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

Energy efficiency, smart energy and green data centres

Carbon data intensity for network energy performance monitoring

Recommendation ITU-T L.1333

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

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Recommendation ITU-T L.1333

Carbon data intensity for network energy performance monitoring

Summary

To meet the targets of the Paris Agreement, telecom operators, like other industries, need to set targets for emission reduction to arrive at a net zero situation as reported in Recommendation ITU-T L.1470.

For a situation in which network traffic will increase, this Recommendation defines a key performance indicator (KPI) useful to evaluate network emission and give an indication on how a network can reduce its emission due to energy usage.

Recommendation ITU-T L.1333 defines a KPI called network carbon intensity energy (NCIe); it also defines how to apply the Recommendation: which part of the network is covered and how to calculate the metric continuously in network evolution.

This Recommendation also defines the correlation between the carbon intensity indicator and energy efficiency metric.

The carbon KPI defined in this Recommendation refers to the energy efficiency metric defined in Recommendation ITU-T L.1331.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1333	2022-09-22	5	11.1002/1000/15028

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GHG, NCIe, network.

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FOREWORD

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

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Introduction

In recent years, a significant interest in GHG emission level from industry has been taken. The need to respect the Paris Agreement and carry out the activities linked to the United Nations Sustainable Development Goals are important aims and the possibility of setting of targets for countries and industries to reduce the amount of CO_2 that they emit also exists. As a consequence, it is clear and accepted that telecom operators, like other industries, need to set targets for emission reductions in line with the trajectories put forward in [b-ITU-T L.1470] to arrive at a net zero state as defined by [b-ITU-T L.1471].

To conform with [b-ITU-T L.1470], ICT companies need to reduce their absolute emissions in line with the science-based decarbonization trajectories it describes. Companies are permitted to use intensity metrics, which may be a more practical tool to monitor the development of networks. However, if intensity metrics are used, [b-ITU-T L.1470], [b-ITU-T L Suppl.37] and [b-ITU-T L Suppl.38] state that these metrics need to be checked at regular intervals to ensure that their development does not deviate from the absolute trajectory.

To align with these Recommendations, it is necessary to consider the GHG emissions from the network owner, which is composed by different contributions, in particular those termed scope 1, scope 2 and scope 3, but the preeminent part of the GHG emissions comes from network use. This is linked to the amount of energy used for the operation of mobile and fixed networks, so they need to reduce the energy consumption of their network and the contribution of network operation to the emission of GHGs.

The big challenge is that this reduction must be achieved in a moment in which global consumer data traffic from cellular and fixed broadband networks is expected to grow at a 29% compound annual growth rate (CAGR) between 2018 and 2024. This corresponds to 5.8 million petabytes (PB) of data in 2024 – the equivalent of every person on the planet uploading over 6700 photos per day – up from around 1.3 million PB in 2018. Within cellular networks, the total traffic is expected to grow by a factor of nearly five times over the same period [b-informa].

The amount of traffic will significantly increase, and it is necessary to define indicators to define the increased efficiency in terms of GHG of a network by linking the amount of GHG emitted to the services provided by the network.

Some operators use internal indicators to evaluate their network emission and give an indication of how they are reducing the contribution of the network to their total emissions [b-informa].

A wider set of intensity metrics will be published by ITU-T SG5 in the future.

Recommendation ITU-T L.1333

Carbon data intensity for network energy performance monitoring

1 Scope

This Recommendation defines a KPI for the carbon emission intensity of a network focused on network energy consumption in relation to data traffic. It includes the KPI definition and describes the KPI calculation and methods of measurement of the quantities necessary to calculate the KPI.

The reporting of GHG emissions related to conformity or reporting in relation to [b-ITU-T L.1470] are outside the scope of this Recommendation, as are other related KPIs of potential interest.

A complete assessment of life cycle network GHG emissions is considered by Recommendation [b-ITU-T L.1410].

The network carbon intensity energy KPI is applicable to a complete network greenness assessment. It does not only encourage the reduction of network electricity consumption, but also the use of low-carbon energy supply and the improvement of energy utilization efficiency.

This Recommendation considers only the network operation phase, i.e., network energy consumption.

The Recommendation is applicable to the public telecom network (PTN), non-public network (NPN) and enterprise network.

