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TECHNICAL SPECIFICATION

**Access, Terminals, Transmission and Multiplexing (ATTM);
Energy management; Operational infrastructures;
Implementation of Global KPIs;
Part 2: Specific requirements;
Sub-part 3: Mobile broadband access networks**

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

The present document is part 2, sub-part 3 of a multi-part deliverable covering the Energy management; Operational infrastructures; Implementation of Global KPIs, as identified below:

ETSI EN 305 200-1: "General requirements";

ETSI TS 105 200-2: "Specific requirements":

Sub-part 1: "ICT Sites";

Sub-part 2: "Fixed broadband access networks";

Sub-part 3: "Mobile broadband access networks";

Sub-part 4: "Cable Access Networks";

ETSI TS 105 200-3: "ICT Sites";

ETSI EN 305 200-4: "Design assessments".

NOTE: Part 2 of this series has also been produced as EN and ES.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

ICT energy needs and costs will continue to increase in the future, while new mobile generations will be deployed and will introduce new active dedicated equipment in the global network architecture.

In this context, and to reflect environmental aspects of sustainability, it is essential for telecommunications network operators to implement effective general engineering of mobile broadband networks and sites provisioning, managing or using those networks (i.e. ICT sites) in order to respond to critical issues of energy consumption. To guide this process, it is essential that metrics are defined that enable energy usage to be managed more effectively.

The Global Key Performance Indicators (KPIs) of the ETSI EN 305 200 series [1] address operational infrastructures and do not consider design or operation of individual components comprising those infrastructures.

The present document specifies the deployment of Global KPIs for energy management (KPI_{EM}) for the mobile access networks of broadband deployment specified in ETSI EN 305 200-2-3 [2].

NOTE: The data traffic measured in the present document does not account for non-"Subscriber Identity Module" (SIM) traffic. This can be considered in a future revision of both ETSI EN 305 200-2-3 [2] and the present document.

The mobile access network described in ETSI EN 305 200-2-3 [2] includes all the active components or parts of the access network.

1 Scope

The reporting of Global KPIs in accordance with ETSI EN 305 200-2-3 [2] requires the collection of data to enable the calculation of the following aspects:

- Objective KPI relating to task efficiency (KPI_{TE}) based on *data_volume* and total energy consumption (KPI_{EC}).
- Objective KPI relating to the use of renewable energy (KPI_{REN}).

The present document supports the requirements of ETSI EN 305 200-2-3 [2] providing a framework for, and detailing, the implementation procedures including any necessary techniques for estimation of energy consumption together with clarification and treatment of different types of data volume.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI EN 305 200 series: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs".

[2] ETSI EN 305 200-2-3: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 3: Mobile broadband access networks".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 303 472: "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for RAN equipment".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI EN 305 200-2-3 [2] and the following apply:

Access Gateway (AG): gateway that interworks a significant number of analogue lines to a packet network

BaseBand Unit (BBU): mobile access network equipment that processes baseband signal, connected to one or more Remote Radio Units through optical fibre or metallic cabling, or by microwave links

downstream: relative location in the mobile access network in the direction of User Equipment

Fixed Wireless Access (FWA): means of providing internet connectivity that uses wireless network technology rather than fixed lines

fronthaul infrastructure: portion of a mobile access network telecommunications architecture including the intermediate links between the BaseBand Units and Remote Radio Units

Management Information Base (MIB): database allowing management of ICT devices using Simple Network Management Protocol (SNMP)

Mobile Network Operator (MNO): provider of wireless communications services that owns or controls all the elements necessary to sell and deliver services to an end user including radio spectrum allocation, wireless network infrastructure, backhaul infrastructure, billing, customer care, provisioning computer systems and marketing and repair organizations

Multi-access Edge Computing (MEC): network architecture that supports increases in data processing and storage at the edge of the of a mobile access network (closer to end-user) to reduce latency

Remote Radio Unit (RRU): radio transceiver equipment connected to a BaseBand Unit

upstream: relative location in the mobile access network in the direction of an Operator Site

3.2 Symbols

For the purposes of the present document, the symbols given in ETSI EN 305 200-2-3 [2] apply.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI EN 305 200-2-3 [2] and the following apply:

AG	Access Gateway
BBU	BaseBand Unit
FWA	Fixed Wireless Access
MEC	Multi-access Edge Computing
MIB	Management Information Base
MNO	Mobile Network Operator
QoS	Quality of Service
RRU	Remote Radio Unit
SIM	Subscriber Identity Module
SMPA	Switched Mode Power Amplifier
SNMP	Simple Network Management Protocol

4 Global KPIs of ETSI EN 305 200-2-3

4.1 Mobile broadband access networks

The network schematic used in the present document is shown in Figure 1 (amended from that of ETSI EN 305 200-2-3 [2]).

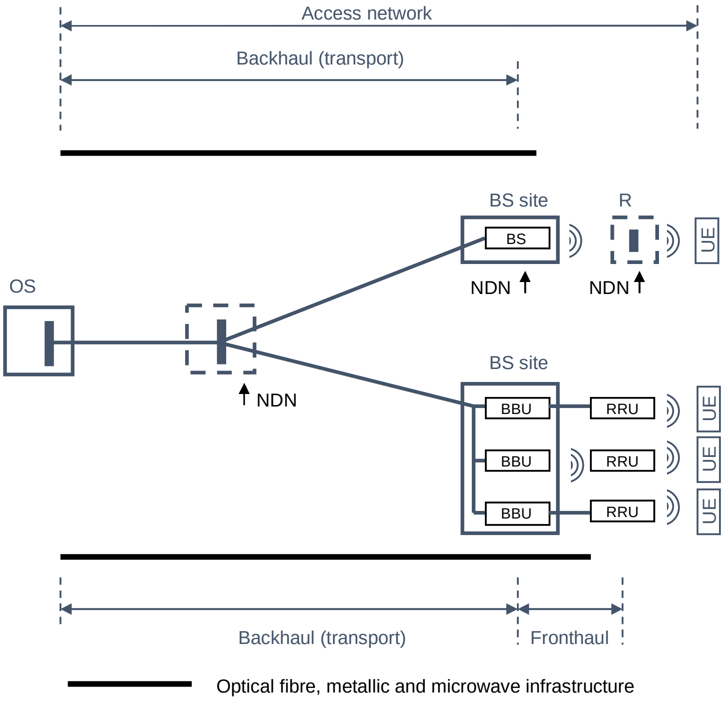

Figure 1: Mobile access network implementations

Within the mobile access network, the term Network Distribution Node (NDN) is employed to describe a variety of aggregations of Network Telecommunications Equipment (NTE) at locations within the backhaul network (also known as transport network) between the Operator Site (OS) and the Base Station site accommodating a Base Station or BaseBand Units (BBU). The BBUs are shown connected over the fronthaul links to Remote Radio Units (RRUs).

BS sites, repeaters (R) and RRUs are shown as specific examples of NDNs.

Figure 1 shows certain NDNs within dashed boxes to indicate that they are:

- optional;
- not restricted in number to the configurations shown.

The present document also considers the use of small cell and Fixed Wireless Access (FWA) implementations.

4.2 KPIs for energy management

4.2.1 Global KPI (KPI_{EM}) for mobile access networks

From ETSI EN 305 200-2-3 [2], KPI_{EM} is a combination of two separate KPIs, in a common assessment period, as follows:

1) the Objective KPI for task effectiveness expressed as KPI_{TE} (see clause 4.2.2.2);

2) the Objective KPI for renewable energy contribution expressed as KPI_{REN} (see clause 4.2.2.3);

and both of these Objective KPIs incorporate a third Objective KPIs for energy consumption expressed as KPI_{EC} (see clause 4.2.2.1).

