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**Environmental Engineering (EE);
Energy Efficiency measurement methodology
and metrics for RAN equipment**

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Foreword

This European Standard (EN) has been produced by ETSI Technical Committee Environmental Engineering (EE).

National transposition dates	
Date of adoption of this EN:	25 September 2018
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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

Energy efficiency has been seen to be a critical issue for telecommunication systems in relation to environmental impact and operational cost.

Within a radio access network (RAN), energy consumption is dominated by the base stations (BSs), the support infrastructure at the BS sites and repeaters (where used).

The key Performance Indicators (KPIs) and the associated measurement processes defined in the present document are used to reflect the operational energy efficiency of a radio access network and supporting infrastructures as specified in the scope.

The present document is related to the following documents:

- ETSI ES 203 228 [1] - addressing energy consumption and efficiency measurement of operational radio access networks using small samples (RAN);
- ETSI ES 202 336-12 [2] - addressing energy consumption monitoring of ICT equipment in telecommunications networks;
- ETSI ES 202 706-1 [i.1], and ETSI TS 102 706-2 [i.2] - addressing energy consumption and efficiency measurements of base stations in the laboratory.

1 Scope

The present document specifies Key Performance Indicators (KPIs), and associated measurement processes, which reflect the operational energy efficiency of the following digital cellular RAN equipment and supporting infrastructures:

- integrated BS;
- distributed BS;
- BS site.

Repeaters are not considered in the present document but are considered for further study (ffs).

Energy consumption of user equipment (UE) is outside the scope of the present document, however, how a user equipment (UE) affects a base station energy performance is considered for further study.

The KPIs specified:

- combine the energy consumption (in the form of electricity) with the volume of data processed;
- combine the energy consumption (in the form of electricity) with the coverage area served;
- are applicable to the above equipment and also, in certain cases, to the sites accommodating the equipment;
- are primarily intended for trend analysis - not to enable comparison between individual BSs unless the conditions of operation are "similar".

The present document specifies KPIs that are only applicable to BS sites supporting a single operator network. KPIs for shared BS and BS site between two operators or more is considered for further study.

The RAN equipment addressed by the present document supports the following RANs, amongst others, both individually and in combination:

- UTRA, WCDMA (IMT-2000 Direct Spread, W-CDMA, UMTS);
- E-UTRA, LTE (IMT-2000 and IMT advanced);
- GSM (IMT-2000 SC, Technology GSM/EDGE).

KPIs for future RAN technologies such as 5G will be considered for future version of the present document once appropriate specifications are completed.

The present document does not define target values for the energy consumption nor the energy efficiency of the equipment for which KPIs are specified.

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 ES 203 228: "Environmental Engineering (EE); Assessment of mobile network energy efficiency".

- [2] ETSI ES 202 336-12: "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model".
- [3] ETSI TS 123 203: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Policy and charging control architecture (3GPP TS 23.203)".
- [4] ETSI TS 132 412: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM) Integration Reference Point (IRP): Information Service (IS) (3GPP TS 32.412)".
- [5] ETSI TS 132 425: "LTE; Telecommunication management; Performance Management (PM); Performance measurements Evolved Universal Terrestrial Radio Access Network (E-UTRAN) (3GPP TS 32.425)".
- [6] ETSI TS 125 306: "Universal Mobile Telecommunications System (UMTS); UE Radio Access capabilities (3GPP TS 25.306)".
- [7] ETSI TS 136 306: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities (3GPP TS 36.306)".
- [8] ETSI TS 136 214: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements (3GPP TS 36.214)".

2.2 Informative references

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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 ES 202 706-1: "Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power Consumption - Static Measurement Method".
- [i.2] ETSI TS 102 706-2: "Environmental Engineering (EE); Metrics and Measurement Method for Energy Efficiency of Wireless Access Network Equipment; Part 2: Energy Efficiency - dynamic measurement method".
- [i.3] ETSI TS 132 405: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM); Performance measurements; Universal Terrestrial Radio Access Network (UTRAN) (3GPP TS 32.405)".
- [i.4] ETSI TS 152 402: "Digital cellular telecommunications system (Phase 2+); Telecommunication management; Performance Management (PM); Performance measurements - GSM (3GPP TS 52.402)".
- [i.5] ISO/IEC 17025: "General requirements for the competence of testing and calibration laboratories".
- [i.6] Recommendation ITU-T L.1350: "Energy efficiency metrics of a base station site".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

backhaul infrastructure: functional elements connecting a base station to an operator site

Base Station (BS): network telecommunications equipment (NTE) which serves one or more cells within a coverage area of a mobile access network

Base Station (BS) site: network distribution node (NDN) which accommodates a base station (BS)

core network: functional elements (that is equipment and infrastructure) that enable communication between operator sites (OSs) or equivalent ICT sites

energy efficiency: relation between the useful output (telecom service, etc.) and energy consumption

extended base station site: base station site which is served under typical operating conditions by on-site generation of electricity

Information Technology Equipment (ITE): equipment providing data storage, processing and transport services for subsequent distribution by network telecommunications equipment (NTE)

mobile access network: See radio access network.