This first edition of this Recommendation refers to data traffic intensities; however, future editions may include other metrics to describe services, such as the number of user connections.

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.1331] Recommendation ITU-T L.1331 (2022), *Assessment of mobile network energy efficiency*.

[ITU-T L.1450] Recommendation ITU-T L.1450 (2018), *Methodologies for the assessment of the environmental impact of the information and communication technology sector*.

[ETSI ES 202 336-12] ETSI ES 202 336-12 V1.1.1 (2015), *Environmental engineering; Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunications networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model*.

[ETSI ES 203 228] ETSI ES 203 228 V1.4.0 (2022-02), *Environmental engineering (EE); Assessment of mobile network energy efficiency*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 base station (BS) [b-ITU-T L.1330]: A generic term used for a network component which serves one or more cells and interfaces the user terminal (through air interface) and a radio access network infrastructure.

3.1.2 energy [b-ITU-T L.1330]: Capacity for doing work; having several forms that may be transformed from one to another, such as thermal (heat), mechanical (work), electrical or chemical, expressed in Joules. For the purpose of this Recommendation, energy will be expressed in Watt-hours (Wh) or kilo Watt-hours (kWh).

3.1.3 mobile network operator (MNO) [b-ITU-T L.1330]: An operator that manages one or more mobile networks.

3.1.4 power [b-ITU-T L.1330]: The rate at which energy is transmitted. Power is measured in units of Watts.

3.1.5 scope 1 emission [b-ITU-T L.1450]: Greenhouse gas (GHG) emission from sources owned or controlled by an organization.

3.1.6 scope 2 emission [b-ITU-T L.1450]: On site greenhouse gas (GHG) emission from the generation of electricity, heat or steam that has been purchased by the reporting organization.

3.1.7 scope 3 emission [b-ITU-T L.1450]: Any other indirect greenhouse gas (GHG) emissions from sources that are located along the reporting organization's value chain.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 network carbon intensity: The ratio between GHG emissions due to the electricity consumption of all the equipment of all sites of a network during a defined period of normal operation and the total amount of data volume traffic handled by the network during the same period.

NOTE – The preferred measurement period would be one year.

3.2.2 total data traffic: The total amount of data traffic carried over a network or processed through the entire network under consideration.

NOTE – The preferred measurement period would be one year.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BS	Base Station
CAGR	Compound Annual Growth Rate
DSLAM	Digital Subscriber Line Access Multiplier
DVMN	Data Volume of the Mobile Network
ECMN	Energy Consumption Mobile Network
$EE_{MN,DV}$	Energy Efficiency Mobile Network Data Volume
EF	Emission Factor
GHG	GreenHouse Gas
ICT	Information and Communication Technology

IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KPI	Key Performance Indicator
MNO	Mobile Network Operator
NCIe	Network Carbon Intensity energy
NPN	Not Public Network
OLT	Optical Line Termination
PPA	Power Purchase Agreement
PTN	Public Telecom Network
PUE	Power Usage Effectiveness
SEE	Site Energy Efficiency
TB	Terabyte

5 Conventions

None.

6 Defining network carbon intensity energy

To create a link between carbon emissions related to the energy consumption of a network and the network data traffic, the relationship between carbon emission and different sources of emissions needs to be understood as well as the composition of data traffic:

- Three type of energy sources are generally considered:
  - Grid electricity: Most of the energy consumed comes from local grid electricity.
  - Backup energy: A small proportion of energy comes from backup diesel or other types, or from generators such as solar panels.
  - Locally generated energy: energy provided by local generators not used for backup functionality, e.g., solar, wind generator.
- Data traffic: The services provided by ICT infrastructure to society relate to the storage, transport and processing of data. Due to the rapid expansion of network coverage and generation upgrades, the data flow handled by each network device has increased significantly over time.

Current carbon indicators used by leading operators are often expressed as the ratio between carbon emission (or energy consumption) and the amount of data carried (or the number of customers). Absolute carbon reduction targets are also used. However, the degree to which operators use a low-carbon energy supply is not always considered.