From ETSI EN 305 200-2-3 [2], KPI_{EM} is defined as:

$$KPI_{TE} = \frac{data\_volume}{KPI_{EC}} \text{ in conjunction with } KPI_{REN}$$

The Global KPI, KPI_{EM}, and the underpinning Objective KPIs are primarily intended for trend analysis - not to enable comparison between mobile access networks.

4.2.2 Objective KPIs

4.2.2.1 Energy consumption (KPI_{EC})

4.2.2.1.1 General

The present document supports the evaluation of the energy consumption required to provide a given level of service as a primary objective.

From ETSI EN 305 200-2-3 [2], KPI_{EC}, for a given assessment period, is defined mathematically as:

$$KPI_{EC} = \sum_{i=1}^{N} C_{OS_i} + \sum_{j=1}^{M} C_{NDN_j}$$

where, for the assessment period:

j = index of NDN sites

N = total number of OS

M = total number of NDN sites

C_{OS_i} = energy consumption of all the mobile access network NTE at OS_i

NOTE 1: C_{OS} includes the energy consumption of the supporting infrastructure at OSs where all the NTE is under common governance.

C_{NDN_j} = energy consumption of all the mobile access network NTE at NDN_j supplied from the utility, from upstream sources or generated on-site

NOTE 2: C_{NDN} includes the energy consumption of the supporting infrastructure at NDNs where all the NTE is under common governance.

The note text in the explanations of the parameters are taken from ETSI EN 305 200-2-3 [2]. However, it should be noted that network and location sharing (see clause 5.2.1.5) implies that not all NTE at OS and NDN sites is under common governance and the present document refines the approach taken in such situations.

The above formula and terms do not take account of equipment that is powered by third parties including small cell (microcell, picocell and femtocell) and FWA equipment powered by the end-user. This is not addressed in ETSI EN 305 200-2-3 [2] and the inclusion of such equipment requires a modification to the above formula (see clause 4.2.2.1.2).

It has to be considered that a mobile access network is complex and consists of a large number of distributed sites accommodating BS and RRU equipment. A typical MNO has many thousand sites, up to tens of thousands. The number of sites is predicted to increase further with the advent of 5G.

KPI_{EC} can be either measured or estimated:

- $KPI_{EC\text{-}measured}$ is the energy consumption obtained through direct measurement by the MNO or electricity supplier, or provided by another MNO if equipment is co-located in the OS or the NDN;
- $KPI_{EC\text{-}estimated}$ is the energy consumption obtained through direct measurement by the MNO or electricity supplier, or provided by another MNO if equipment is co-located in the OS or the NDN.

NOTE 3: This is applied in mixed, "access/core", network sites where equipment of other network segments is present (core, fixed access, etc.) and the energy split is not made through continuous measurement. Estimation is also needed for the energy consumed by network equipment in small cells, powered from CP as described in clause 4.2.2.1.2.

4.2.2.1.2 Small cells in CP, FWA, public WiFi and "street level" equipment within the calculation of KPI_{EC}

For coverage extension, offloading of data traffic and to improve Quality of Service (QoS), operators install small cells near the users' location and propose that end-users acquire service via a cell in their own location. These cells can be deployed in different places such as:

- microcells, typically outdoors, at "street level";
- picocells (typically installed in residential, commercial and industrial premises);
- femtocells in homes or other CP which are connected to, or integrated within, CP equipment;
- WiFi access points for public WiFi service.

The consumption of the equipment or an apportionment relevant to the mobile access network, even if it is not directly accounted for by the MNO, has an integral role in powering the mobile access network and should be part of the KPI_{EC}.

The estimation of this consumption can be made by multiplying the quantity of such equipment by its maximum energy consumption.

The presence of CP powered equipment within the mobile access network requires an amendment of the formula for KPI_{EC} of clause 4.2.2.2.1 as follows:

$$KPI_{EC} = \sum_{i=1}^{N} C_{OS_i} + \sum_{j=1}^{M} C_{NDN_j} + C_{SC}$$

with:

$$C_{SC} = \sum_{k=1}^{P} C_{SC_k}$$

where, for the assessment period:

k = index of small cells

P = total number of small cells under consideration

C_{SC_k} = energy consumption of small cell k

Considering the power needed by small cells varies from a few watts for home equipment femtocells up to 200 W for microcells, the total amount of energy could become significant as the number of such equipment grows dramatically in the coming years. For example, the picocell function integrated within an Access Gateway (AG) can consume up to 25 % of the maximum AG energy consumption (as specified in the equipment's technical specification).

NOTE: This represents the energy portion of the AG to deliver the mobile service and its need to remain always on.

The energy consumption of the TE of FWA services (that can be integrated within the antenna) should also be accounted for.

As a result the total C_{SC} is reported separately (see clause 7).

4.2.2.1.3 Measurement (and estimation) of total energy consumption

As indicated above KPI_{EC} (as either $KPI_{EC\text{-}measured}$ or $KPI_{EC\text{-}estimated}$) is the arithmetic sum of the consumption of all the NTE of the mobile access network, together with the energy consumed by their supporting infrastructure where all the NTE is under common governance. The supporting infrastructure considers powering; cooling; lighting and any further ancillary equipment in the mobile access network sites.

As described in detail in clause 5.2.1, the consumption information sources can be:

- the utility meter, through the fiscal energy billing;
- a sensor and metering network installed by the MNO;
- energy consumption estimation;
- consumption of small cells (see clause 4.2.2.1.2).

Although the primary objective of present document is the evaluation of KPIs of a mobile access network only, in some cases it could prove difficult to apportion the consumption of mixed-use sites, that are hosting both access and core network equipment and even offices for the MNO's employees. This could lead to extensive need to split by estimation of the shares due to the various network segments (see clause 5.2.1.5).

This complexity is going to increase as the Multi-access Edge Computing (MEC) equipment is going to spread across the access network sites. In such a case, in addition to NTE, other infrastructures composed of ITE will be present in the ICT site. In order to simplify the task for the MNO and to improve dependability of the data, it could then be acceptable that the consumption of the MEC ITE equipment, up to that of the whole mobile network is used as KPI_{EC}. The approach chosen on the network boundaries considered will have to be declared in the Reporting Template.

KPI_{EC} is expressed in kWh; the unit for consumption of electricity which is the main source of energy in mobile access networks. Nevertheless, other energy vectors can be part of the total energy consumption such as: diesel oil used in gen-sets that power off-grid, remote sites, natural gas used in high efficiency "combined heat and power" co/tri-generators. The additional use of energy from different sources than electricity has to be converted from the original form into kWh.

Requirements or recommendations in relation to the improvement of the energy consumption of the NTE and support infrastructures are not within the scope of the present document.

It is desirable that the actual energy consumption of all relevant NTE and supporting infrastructure equipment is measured and used to calculate the KPI. However, in situations where direct measurement of the consumption is not possible, the maximum consumption of the equipment contained within the vendors technical specification may be used. This latter approach will result in a generally higher value of KPI_{EC}. This will encourage the implementation of methodologies to enable the direct measurements to be made.

4.2.2.2 Task effectiveness (KPI_{EC})

4.2.2.2.1 General

The present document supports the evaluation of the task effectiveness as a primary objective.