Network Distribution Node (NDN): grouping of NTE equipment within the boundaries of an access network providing distribution of service from an operator site (OS)

NOTE: Where all the network telecommunications equipment (NTE) at a given location is under common governance, any supporting infrastructure for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability is included as part of the NDN.

Network Telecommunications Equipment (NTE): equipment between the boundaries of, and dedicated to providing direct connection to, core and/or access networks

Operator Site (OS): premises accommodating network telecommunications equipment (NTE) providing direct connection to the core and access networks and which may also accommodate information technology equipment (ITE)

NOTE 1: An operator site that is only connected to the core network is considered as a network data centre.

NOTE 2: An operator site of a cable access network may be termed a local head-end.

Radio Access Network (RAN): telecommunications network in which the access to the network (connection between user equipment and network) is implemented over the air interface

NOTE: Part of GERAN, UTRAN or E-UTRA networks defined by 3GPP.

renewable energy: energy from renewable sources" as energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases

repeater (R): device with two RF ports, both of which are intended to be connected to antennas, which is capable of receiving, amplifying and transmitting simultaneously in one direction a signal in a base station's transmit band and in the other direction a signal in the corresponding base station's receive band

user equipment (UE): device allowing user access to the services provided by the mobile access network

NOTE: Examples of user equipment include a mobile phone, tablet, data modem and connected devices such as meter or actuator.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

DV_{MN}	Data volume
E_{BS}	Energy consumption of an individual BS
$EL_{non-renewable\ grid}$	Energy in the form of electricity from non-renewable sources within the utility (grid) supply consumed by an extended BS site over a given period
$EL_{non-renewable\ on-site}$	Energy in the form of electricity from non-renewable sources produced at, and consumed by, an extended BS site over a given period
EL_{tot}	Total energy in the form of electricity consumed by an extended BS site over a given period
$EL_{renewable\ grid}$	Energy in the form of electricity from renewable sources within the utility (grid) supply and consumed by an extended BS site over a given period
$EL_{renewable\ on-site}$	Energy in the form of electricity from renewable sources produced at, and consumed by, an extended BS site over a given period
$KPI_{EE-capacity}$	Energy efficiency KPI related to capacity
$KPI_{EE-coverage}$	Energy efficiency KPI related to coverage area
$KPI_{EE-site}$	Energy efficiency KPI related to base station site
$KPI_{REN-onsite}$	Energy efficiency KPI related to renewable electrical energy provided by an extended base station site
$KPI_{REN-tot}$	Energy efficiency KPI related to renewable electrical energy provided at an extended base station site

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3 rd Generation mobile Partnership Project
BS	Base Station
CDMA	Collision Detection Multiple Access
CN	Core Network
CS	Circuit Switched
DL	DownLink
DV	Data Volume
DVMN	Data Volume of the Mobile Network
ES	ETSI Standard
E-UTRA	Evolved UMTS Terrestrial Radio Access
ffs	for further study
GERAN	GSM/EDGE Radio Access Network
HSPA	High Speed Packet Access
ICT	Information and Communications Technology
IMEI	International Mobile Equipment Identity
IMT	International Mobile Telecommunications
IP	Ingress Protection classification
ITE	Information Technology Equipment
KPI	Key Performance Indicator
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MNO	Mobile Network Operator
NDN	Network Distribution Node
NTE	Network Telecommunications Equipment
OS	Operator Site
PS	Packet Switched
QoS	Quality of Service
R	Repeater
RAB	Radio Access Bearer
RAN	Radio Access Network
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control
RRH	Remote Radio Head
RRU	Remote Radio Unit or module

RSRP	Reference Signal Received Power
RSSI	Received Signal Strength Indication
SINR	Signal to Interference and Noise Ratio
UE	User Equipment
UL	UpLink
UMTS	Universal Mobile Telecommunication Service
UTRAN	UMTS Terrestrial Radio Access Network
WCDMA	Wideband Code Division Multiple Access

4 Base station (BS) site and BS configurations

4.1 Mobile/radio access network

Figure 1 shows an core network site (CN) connected to a base station (BS) at a BS site via a backhaul infrastructure.

BS sites are described in clauses 4.2 and 4.3. BS configurations are described in clause 4.4.