Considering that, we define a KPI that meets the following requirements:

- It should include the carbon emissions (GHG) related to the electricity consumption of all sites including both ICT goods and supporting equipment, such as air conditioning and power feeding equipment.
- To avoid results that are sensitive to daily, weekly, and seasonal variations in ICT demand, the KPI measurement should cover a long period of time (preferably 1 year).
- It should include the total data traffic provided during this period, which currently can be measured in bytes of data managed by the network. A future version could use another KPI to describe network performance, such as the number of user connections.

- It should reflect the reduced impact of using a low-carbon energy supply (including local generation) and energy efficient equipment/solutions.

7 Network considered

This Recommendation considers all types of network including mobile networks, fixed networks and transport networks independently whether they are owned by same company or by different companies.

The network types considered are public telecom network (PTN), non-public network (NPN) and enterprise network.

This Recommendation consider only network energy consumption; other sources of GHG emission such as owner maintenance activities are excluded.

The network carbon intensity KPI is more applicable to the realization of a complete network greenness assessment.

8 KPI definition

The network carbon intensity energy (NCIe) KPI is defined according to Equation (8-1):

$$Network\ carbon\ intensity\ \ (NCIe)\ \ \left(\frac{\mathrm{kgCO_2}e}{\mathrm{TB}}\right) = \frac{Total\ Carbon\ Emission\ of\ network\ operation}{Total\ Data\ traffic} \qquad (8\text{-}1)$$

The calculation of NCIe is mainly applicable to the monitoring of the development of performance of the entire network infrastructure under consideration over time.

Given the great variation in function and topology between different types of network infrastructure and technologies and the varying availability of low-carbon energy, the proposed KPI is not suitable for a comparison between different types of network infrastructure; but it is suitable for comparisons between similar network infrastructure in different regions.

It is a suitable benchmark for a particular operator to track over time the evolution of network functionality.

NOTE – The unit TB refers to Terabytes and is equivalent to 2^{40} bytes or 8×2^{40} bits.

The KPI is calculated as shown in Equation (8-2) considering the total energy consumption of the network divided by the amount of data traffic managed by the network:

$$NCIe = \frac{\boldsymbol{E}_{\mathbf{total}}}{\boldsymbol{Total\ data\ traffic}} \times \boldsymbol{EF} = \frac{\sum \boldsymbol{E}_{\mathbf{j}} \times \boldsymbol{EF}_{\mathbf{j}}}{\sum \boldsymbol{Data\ traffic}_{\mathbf{j}}} \qquad (8\text{-}2)$$

In Equation (8-2), total data traffic is the total traffic/volume of the network under consideration in TB.

The emission factor (EF) (kg CO2e/kWh) is the emission factor represented by the mass of carbon emitted per kWh of electricity. In line with [ITU-T L.1450], the EF shall be sourced from recognized public sources and shall consider energy supply chain and distribution losses. Different emissions factors apply for different energy supplies such as grid electricity and local sources such as diesel and solar.

E_{Total} is the total electrical energy from the grid or local generators consumed by the network system during the same period. To distinguish green energy (wind, hydro, solar, etc.) from traditional energy in terms of carbon intensity, the numerator of E_{Total} can be extended as follows considering different sources and different generation types, as shown in Figure 1

$$\mathrm{E_{Total}} = \mathrm{E_1} + \mathrm{E_j} + \mathrm{E_n} \qquad (8\text{-}3)$$

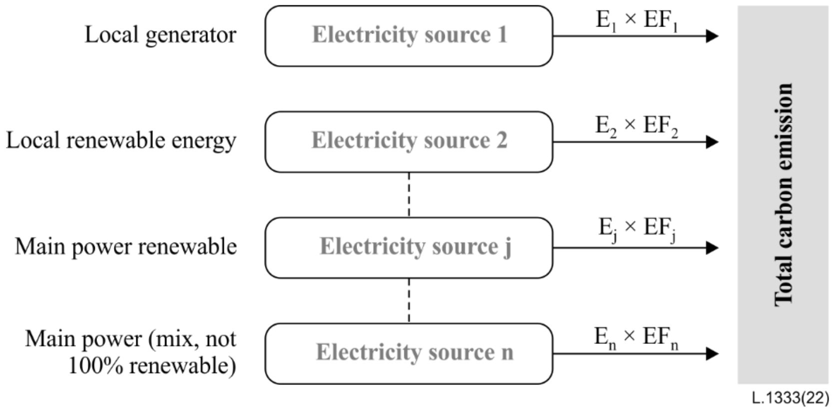

Figure 1 – Composition of E_{Total}

8.1 Carbon emission factor

Equation (8-2) introduces the term EF, which is the carbon emission conversion factor for electric energy that gives the GHG emission for an electricity energy unit depending on the energy mix and type of energy used.