KPI_{TE} is a measure of the data volume transported across the mobile access network per unit of energy consumed by the entire network.

An improvement of KPI_{TE} reflects a reduction of the overall energy consumption required to deliver a given data volume (which is noted by a reduction in KPI_{EC}) and/or an increase in the data volume provided for a given level of energy consumption.

From ETSI EN 305 200-2-3 [2], KPI_{TE}, for a given assessment period, is defined mathematically as:

$$KPI_{TE} = \frac{\sum_{i=1}^{N} data\_volume_i}{KPI_{EC}}$$

where, for the assessment period,

KPI_{EC} = total of $KPI_{EC\text{-}measured}$ and $KPI_{EC\text{-}estimated}$

i = index of BS

N = total number of BSs

$data\_volume_i$ = total data volume at BS_i (which can be measured at the highest hierarchical level which provides clear and unambiguous data)

In order to obtain the total data volume, it is not necessary to measure the data traffic at each BS as an aggregated view of data volume can be obtained by measurement at the core level or other location in the network where data are aggregated.

This represents a wider interpretation to that given ETSI EN 305 200-2-3 [2] which implies measurements at BS locations in accordance with ETSI EN 303 472 [i.1].

4.2.2.2.2 Measurement of data volumes

The measurement of the total data volume transported across the mobile network could be made at different probing points, from each NDN, up to the core network. Nevertheless, measuring at each NDN is quite complex both due to the quantity of equipment involved and the lack of such probing points in legacy equipment. Practical reasons favour the measurement at high level network points (towards the boundaries between access and core network) as they are significantly less numerous and, anyway, in today's network architecture all the mobile data traffic is crossing them. The introduction of MEC will introduce new paths for the data flow as a relevant part of the data served to customers will not cross the core network anymore, but will be limited to the extreme downstream part of the access network. In order to ensure that the data traffic of these future mobile services is accounted for, each MEC installation shall be provided with data flow measurement features.

Some legacy technologies are expressing the traffic in other terms than bit rate. Voice traffic (In GSM or UMTS for 2G and 3G mobile generations) is expressed in "minutes of call". To determine the data traffic contribution of such technologies it is then needed to convert the minutes of calls using the following formulas:

$Traffic_{voice}$ = 22 [kbits/s] x 60 [s/minutes] x $CALL_{million\ minutes.}$ x 2 (bi-directional data flow)

where:

$Traffic_{voice}$ = data volume equivalent (Gbit) of total call time of the mobile access network

$CALL_{million\ minutes}$ = total call time (in millions of minutes) over the mobile access network

NOTE: The "22 [kbit/s]" values comprises the bit rate for the call itself + an additional bit rate for the signalling and framing overhead.

4.2.2.3 Renewable energy (KPI_{REN})

4.2.2.3.1 General

From ETSI EN 305 200-2-3 [2], KPI_{REN}, for a given assessment period, is defined mathematically as:

$$KPI_{REN} = \frac{\sum_{i=1}^{N} C_{OS_i} \times R_{OS_i} + \sum_{j=1}^{M} C_{NDN_j} \times R_{NDN_j}}{KPI_{EC}}$$

where, for the assessment period,

i = index of OS

j = index of NDN sites

N = total number of OS

M = total number of NDN sites

C_{OS_i} = energy consumption of all the mobile access network NTE at OS_i

C_{NDN_j} = energy consumption of all the mobile access network NTE at NDN_j supplied from the utility, from upstream sources or generated on-site

R_{OS_i} = ratio of renewable energy generated on-site at OS_i

R_{NDN_j} = ratio of renewable energy generated on-site at NDN_j

KPI_{REN} is the ratio of energy consumption from renewable sources to the total energy consumption of clause 4.2.2.1. It is a dimensionless number.

Small cells (as described in clause 4.2.2.1.2) are not considered within calculations of KPI_{REN} unless the energy source is under the control of the MNO.

4.2.2.3.2 Measurement of renewable energy consumption

ETSI EN 305 200-2-3 [2] and the present document support the use of renewable energy as a primary objective.

KPI_{REN} is the ratio of energy consumption from renewable sources to the total energy consumption of clause 4.2.2.1. It is a dimensionless number.

Only the sources contributing to KPI_{EC} will be taken into account, whether dedicated or shared.

KPI_{REN} takes account of renewable energy that is produced by:

a) sources dedicated to and directly serving an NDN;

b) sources under common governance with the NDNs they serve and from which it is conveyed by the utility (grid) serving an NDNs in the group defined for the application of the KPI_{EM}.

In the case of b):

- the renewable energy shall not be included within KPI_{REN} of the recipient site if it is already included in the proportion of "green" energy within the energy mix of the utility (grid) supplied to the NDN as defined in European standards or other international schemes;

NOTE: Any proportion in the mix of utility electricity supplies certified as "renewable" (e.g. based on the carbon footprint of the energy source) by electricity suppliers or in accordance with nationally recognized schemes is not recognized by the present document.

- the portion of such energy allocated to the recipient NDN added to other NDN consumptions shall not exceed the overall energy consumption by the NDN.

5 Collection of data

5.1 General

The data collection provides the input for KPI calculation. Data are obtained from different sources at the sites or equipment comprising the mobile access network as described in clause 4.

This clause describes the origin of the data and the way they could be collected.

It is not within the scope of the present document to provide a detailed view of mobile access network equipment (see ETSI EN 303 472 [i.1]). However, some basic information is required to allow the calculation of the Objective KPIs.

Information related to energy consumption can be collected from different sources as described in clause 5.2.1.1.

Once the data are collected by the operator, they will have to be stored in a database to be analysed and sorted for providing the KPIs and help stakeholders in the management and improvement of their energy usage.

A certain level of basic information is required to calculate the different indicators (see clause 4.2.2). Partial information, or a too high level of extrapolation will not give a realistic view of the energy consumption, KPI_{EC}, task efficiency, KPI_{TE}, and renewable energy usage, KPI_{REN}. This will also falsify the results of the global indicator KPI_{EM}.

Figure 2 is a schematic view of data collection and storage which excludes any contribution of energy provided from CPs.