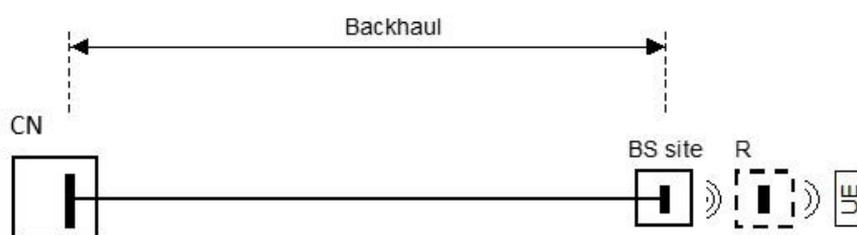


Figure 1: Simplified network schematic

In certain circumstances the coverage area of a BS may be extended by the use of a repeater (R). The present document addresses the energy efficiency of the BS together with the BS site in certain circumstances. The impact of repeaters on energy efficiency of networks is for further study (ffs).

Clause 5 specifies KPIs for the BS ($KPI_{EE-capacity}$ and $KPI_{EE-coverage}$) and for both a BS site and an extended BS site ($KPI_{EE-site}$, $KPI_{REN-tot}$ and $KPI_{REN-onsite}$).

4.2 Base station (BS) site

As shown in the schematic of Figure 2, a BS site accommodates the following:

- one or more groups of network telecommunications equipment (NTE) providing the function of a radio access network (RAN); A detailed description of BS is present in ETSI ES 203 228 [1];
- site support equipment (all additional equipment which is installed at the site to provide additional functionality, including power backup, air-conditioning, lights, security system, etc.).

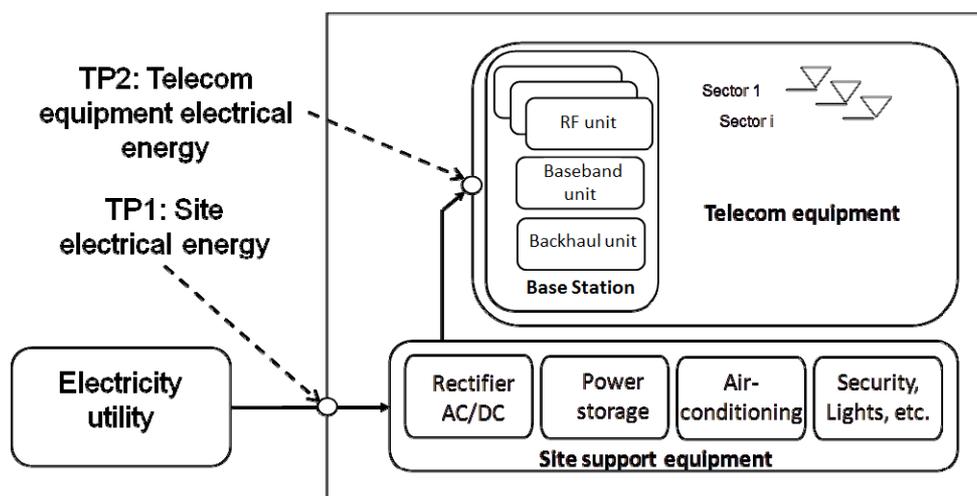


Figure 2: BS site configuration and equipment classification

A site may support multiple, separate, groups of components each of which comprises an individual BS, may serve different networks and be under separate governance from each other and from the site support equipment. In such cases it is impractical to consider the allocation of site support equipment resources to each BS. The present document does not address the energy consumption overhead associated with any such equipment. As a result $KPI_{EE-site}$ cannot be applied in such circumstances.

However, a site may support multiple, separate, groups of components each of which comprises an individual BS, may serve different networks and be under common governance with the site support equipment. In such cases $KPI_{EE-site}$ may be applied.

4.3 Extended base station (BS) site

A base station site contains the telecom equipment and its supporting equipment such as backhaul, security equipment, air-conditioning, lightning, power back-up. The basic BS site is solely powered by electricity delivered via the utility grid. A BS site might be extended with own electricity generation equipment, such as gensets, solar cells, etc. The extended site has additional energy inputs to generate the electricity need to operate the BS site such as chemical fuels, solar irradiation, etc.

Figure 3 shows a schematic of the energy characteristics of an extended BS site.