EF (kg CO_2e/kWh) is the mass of carbon emitted per kWh of electricity generated by the grid and auxiliary power generator using traditional energy and green power.

The EF for all three types of energy shall consider the electricity supply chain.

The value of EF_j depends on the electrical energy characteristics utilized. EF_j shall be derived from existing national statistical data available in the country where the network is located or from international data such as that available from the IPCC, IEA or others.

Additionally, not only geographical based EF will be considered but also EF linked to market-based EF corresponding to a power purchase agreement (PPA) or similar contact agreement.

If the network owner purchases renewable electricity, the emission factor shall be referred to as market-based for this share of EF, requiring from the source/supplier of electrical energy the specific emission factors for the electricity purchased. This is described in the [b-GHG protocol].

It is necessary to calculate emissions according to both location-based and market-based methods, in line with the [b-GHG protocol].

In the case of renewable or mixed energy purchased in the market, consideration shall be given to losses occurring during electricity transport and distribution, which also need to be considered in the calculation of the EF.

In the case of renewable energy produced locally on site, the related EF shall be equal to zero considering that losses in power distribution are negligible.

9 KPI calculation

The KPI considers the energy consumption of the network, so it is necessary to monitor the network for a certain amount of time.

The time duration of the measurement shall be one year (365 days).

In cases where the network owner has a need, for their internal consideration, to use a shorter period of calculation, the following periods can be utilized:

- one month (30 days);
- one week (7 days).

The energy measurement shall be derived by monitoring the system on the sites composing the network under consideration or by utility information in cases where real measurements are not available.

In the case of a site with mixed network scope, the same procedure reported above needs to be implemented collecting the information for the equipment present on the site.

The network traffic will be measured at the aggregated point of the user interface; see Figure 2.

In this way, we will measure the real traffic entering and leaving the network received or generated by users that is considered the only real traffic.

In detail, it is proposed to use the monitoring interface of equipment present at these network points.

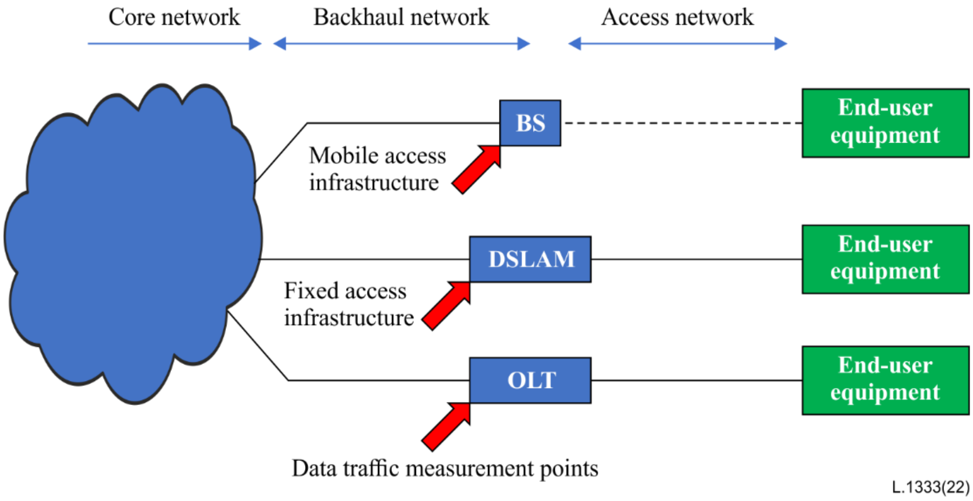

Figure 2 – Data traffic measurement points

For mobile interfaces, the traffic data can be derived from the information provided by equipment as described in [ITU-T L.1331].

For other network types, the measurement point shall be the aggregate traffic at DSLAM or OLT equipment level, depending on the type of user connection.