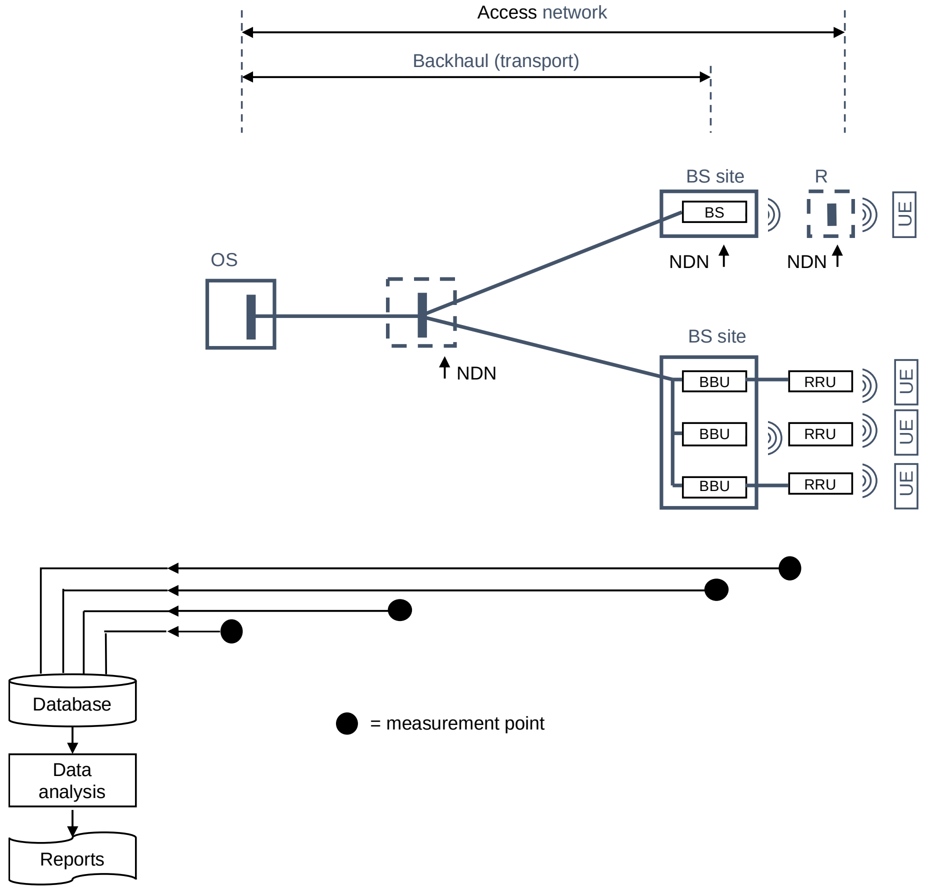

Figure 2: Data collection architecture

Figure 3 is a schematic view of the several steps to produce reporting for the KPIs.

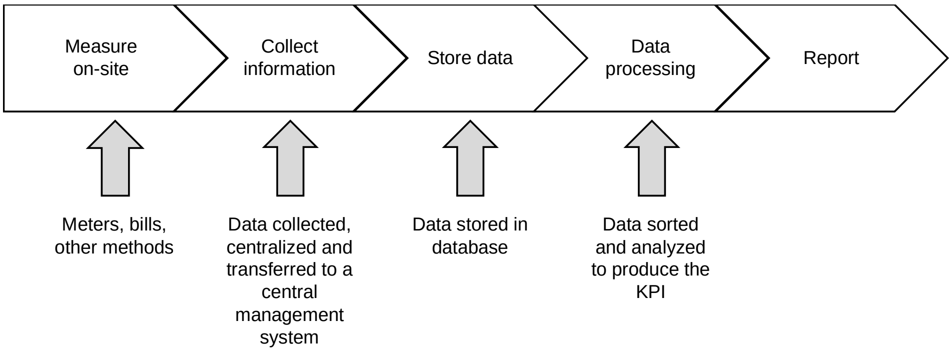

Figure 3: Data processing and reporting architecture

Clause 7 describes a reporting template for the mobile access network KPIs.

5.2 Estimation of energy consumption and renewable content

5.2.1 Energy consumption

5.2.1.1 Overview

The estimation of the energy consumption is given by the KPI_{EC} indicator.

For a mobile access network, composed of thousands of remote sites, the KPI_{EC} for the global access network will be the arithmetic sum of all KPI_{EC}, estimated or measured, for each site (OS or NDN). This is the same for the objective KPI_{REN}. For example, KPI_{REN} will be the quantity of renewable energy which is locally generated at all the sites which are fully or for a part-powered with renewable energy (solar, wind or other).

NOTE 1: Any proportion in the mix of utility electricity supplies certified as "renewable" (e.g. based on the carbon footprint of the energy source) by electricity suppliers or in accordance with nationally recognized schemes is not recognized by the present document.

Figure 4 is a schematic from ETSI EN 305 200-2-3 [2] which has been modified to include the concept of powering of sites from CPs.

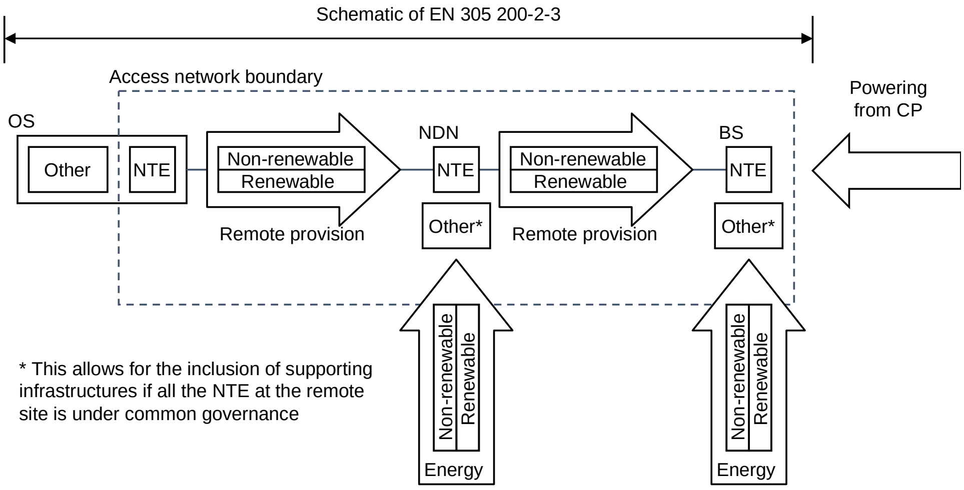

Figure 4: Schematic of mobile access network energy consumption

For an MNO, the large number of sites make it difficult to collect the data to estimate their individual site consumption and efficiency since the deployment of a smart metering solution on each site is very costly.

This clause describes the origin of the data giving some elements in order to evaluate the energy consumption.

For the energy use, data can be collected from different sources such as:

- energy bills from the electricity/gas/fuel supplier (see clause 5.2.1.2);
- proprietary meters installed on sites at different levels in the access network (see clause 5.2.1.3);

NOTE 2: This solution ideally enables full coverage of all sites but the complexity and costs of monitoring the many thousands of sites in a typical mobile access network often force the MNO to only cover a sample of the sites.

- estimation by the MNO, based on samples of typical access network sites (see clause 5.2.1.3). However, this will reflect an approximate view of the energy consumption and usage;
- the equipment itself, if it is equipped with the appropriate mechanism to record data on energy consumption (see clause 5.2.1.4). All equipment at the site, including that for the ancillary services, has to be equipped with such features.

The MNO has to provide the consumptions related to the different points of measurement, for all sites or equipment connected to the grid, and for the renewable part, the global amount of energy generated by the production source.

The information detailed above is meaningful only for dedicated ICT sites since supporting infrastructure consumption is included for KPI_{EC} in such locations. Clause 5.2.1.5 addresses network and location sharing.

5.2.1.2 Energy bills

Most sites connected to the grid are equipped with a meter provided by the electricity supplier. This meter allows the supplier to collect (manually or automatically) the energy consumed during a certain period (typically monthly). The collected information on the consumption are used by the supplier to invoice the customer. The collection, storage and analysis of information given by the bill is generally made by MNO and provides a clear and dependable view of the entire energy consumption of all sites which are connected to the grid.

Similarly, if the site produces energy based on renewable sources and feeds energy to the electricity supplier, this will be separately recorded by the meter used for the Feed-in Tariff. Clause 4.2.2.3.2 specifies how such renewable energy may be included in KPI_{REN} at other sites under common ownership.

5.2.1.3 Meters installed by the MNO (smart metering)

Some MNOs, for various reasons, have deployed their own meters on some, or all, of their sites, together with a software platform to analyse data and produce detailed reporting.