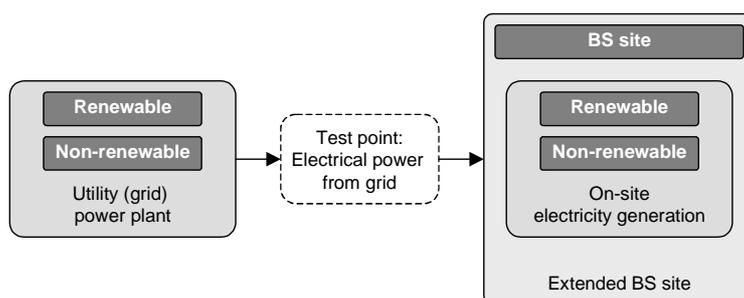
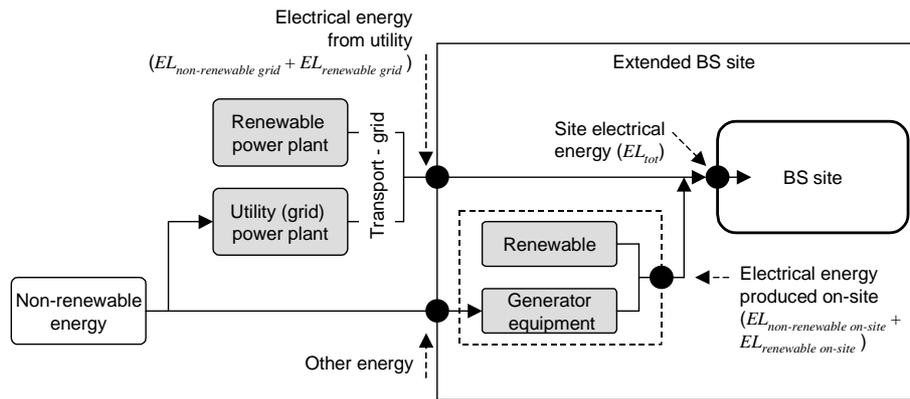


Figure 3: Schematic representation of the energy sources for an extended BS site

The schematic of Figure 4 separately identifies the contribution of non-renewable and renewable sources of electricity supporting the BS site. Please note that this clause is consistent with Recommendation ITU-T L.1350 [i.6].



NOTE: Other energy includes chemical energy delivered to the site to generate electricity such as gasoline, etc.

Figure 4: Schematic of energy sources for the electricity provision at an extended BS site

The total amount of electrical energy consumed by the site is defined as:

$$EL_{tot} = EL_{renewable\ grid} + EL_{renewable\ on-site} + EL_{non-renewable\ grid} + EL_{non-renewable\ on-site}$$

4.4 Base station (BS) configurations

A BS is a combination of NTE which serves one or multiple cells, configured to provide the required coverage and capacity, antenna diversity and the number of input and outputs (MIMO).

A BS is classified as either:

- an integrated BS where all BS functional equipment is installed at a central point but including, where appropriate, tower-mounted amplifiers for uplink (UL) enhancement as shown in Figure 5 (tower-mounted amplifier is not shown); or
- a distributed BS where one or more remote radio head (RRH) or radio unit/module (RRU) is located separately from the baseband signal processing and backhaul transceiver unit(s), see Figure 6.

In both cases, the complexity of a BS is unrestricted since:

- the number of RF units will reflect the number of mobile access network cells required to be supported;
- the capacity of the baseband signal processing unit will reflect the peak traffic load.

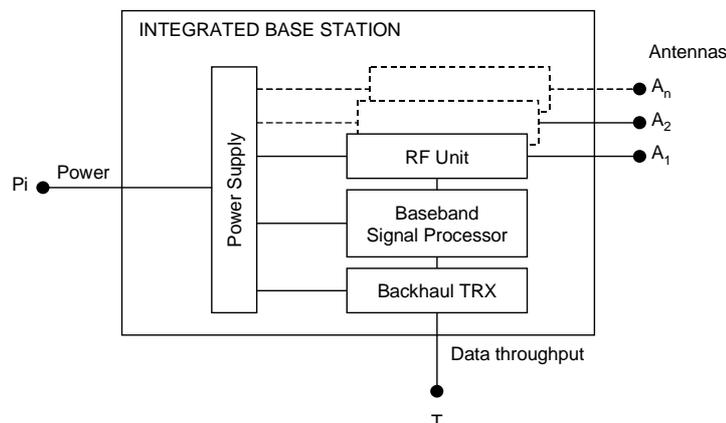


Figure 5: Integrated BS model

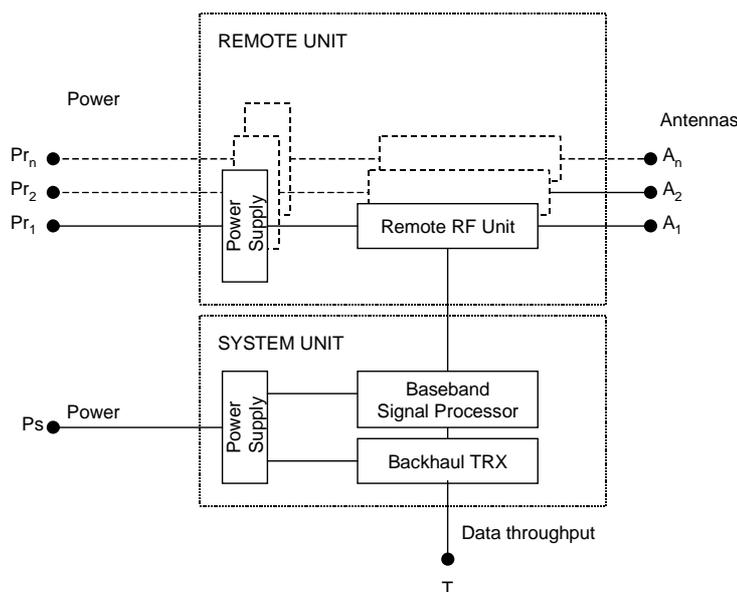


Figure 6: Distributed BS model

5 BS and BS site KPIs

5.1 General

5.1.1 Application of KPIs

Clause 5 specifies KPIs for the BS ($KPI_{EE-capacity}$ and $KPI_{EE-coverage}$) and for both a BS site and an extended BS site ($KPI_{EE-site}$, $KPI_{REN-tot}$ and $KPI_{REN-onsite}$).