9.1 NCIe in mobile networks

In cases where there is a mobile network only, it is possible to derive the KPI from the mobile network data-energy efficiency ($EE_{\text{MN,DV}}$) defined in [ETSI ES 203 228] or [ITU-T L.1331]; this is the ratio between the data volume (DV_{MN}) and the energy consumption (EC_{MN}) when assessed during the same time period.

$$EE_{\text{MN,DV}} \left[\frac{\text{bit}}{\text{J}}\right] = \frac{\text{DV}_{MN}}{\text{EC}_{MN}} \tag{9-1}$$

In this case it is possible to start from Equation (8-2) considering (9.1) and the conversion factor form Joule to kWh e and from bit to terabit meaning that NCIe in this case is:

$$NCIe \left(\frac{\text{kgCO2e}}{\text{TB}}\right) = \frac{1}{EE_{\text{MN,DV}}} \times EF \times \frac{8 \times 2^{40}}{3.6 \times 10^{6}} \tag{9-2}$$

The conversion factors necessary to use $EE_{\text{MN,DV}}$ are:

- 3.6×10^{6} Joules = 1 kWh;
- 2^{40} Bytes = 1TB; 8 bits = 1 Byte

More details on $EE_{\text{MN,DV}}$ are available in [ETSI ES 203 228] and [ITU-T L.1331]. Usually, data volume is used as the performance indicator, but with the development of networks, more service types and scenarios will emerge. Besides service volume, service quality also needs to be considered, and the definition of a performance indicator can evolve in future versions of referred standards.

9.2 NCIe in case of fixed and access network only

In this case, the total traffic can be measured at DSLAM or OLT equipment level, depending on the type of user connection.

The measurement shall be derived from information provided by equipment monitoring, in this case the total data volume (traffic) is equivalent to the sum of OLT or DSLAM data traffic.

The energy consumption of different elements composing the network can be derived from the equipment monitoring system in line with [ETSI ES 202 336-12]. In this case E_j, EF_J and $Datatraffic_j$ need to be considered site by site and then summed as reported in Equation (8.2).

Appendix I

From the site KPI to the overall evolution KPI network carbon intensity

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

When it comes to a more detailed and specific level of energy utilization assessment, such as for certain fixed and wireless networks, or data centre cases, there are existing and mature standards to make a targeted evaluation of energy efficiency and carbon emission.

For example, in wireless applications $EE_{MN,DV}$, defined by ETSI and ITU-T as mentioned above, is used to present data-energy efficiency. The index is defined as the ratio between total data volume and total device energy consumption in a wireless network. It represents the data-generation efficiency of a wireless network. The higher the value, the higher energy–data conversion rate the network has.

In addition, there is also a similar index defined by ITU in [b-ITU-T L.1350], called site energy efficiency (SEE) in wireless applications, defined as the ratio between energy consumption from site devices and the total energy consumption of the whole site. This KPI displays what percentage of total energy consumption of one site is utilized by needed functions, e.g., providing data mobile coverage in a certain area.

In data centre cases, power usage effectiveness (PUE) is commonly used to describe energy utilization efficiency. This KPI is the ratio of total energy consumption to its IT energy consumption. It can intuitively present the energy utilization performance of the data centre facility.

Compared with these conventional and specific KPIs for energy utilization, the network carbon intensity KPI is more applicable to a complete network greenness assessment, considering a network in its totality. It not only encourages the reduction of auxiliary electricity consumption, but also the use of green energy sources and improving energy utilization efficiency. For overall green KPI evaluation and horizontal comparison of the macro network, the NCI assessment can be intuitive and reliable.

Appendix II

Calculation of averaged EF

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

In some cases of analysis, it could be useful to consider an averaged carbon factor.

This can be expressed as:

$$EF = \frac{Carbon_{\text{Total}}}{EG_{\text{Total}}} \tag{II.1}$$

Considering the utilization of electricity energy from different sources, the previous formula can be written as:

$$EF = \frac{I_{\text{CarbonperkWh}}}{\eta}(1 - EF_{\text{Green}}) \tag{II.2}$$

where η is the energy efficiency.

Considering the different typology of energy source, with reference to Figure 1, it is possible to write:

$$EF = \frac{\sum_{1}^{n} E_{\text{i}} \times EF_{\text{i}}}{\sum_{1}^{n} E_{\text{i}}} \tag{II.3}$$

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