This solution, even if it is the best to know clearly where energy is consumed, is very costly because it needs to deploy, instead of primary meters at the site entrance, some sub-meters in all parts of the sites, for cooling, racks, equipment, etc.

To cover the whole mobile access network, this implies the deployment of thousands of meters and probes. Generally, the MNO limits these solutions to their main ICT sites and a sample of other, typical, access network sites. They then extrapolate to the entire range of access network sites. For such reasons it is normally considered not a practical solution to obtain a dependable information on the exact overall energy consumption of the network.

5.2.1.4 Energy consumption provided by the equipment

Certain equipment such as servers, base stations, even cells, is now able to collect internally information on its own energy consumption and store this information in a Management Information Base (MIB).

NOTE: Older equipment does not implement such features and this option is of limited value for legacy installations.

The MIB can be collected through the network and be managed by a software platform to provide any KPI as defined by the MNO.

This method can be valid to keep track of the consumption of more modern equipment, but is not available for older NDNs and not, normally, for the consumption of the ancillary equipment.

5.2.1.5 Network and location sharing

Mobile infrastructure sharing means the process by which MNOs share their infrastructure to deliver a mobile service to end users.

In the case of the mobile access network, one of the main challenges will be to be in order to split the consumption between several stakeholders, knowing that a great part of the network, the sites, the equipment, could be shared with other MNOs. Usually, the energy meter provided by the electricity company gives a global consumption for the whole site.

Sharing the mobile access network is a widespread policy, and several levels of sharing exist including:

- real estate (field, site, building);
- mast (several operator's RRUs on the same mast);
- mobile access network technologies and components;
- technical infrastructure (energy, cooling);
- core network elements;
- service platforms.

Two main domains of sharing are addressed in the present document.

- Passive sharing: sharing of the passive elements of network infrastructure such as masts, sites, cabinet, power, and environmental control.

  This happens where a BS accommodates equipment for more than one MNO or where a BS is hosted in an OS that provides the BS with power and environmental control.

- Active sharing: sharing of active elements.

In both cases the energy consumption is apportioned among those present by the site owner and the way the energy cost is subdivided is normally defined in the contract between the site owner and the MNO.

The higher levels of sharing (core network elements and service platforms) are not considered in the present document.

5.2.2 Renewable energy

Two different methods are possible to collect data for renewable energy:

- measure the total of energy generated from renewable sources in a site;
- measure the renewable energy consumption of the site (which may differ form that produced at the site).

5.3 Data related to traffic

For KPI_{TE}, (related to measure the data volume transported across the mobile access network per unit of energy consumed by the entire network), the energy consumption depends on two parts.

The first is related to the infrastructure and it is the "fixed" part, typically responsible for major part (50 % to 70 %) of the energy consumption, the other part is linked to the load of the network activity. This amount of energy consumption depends on the traffic and data-volumes generated at the different levels of the network and linked to the type of communication and service offered.

Data volumes are obtained via monitoring probes that can be placed over suitable interfaces within the mobile access network. Depending on their position, these probes allow to data volumes to be captured with various levels of granularity. Probes may take measurements at different levels of the network such as:

- core network (charging and policy servers, gateways);
- OSs;
- NDNs including BSs.

The present document focusses on the measurement of the total aggregated information and there is no requirement for the collection of data from each OS or NDN. However, the introduction of MEC will require each MEC site to be provided with the capability to measure their individual data flow in order to ensure the correct data volume is accounted for.

5.4 Clarification of data

There are two different types of data which are basic to KPI_{TE} calculation:

- energy consumption: all data containing information on the energy consumed or any energy generated by renewable sources;
- data-traffic: all data containing information on the volumes of information (uplink and downlink) exchanged on the network between the UE and the BS (see Figure 1).

Each type of data refers to one or more objectives indicators (KPI_{EC}, KPI_{TE}, KPI_{REN}). The data will have to be identified to provide the appropriate information for the calculation method of the KPIs:

- data related to energy consumption as input for KPI_{EC};
- data related to renewable energy generated as input for KPI_{REN};
- data related to traffic volumes as input for KPI_{TE}.

6 Trend analysis

6.1 Overview

Mobile access networks have developed significantly over recent years and offer data-oriented services that include, in addition to voice communications, multimedia communication, online gaming, high-quality video streaming, and many other future services needing increasing bandwidth and generating substantial growth of traffic on the mobile access network. The number of mobile subscribers has also increased forcing MNOs to deploy more and more BS to serve the demand.

Each new generation of network requires a new infrastructure to be deployed. The number of network components to be exchanged in such a programme together with the new features provided by equipment increases the energy consumption of the network.

NOTE: For a period of time, the existing and new networks co-exist to maintain legacy service provision which can further increase energy consumption.

However, this increase is balanced by the effectiveness of the new equipment in terms of ratio of kbps/W which has been multiplied by more than 1 000 over the last thirty years (see Figure 5).

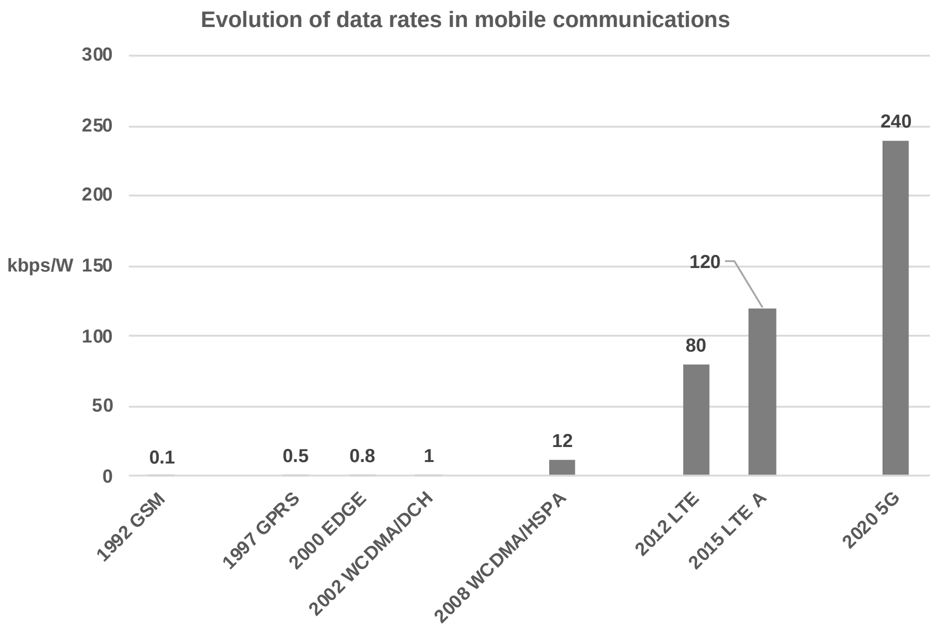

Figure 5: Growth of traffic data rate per W

Considering that each new mobile generation is associated with an increase of the total energy needs to guarantee the service. Each new generation of mobile access network exhibits an improved efficiency and can affect positively the KPI_{TE} by offering a higher ratio of kbps/W.

The energy consumption of the mobile access networks can be reduced by one of more of the following:

1) the use of more energy efficient hardware - reducing KPI_{EC} and increasing KPI_{TE} of BS equipment;

2) the increased adoption of renewable energy systems as main power sources for BSs, where relevant - increasing KPI_{REN};

3) the intelligent management of the network elements in operation, management and deployment (such as the application of sleep mode features described in clause 6.3) based on traffic load variations and geographical considerations.