The KPIs of the present document shall be used to indicate trends within a particular implementation of a given type of operational infrastructure and to indicate improvements obtained.

For the BS parameters, the two KPIs are measures of energy efficiency on the basis of energy consumption in relation to:

- BS data volume ($KPI_{EE-capacity}$);
- BS coverage area ($KPI_{EE-coverage}$).

The purpose of these KPIs is to demonstrate improvements in energy efficiency of BS components or to show improvements in efficiency through network technology evolution e.g. 3G to 4G, etc.

The primary purpose of the KPIs is trend analysis. It is not the purpose of any KPI to enable comparison between individual BSs unless the conditions of operation are "similar". Examples of such conditions include operating environment, path loss and timing advance. A full list of comparative conditions is included in Annex A. It has not been determined how many of the conditions can be "integrated" with the principal KPI.

For a BS site, $KPI_{EE-site}$ is a measure of the energy efficiency of the support infrastructures of the site as compared to the consumption of the BS(s) of the site. The purpose of these KPIs is to demonstrate improvements in energy efficiency of the site support infrastructures which, in turn, may reflect changes to the operating conditions of the BS components. $KPI_{EE-site}$ may also be useful in enabling an organization responsible for the site support systems only to check its efficiency improvements.

For an extended BS site, $KPI_{REN-tot}$ and $KPI_{REN-onsite}$ provide a measure of the renewable content of the electrical energy consumed.

The KPIs are applicable to all stages of network evolution e.g. migration from 3G to 4G.

The KPIs are applicable to all stages of network utilization. However, it has to be recognized that as base station utilization increases:

- $KPI_{EE-capacity}$ will increase - since the BS equipment operates more efficiently at higher load levels;
- $KPI_{EE-coverage}$ will decrease - since the energy consumption increases with increase data volumes but the coverage remains unchanged (or possible reduces);
- $KPI_{EE-site}$ will increase.

For an extended BS site, $KPI_{REN-tot}$ and $KPI_{REN-onsite}$ are independent of network utilization.

5.1.2 Conditions of assessment

In order for the KPI of clauses 5.2 to 5.6 to provide a valid basis for trend analysis or comparison, where possible, it is necessary define the characteristics of operation during the periods of assessment.

For a BS, BS site or extended BS site it is necessary to:

- 1) identify the equipment under test (see clause 4):
 - 1.1) identify the BS basic parameters (see, Table A.1);
 - 1.2) list the BS configuration (see Table A.2);
 - 1.3) list the energy saving features and capacity enhancement features used (see Table A.2);
- 2) classify the site (see clause 4);
- 3) for $KPI_{EE-capacity}$, measure the energy consumption and data volume of the BS in accordance with clause 7.1 for the operational network under actual load conditions (excluding periods of abnormal activity, such as widespread emergency situations) and a sufficient time duration (see clause 6 and Table A.2);
- 4) for $KPI_{EE-coverage}$, measure the energy consumption and coverage area of the BS in accordance with clause 7.2 for the operational network under typical load conditions and a sufficient time duration (see clause 6 and Table A.2);
- 5) for $KPI_{EE-site}$, measure the energy consumption of the BS(s) and the BS site in accordance with clause 7.3 for the operational network under typical load conditions and a sufficient time duration (see clause 6 and Table A.2);
- 6) document the measurement results (see Table A.3);
- 7) calculate and report KPIs (see clause 8).

5.2 Capacity energy efficiency KPI ($KPI_{EE-capacity}$)

This is the data volume of the BS over the backhaul network divided by the total energy consumption of the BS site (including the support infrastructure). The detailed measurement of $KPI_{EE-capacity}$ is addressed in clause 7.1.

5.3 Coverage energy efficiency KPI ($KPI_{EE-coverage}$)

This is the coverage area of the BS divided by the total energy consumption of the BS site (including the support infrastructure). The detailed measurement of $KPI_{EE-coverage}$ is addressed in clause 7.2.

5.4 Site energy efficiency KPI ($KPI_{EE-site}$)

This is the total of the power supplies of the BS(s) of the BS site divided by the total energy consumption of the BS site (including the support infrastructure). The detailed measurement of $KPI_{EE-coverage}$ is addressed in clause 7.3. Please note that this clause is consistent with Recommendation ITU-T L.1350 [i.6].

