of allocation of the impact of a data centre

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

In a data centre, there are ICT goods such as servers and storages and ICT networks. If the data centre is located within the boundaries of a city, impacts from those ICT goods and networks are assessed according to the prescription in the preceding sections.

Such data centres can be used by not only users within the city boundaries but also users outside the city boundaries. In this case the sources of GHG emissions and energy consumption are located within the city but they also benefit users from outside the city.

Despite this, the assessing city shall take into account all of the impacts of a data centre located within the boundaries of the city and used by households and organizations inside and outside the city boundaries. On the other hand, impacts from data centres located outside the city and used for the city are not allocated to the city.

A typical scenario is a data centre in a city which is frequently used from outside the city. In this case and from an environmental point of view a big data centre in a city, may be a better solution than many small data centres in different locations. The city footprint would increase, but overall emissions would be lower. Thus, the replacement of small less efficient data centres may give a smaller footprint overall. Interpretations like the one above may encourage the city to locate the data centre within its boundaries. To show this effect more directly, impacts of the ICT project should be assessed.

To understand to what extent a specific data centre actually benefits the citizens, the assessment could include some extra calculations. For instance, the city could divide the GHG emissions and energy consumption of the data centres located within the city boundaries and used inside and outside the boundaries into those attributable to users within the city boundaries and those attributable to users outside the city boundaries. The assessing city could report the GHG emissions and energy consumption attributable to users outside the city boundaries separately from the total impacts. The same kind of refinement of results may be applied also to other ICT network goods.

Figure VII.1 shows data centre impacts allocation.

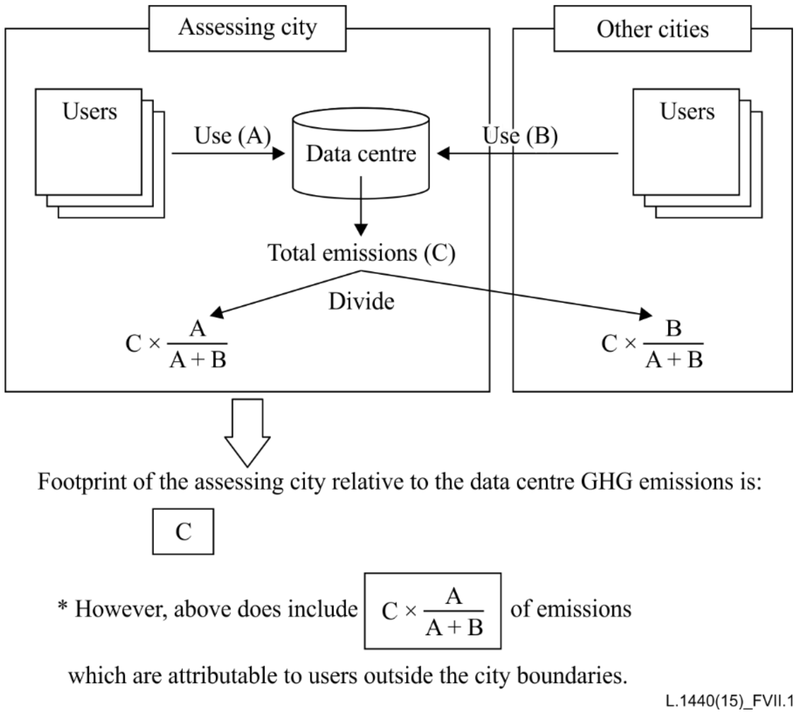


**Figure VII.1 – Data centre impacts allocation**

# Bibliography


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