6.2 Renewable energy sources

BSs could be supplied in part or in full using the renewable energy. Different ways to generate renewable energy to supply Access Networks sites are presented in Annex A.

Currently, the most important part of renewable energy in mobile access network is the use of solar photovoltaic panels for energy generation for BS sites. This has the advantage of being easy to deploy in many different countries and regions.

Some electricity suppliers propose to acquire via the grid energy with a guarantee of "green" renewable sources. Both ETSI EN 305 200-2-3 [2] and the present document do not consider this aspect.

Renewable energy powered cellular BSs are a relevant solution for the mobile access network in the following conditions:

- "off-the-grid" areas;
- regions that suffer from frequent power cuts;
- optimal climatic conditions for solar and wind energy generation;
- proximity of a river, torrent, sea current, tides for hydraulic energy generation (see note);

- possibility to obtain vegetal or animal wastes, generally in rural areas for energy generation from biomass (see note).

NOTE: This solution is generally at an experimental state but will certainly become more deployed in the future due to their potential yield.

Renewable energy sources can only produce electricity when some conditions are respected. To avoid power cuts, it is usually coupled with a backup source (grid or generator) or in most cases, batteries which can assume the service continuity during non-production hours or days.

6.3 Intelligent management

The deployment of many BSs to cover quite small dense areas could make "sleep mode" a solution to save significant energy.

For example, a large business district in a city with a deep coverage in terms of BS, due to the needs during the working hours, will see significant reduction in activity at night and at weekends. In such a case, for these BSs, the sleep mode is relevant. This approach conserves energy by monitoring the traffic load in the network and deciding appropriate times to switch off/on certain elements of the network, such as power amplifiers, signal processing units, cooling equipment, the entire BS. However, a minimum number of BSs shall remain "on" to support the basic operations.

As sleep mode techniques are based on the current architecture of BSs, they can be easily implemented, and they do not need replacement of physical components.

By reduction of the distance between the UE and BS it possible to increase data rate and reduce the power thereby improving the energy efficiency of communication.

The deployment of small cells and heterogeneous networks increases energy efficiency by decreasing the propagation distance between UE and BS.

A significant amount of energy and traffic capacity can be saved by deploying micro BSs in consideration of other network design parameters. Integrating the deployment of small cell BSs using sleep mode schemes can save a large amount of energy. Turning the transceivers on and off to be in line with the variations of traffic demand can also reduce energy consumption.

Using sleep modes to reduce the total energy consumption in mobile access networks is generally preferred because they are software features and do not require the replacement of physical components and therefore have a low implementation cost. These features shall only be automatically activated when needed.

6.4 Summary of possible actions to improve KPI_{EM}

Each new generation of mobile access network represents a step-change in energy performance. However, within each generation, improvements in equipment design, changes to network deployment and the application of software features provide ongoing opportunities for the improvement of KPI_{EM}.

Table 1 summarizes the different techniques to improve KPI_{EM} by the reduction of energy consumption.

KPI_{EM} can also be improved by the use of renewable energy which also reduces carbon footprint and operating expenditure. The opportunity for this depends upon climatic/meteorological conditions at the location of the ICT site and the type of renewable energy source but can involve high capital expenditure.

Table 1: Techniques for improvement of KPI_{EM}

Approach	Energy savings	Advantages	Considerations
Improved power amplifier design	Up to 85 % of the power amplifier consumption, dependent on specific design.	Significant savings when using certain technologies such as switched-mode power amplifiers.	High capital expenditure to replace power amplifiers.
Network operations and management	Up to 50 % in certain areas. Dependent on the number of BS placed in sleep mode (and the duration of sleep mode).	Easy to implement. East to test.	Coverage and QoS.
Network deployment	Up to 60 %.	Low implementation costs. Significant savings.	Inter-cell interference. Resource management. QoS and complexity.

6.5 Reporting of trend data

KPI_{EM} represented by the combination of KPI_{TE} or KPI_{REN} is a measure of the energy management across an entire mobile access network. MNOs can demonstrate their commitment to improving the energy management by highlighting trends in the measured values of KPI_{TE} or KPI_{REN}.

However, certain operational decisions can mask the true energy performance of the network by effectively "outsourcing" energy consumption to third party.

An example of this would be a move towards the use of shared infrastructures at ICT sites and NDNs. This could produce a significant improvement in KPI_{TE} which could overwhelm both smaller improvements, or even reductions, in energy performance elsewhere.

See clause 7 for reporting requirements.

7 Reporting templates

As specified in the ETSI EN 305 200-2-3 [2] the following values shall be reported for the mobile access network for which the KPI_{EM} has been determined using the template of Table 2:

- T_{KPI}: the period of time over which the Objective KPIs are assessed;
- T_{REPEAT}: the time between which the Objective and Global KPIs are assessed to determine relevant trend information;
- Δt: the maximum time variation between measurement points of the different Objective KPIs within a given Global KPI.

In view of the two options for the assessment of energy consumption the KPI_{EC} shall be reported as either:

- $KPI_{EC\text{-}power}$: Objective KPI of energy consumption if any OS or NDN measurements are based on power rather than energy;

or

- KPI_{EC}: Objective KPI for energy consumption (indicated as either $KPI_{EC\text{-}measured}$ or $KPI_{EC\text{-}estimated}$).

In addition, the existence of small cells being powered by CP requires the separate reporting of the total energy consumption C_{SC} (see clause 4.2.2.1.2) in addition to its inclusion in $KPI_{EC\text{-}power}$.

The report shall also include any relevant business information which serves to explain any trends in the Global KPI (as either KPI_{TE} or KPI_{REN}) which the report highlights. Such information includes, for example, a significant move towards shared infrastructure which improves KPI_{TE} as described in clause 6.5.

Table 2: Template for mobile network report

Mobile network	Name, designation, etc.
Assessment date	**End date of assessment**
Foundations	**Value**
Δt	To be determined by the MNO
T_{REPEAT}	To be determined by the MNO
T_{KPI}	To be determined by the MNO
N (total number of OS)	To be completed by the MNO
M (total number of NDN)	To be completed by the MNO
P (total number of small cells powered by CP)	To be completed by the MNO
Baseline data	**Value**
KPI_{EC} as either $KPI_{EC\text{-}measured}$, $KPI_{EC\text{-}estimated}$ or $KPI_{EC\text{-}power}$	Calculated
C_{OS} (energy consumption of the MNO NTE at all the OSs)	Calculated
C_{NDN} (energy consumption of the MNO NTE at all the NDNs supplied from the utility, from upstream)	Calculated
C_{SC} (total energy consumption of all the small cells supplied from downstream CPs)	Calculated
Total data volume	Calculated
KPI results	**Value**
KPI_{REN}	Calculated
KPI_{TE}	Calculated

Annex A (informative): Mobile access networks and energy

A.1 Network energy consumption and supply

The mobile access network delivers communications between the BSs and the UE and includes the following equipment:

- BSs;
- RRUs;
- small cells (microcell, microcells, picocells and femtocells);
- functional elements within fronthaul and backhaul links;
- other active equipment such as repeaters, etc.

As shown schematically in Figure 1, the first generations of mobile access networks (2G, 3G), BSs were usually located on the same site as the cells and the RRUs, both in outdoor and indoor sites. Current and future network technologies, BSs (physical or virtual) are or will be centralized in sites, which could be OS, Points of Presence, BBU in order to distribute the network to a great number of remote cells.