5.5 Extended BS total renewable energy KPI ($KPI_{REN-tot}$)

$KPI_{REN-tot}$ gives the fraction of the electricity used by an extended BS site that has been supplied by renewable resources, presented as a percentage, as follows:

$$KPI_{REN-tot} = \frac{EL_{renewable\ grid} + EL_{renewable\ on-site}}{EL_{tot}}$$

In the ideal case $KPI_{REN-tot} = 100\%$ (where all electrical energy consumed by the extended BS site is supplied by renewable sources). Where no electrical energy from renewable sources is consumed then $KPI_{REN-tot} = 0\%$.

5.6 Extended BS on-site renewable energy KPI ($KPI_{REN-onsite}$)

$KPI_{REN-onsite}$ gives the fraction of electricity generated from renewable energy at a site vs. the total electricity generated at a site, presented as a percentage:

$$KPI_{REN-local} = \frac{EL_{renewable\ on-site}}{EL_{renewable\ on-site} + EL_{non-renewable\ on-site}}$$

In the ideal case $KPI_{REN-onsite} = 100\%$ (where all electrical energy consumed by the extended BS from renewable energy is produced on-site). Where no electrical energy from renewable sources is generated on-site then $KPI_{REN-onsite} = 0\%$.

6 Measurement conditions

6.1 General requirements

6.1.1 Measurement period

Any measurement period applied shall be continuous.

The default measurement period for the KPIs of clause 5 shall be 365 days. This is because:

- each BS (and R (ffs)) may be subject to different environmental conditions which will affect the energy consumption required to maintain the desired conditions for effective and long-term operation of the NTE accommodated at those locations;
- those environmental conditions may vary over time in a random manner due to their location and the construction of the structure housing the BS site.

Shorter measurement periods (subject to a minimum of 7 days) may be applied where:

- seasonal climate variations are sufficiently small to enable the measurement period to exhibit the equivalence to the default measurement period;
- the period is able to reflect annualized data volume based on historical traffic patterns for the BS.

The BS configuration shall not change during the measurement period. In case of change a new measurement period shall be initiated. The period shall exclude any time during which engineering trials of energy efficiency measures are employed on a temporary basis.

6.1.2 Measurement configuration

The actual conditions as well as the specific site classification shall be documented as specified in Table A.1.

The measurement report shall include the configuration of the BS as specified in Table A.1.

6.2 Measurement and test equipment

Power and energy consumption measurement methods and accuracy shall meet the requirements of ETSI ES 202 336-12 [2].

7 Measurement methods

7.1 Measurement method for $KPI_{EE-capacity}$

7.1.1 Definition of data volume

The useful data volume (excluding retransmission) shall be collected on Radio Link Control (RLC) Layer 3 as defined as DV_{MN} of ETSI ES 203 228 [1].

DV_{MN} shall be derived from:

- standard counters defined in ETSI TS 132 425 [5] for LTE;
- standard counters defined in ETSI TS 132 412 [4] for UMTS;
- equivalent counters used for 2G and 3G;

integrated over the measurement duration T.

The counter Quality of Service (QoS) reported in QoS Class Identifier (QCI) and described in ETSI TS 123 203 [3] shall be used for reporting the quality of service.

NOTE: RLC Layer 3 includes data re-transmission.

7.1.2 Formulae

The $KPI_{EE-capacity}$ of the BS site is calculated as the integrated data volume divided by the energy consumption (power consumption integrated over the measurement period):

$$KPI_{EE-capacity} = \frac{\sum data_volume}{E_{SI} + \sum E_{BS}} \text{ Mbits/Wh}$$

where:

- data_volume is the total data volume delivered by the BS site during the measurement period (see clause 6.1.1);
- E_{BS} is the total energy consumption of each BS of the BS site during the measurement period (see clause 6.1.1) presented in Wh;
- E_{SI} is the total energy consumption of the support infrastructure of the BS site during the measurement period (see clause 6.1.1) presented in Wh.

The unit of the measurement shall be appropriate for the period measured but should reflect "bits/Wh". Other units may be used (e.g. bits/J) but information shall be provided to revert to the default.

$KPI_{EE-capacity}$ may be applied to an individual BS according to the following formula:

$$KPI_{EE-capacity-BS} = \frac{\sum data_volume}{E_{BS}} \text{ Mbits/Wh}$$

7.2 Measurement method for $KPI_{EE-coverage}$

7.2.1 Definition of coverage area

7.2.1.1 General

The coverage area is subject to network planning and intended services delivered within a certain geographic area. These parameters vary according to the strategy of mobile network operator (MNO) and can differ from MNO to MNO and also for different geographical areas within the network of an MNO.

For the purpose of energy efficiency assessment, drive tests and similar additional measurement campaigns are not required.

The coverage area shall be characterized by the following parameters:

- 1) the designated coverage area (CoA_{des});
- 2) this defines the area in which a network coverage is provided by the selected sub-network and it is derived by planning models from network design, planned service and geographical data. This is termed $A_{coverage}$ within the formula for $KPI_{EE-coverage}$;
- 3) a coverage quality factor (CoA_{Qdes});
- 4) this takes into account measured feedback from user equipment (as described in Table 1). This coverage quality factor signifies that networks can experience false coverage issues (e.g. inside buildings), load congestions or high interference issues and has to be taken into account in any interpretation of $KPI_{EE-coverage}$.

NOTE: These parameters should not be confused with the total geographical area of a country (CoA_{geo}) which includes the total geographical area which falls into the network operators responsibility (total network and/or sub-area under investigation). A network might cover the geographical area only to a certain fraction (often defined by the license agreements, for example area coverage of a complete country or of a region).

7.2.1.2 Designated coverage area

The designated coverage area is the area to be covered based on network planning and presents the actual geographic area where the MNO officially promises coverage. This area is defined by the network service plan of the MNO where the coverage according to the license agreement or similar is delivered. The area (sometimes referred to as "best server" area), is based on base station power, propagation conditions in the selected area, accepted outage criteria, and considered planning models (and therefore rarely comparable).

The designated coverage area includes also in-building coverage within this area. The in-building area (for example, of multi-story buildings) is only considered as the footprint of the building, not the actual building area.

7.2.1.3 Coverage quality

The actual coverage area where UE can be served can differ from the originally designated coverage area (i.e. false coverage zones within the considered area). The coverage quality is a measure to estimate the actually covered fraction of the planned total coverage area. UE reports such as failed call attempts (see Table 1) shall be used to determine how well the users within the coverage area are covered.

The coverage quality indicator shall be provided for network efficiency result evaluations. It is linked to network quality and has to be defined in relation to the quality of service (QoS) definitions.

A coverage map based on signal quality (SINR) as shown in Figure 7 could be used to determine the fraction of the total area where a signal quality above a certain minimum value is achieved. However, such maps require a large amount of measurements and drive tests.

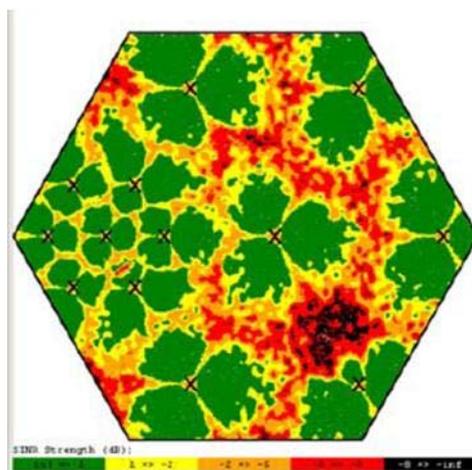


Figure 7: Typical SINR distribution of a mobile network

Technical details on how to calculate or measure coverage are available in ETSI ES 203 228 [1].

7.2.2 Formulae

The $KPI_{EE-coverage}$ of a BS site is calculated as the coverage area divided by the energy consumption of the BS site during the measurement period:

$$KPI_{EE-coverage} = \frac{A_{coverage}}{E_{SI} + \sum E_{BS}}$$

where:

- $A_{coverage}$ is the BS site coverage area [km²];
- E_{BS} is the total energy consumption of each BS of the BS site during the measurement period (see clause 6.1.1) presented in Wh;
- E_{SI} is the total energy consumption of the support infrastructure of the BS site during the measurement period (see clause 6.1.1) presented in Wh.

The unit of the measurement shall be appropriate for the period measured but should reflect "km²/Wh". Other units may be used but information shall be provided to revert to the default.

For the calculation of the coverage KPI the designated coverage area as described in clause 7.2.1.2 shall be used and shall be reported together with the coverage quality factor described in clause 7.2.1.3.

If multiple radio technologies (LTE, HSPA, GSM) are collocated:

- the designated coverage areas shall be reported for each different technology together with corresponding coverage quality factor;
- E_{BS} shall be measured for each technology and the measured site overhead shall be added in proportion to the energy consumptions of the different technologies;
- in the case of multi-standard BS (multiple technologies provided by one BS) the measured BS power consumption shall be allocated to each technology based on total RF power ratio of the technologies.