The energy consumed by the great majority of urban and rural sites is provided by the grid. Operators or third party stakeholders providing facilities and accommodation for sites are searching to introduce renewable energy solutions in order to decrease operating expenditure by generating a part of the energy needed.

Table A.1 presents some existing solutions of renewable energy sources that are or could be used to supply energy for the access network. Some of them are already deployed by operators in part of their networks, some others are currently experimental solutions, but could be relevant solutions for the future.

Table A.1: Renewable energy source solutions

Renewable energy sources	Yield	Location	Types of ICT sites or equipment	Type of supply
Solar (photovoltaic) panels	Dependent on solar conditions	Urban or rural areas	NDN, BS, Cells, WiFi hotspots, sensors	Primary, backup
Windmills	Dependent on wind conditions	Urban or rural areas	OS, NDN, BS, Cells,	Primary, backup
Fuel cells	24h/24	Urban or rural areas	OS, NDN, BS, Cells,	Primary, backup
Hydraulic turbines	Possibly 24h/24 dependent on location	Rural areas	BS, Cells,	Primary
Gas turbines (methane)	Possibly 24h/24 dependent on location	Rural areas	OS, NDN	Primary
Primary batteries (non-rechargeable)	24h/24	Urban or rural areas	Sensors	Primary

A.2 Energy consumption trends

The data collected by means of the annual reports and other information obtained during the processing of that data will generate the set of KPIs defined in present document. In addition to presenting the information in tabular form, it can be useful to represent them in graphical form so to enable visual trend analysis.

Examples for such representations are given in the Figure A.1 to Figure A.6. These figures are provided as pure guidance only and should not be considered as having any implication for the MNOs that will apply the present document.

The historical data in Figures A.1 to A.6 come from trend information MNOs such as sustainability reports and conference papers. The data for the 2020-2030 periods are based public internet traffic forecasts and network development trends. They are included for guidance for possible evolution due to the appearance of new technologies (e.g. 5G) or to the removal of legacy ones (e.g. 2G and 3G). The development of small cells, often installed at the CPs, will rely on customer providing the necessary power. The impact on the consumption at the CPs has been taken into account.

Figure A.1 shows the exponential growth of data volumes. The share due to voice calls, one dominant, has become marginal and is due to disappear as the 2G and 3G platforms have come of age and are will be removed in the next decade. In addition, the frequencies will be re-framed for 5G. Then the voice traffic of mobile access networks will be directly originated as VoIP.

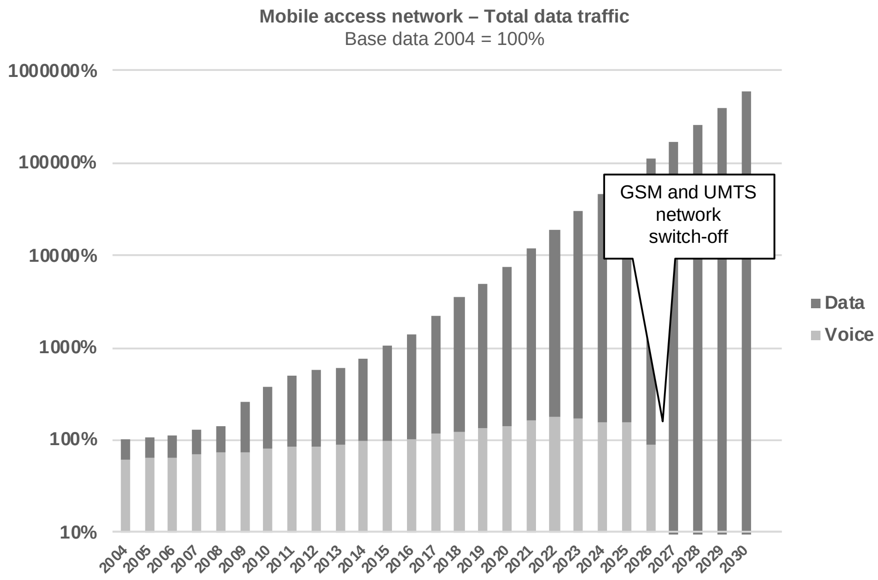

Figure A.1: Trends in data volume

Figure A.2 shows the historical, non-regular, behaviour of the yearly increase of the data volume. Such irregularity is due to the various phases of development of mobile access technologies and to the advent of more data-hungry services, such as video streaming.

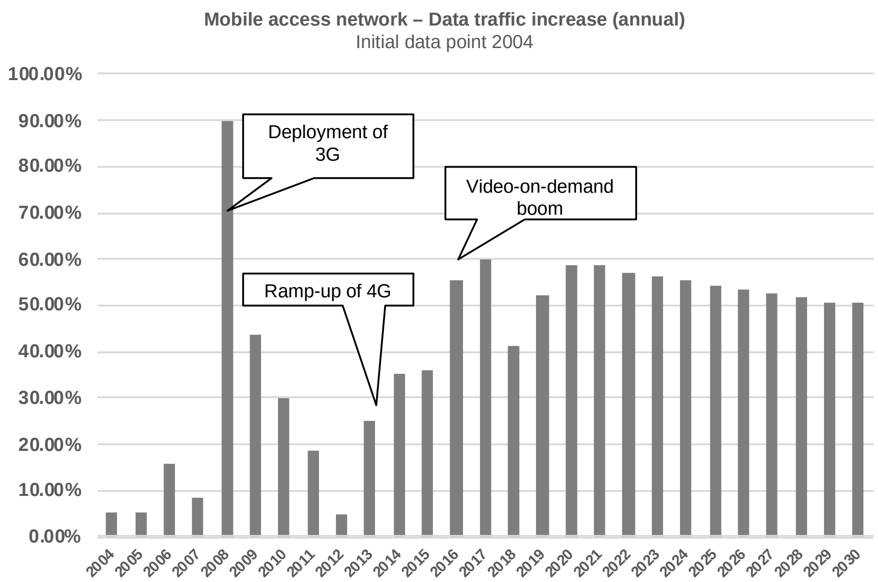

Figure A.2: Trends in data volume increase (annual)

As shown in Figure A.3, the energy consumption of mobile access networks exhibits a step increase each time a new network technology is installed. MNOs try to counterbalance such increases with efficiency actions. One of such efficiency actions has been the replacement of the older equipment of 2G and 3G networks with more modern and efficient ones. The switch-off of the earlier generations will produce a major energy consumption reduction. The development of 5G will produce a remarkable additional energy load, both directly at the MNO and at the customer premises where most of the small cells are going to be installed.

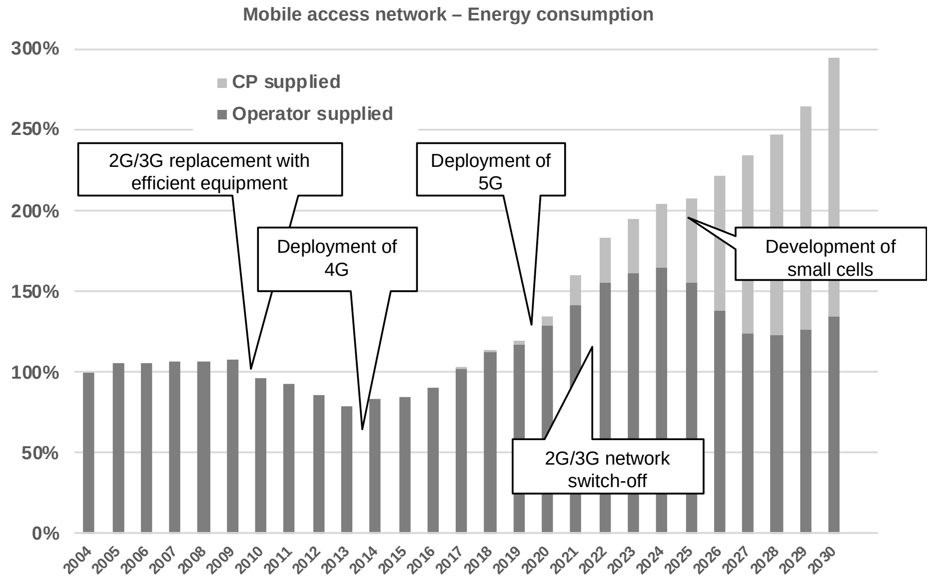

Figure A.3: Trends in energy consumption and sourcing

As shown in Figure A.4, in the past, only a substantial fraction of the energy consumption of the mobile access network was estimated as the energy load of the BSs hosted in fixed network central offices was not directly sub-metered. Since then, that percentage has reduced. For the future it is foreseeable that the amount of estimated energy load will grow, mainly due to the user powered small cells.

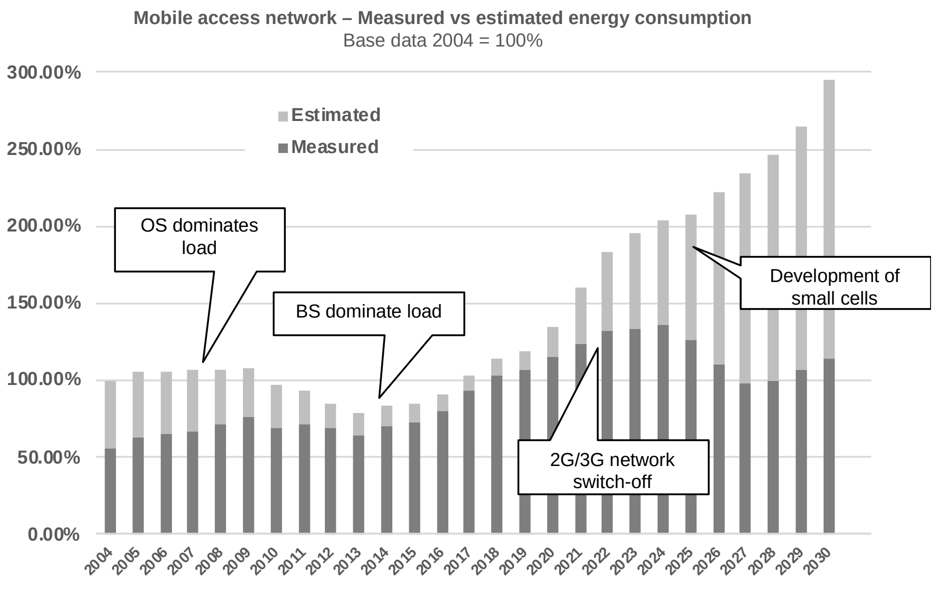

Figure A.4: Trends in energy consumption and sourcing

As shown in Figure A.5, the dramatic increase in the amount of data delivered, while the energy consumption has remained nearly constant, has produced an enormous growth of KPI_{TE}. Such trend is expected to be maintained in the next decade also.

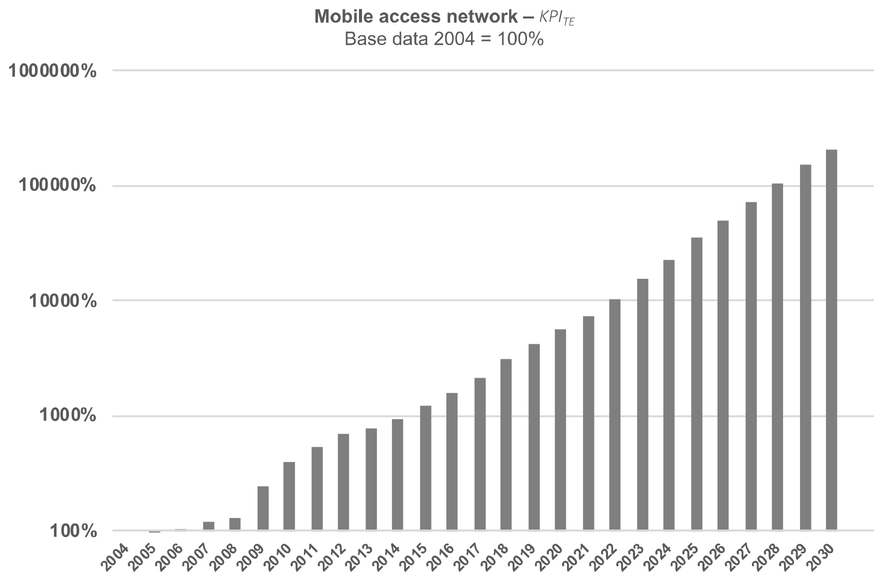

Figure A.5: Trends in KPI_{TE}

As shown in Figure A.6, the yearly progress of KPI_{TE}, is expected to generally follow the incremental rate of the data traffic.

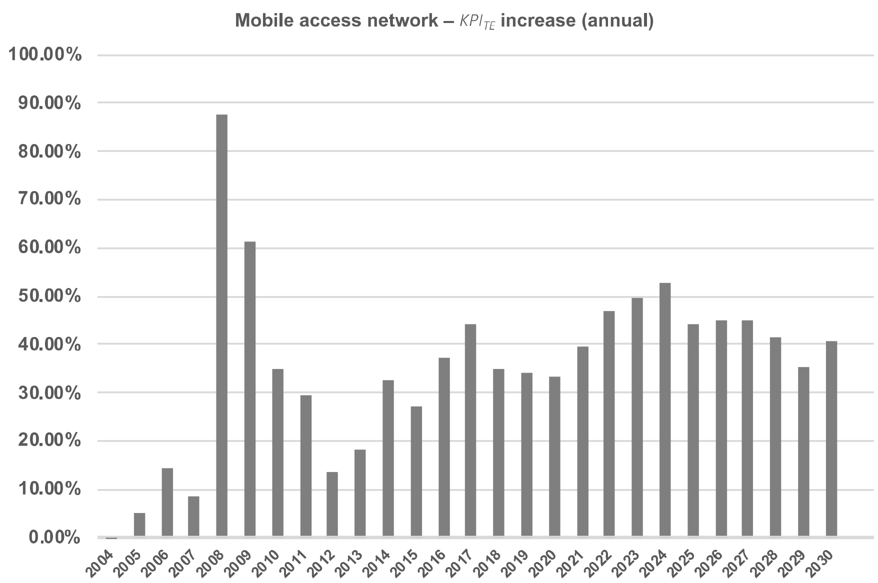

Figure A.6: Trends in KPI_{TE} increase (annual)

Annex B (informative): Change History

Date	Version	Information about changes
05-2019	0.0.1	First formal WD for circulation and comment
05-2019	0.0.2	Second formal WD for circulation and comment
05-2019	0.0.3	Third formal WD for circulation and comment
06-2019	0.0.4	Fourth formal WD for circulation and comment prior to stable draft
29/07/2019	0.0.5	Stable draft

History

Document history		
V1.1.1	June 2018	Publication as ETSI EN 305 200-2-3
V1.2.1	December 2019	Publication