Table 1: Measurement parameters required for coverage quality calculation

Network	Parameter	Function	Counter name
LTE	RRC connection establishment failures	Radio resource control	RRC.ConnEstabFail.sum
	RRC connection establishment attempts	Radio resource control	RRC.ConnEstabAtt.sum
	E-RAB setup failures	Initial E-RAB setup	ERAB.EstabInitFailNbr.sum
		Additional E-RAB setup	ERAB.EstabAddFailNbr.sum
	E-RAB setup attempts	Initial E-RAB setup	ERAB.EstabInitAttNbr.sum
		Additional E-RAB setup	ERAB.EstabAddAttNbr.sum
	E-RAB release failures	E-RAB release	ERAB.RelFailNbr.sum
E-RAB release attempts	E-RAB release	ERAB.RelAttNbr.sum	
UMTS	RRC connection establishment failures	Radio resource control	RRC.FailConnEstab.sum
	RRC connection establishment attempts	Radio resource control	RRC.AttConnEstab.sum
	RAB setup failures	RAB setup for CS domain	RAB.FailEstabCSNoQueuing.sum, RAB.FailEstabCSQueuing.sum
		RAB setup for PS domain	RAB.FailEstabPSNoQueuing.sum RAB.FailEstabPSQueuing.sum
	RAB setup attempts	RAB setup for CS domain	RAB.AttEstabCS.Conv.<U><D> RAB.AttEstabCS.Strm RAB.AttEstabCS.Intact RAB.AttEstabCS.Bgrd
		RAB setup for PS domain	RAB.AttEstabPS.Conv RAB.AttEstabPS.Strm.<U><D> RAB.AttEstabPS.Intact RAB.AttEstabPS.Bgrd
	RAB release failures	RAB release for CS domain	RAB.FailRelCS.sum
		RAB release for PS domain	RAB.FailRelPS.sum
	RAB release attempts	RAB release for CS domain	RAB.AttRelCS.sum
		RAB release for PS domain	RAB.AttRelPS.sum
GSM	Immediate assignment success	IMMEDIATE ASSIGNMENT	succImmediateAssingProcs
	Immediate assignment attempts	IMMEDIATE ASSIGNMENT	attImmediateAssingProcs
NOTE: For 2G definition source see ETSI TS 152 402 [i.4]. For 3G definition source see ETSI TS 132 405 [i.3]. For 4G source/definition see ETSI TS 132 412 [4].			

ETSI TS 136 306 [7]: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities (3GPP TS 36.306)".

7.3 Measurement method for $KPI_{EE-site}$

7.3.1 General

In order to allow a more precise assessment of the energy consumption impact of local factors (like location specific site equipment) it is necessary to record the BS site consumption separately for:

- BS equipment (as in clauses 7.1 and 7.2);
- support equipment (the non-BS equipment installed at the BS site needed to operate the site such as environmental control, back-up power, lighting, etc).

The site equipment shall be classified according to operational temperature range.

7.3.2 Formulae

The $KPI_{EE-site}$ of the BS site is calculated as the total energy consumption of all the BS equipment at the site divided by the total energy consumption of the BS site during the measurement period.

This is presented as follows:

$$KPI_{EE-site} = \frac{\sum E_{BS}}{E_{SI} + \sum E_{BS}}$$

where:

- E_{BS} is the total energy consumption of each BS of the BS site during the measurement period (see clause 6.1.1) presented in Wh;
- E_{SI} is the total energy consumption of the support infrastructure of the BS site during the measurement period (see clause 6.1.1) presented in Wh.

The above metric gives an indication of site efficiency in terms of the energy consumption overhead employed to support the BS equipment.

7.4 User equipment (UE) reporting parameters

UE reporting parameters provide significant insight in the performance (QoS) of a radio network. The documentation of a set of key UE parameters are essential to analyse and utilize the energy efficiency KPIs defined in the present document.

UE power consumption is not considered in the present document. However, UE performance has a significant impact on mobile network energy efficiency. To place any assessment of the energy consumption and energy efficiency of a network into context it is necessary to collate information regarding the UE served during the assessment period.

UE reporting parameters provide significant insight in the performance (QoS) of a radio network. The documentation of a set of key UE parameters are essential to analyse and utilize the energy efficiency KPIs defined in the present document.

The International Mobile Equipment Identity (IMEI) is a unique 15-digit serial number allocated to each UE which reveals information such as its country of origin, the manufacturer and model number. The IMEI is sent to the network operator by the UE with every connection to the network. The complete IMEI number allows to identify each single device but the present document only requires the first 8 digits (representing the model and source of the UE) of the IMEI code to be collected.

NOTE: This avoids any infringement of personal data protection.

The downlink (DL) capability of LTE UE is presented as one of twelve "Categories" specified in ETSI TS 136 306 [7]. UE DL category statistics shall be reported for the measurement period.

For 3G UE, a complex categorization for different parameters is specified in ETSI TS 125 306 [6]. The HS-DSCH physical layer category statistics shall be reported for the measurement period.

Received Signal Strength Indication (RSSI) and Reference Signal Received Power (RSRP) provides an indication of the reception quality for a given class of mobiles in a cell. This gives an indication for the combined effect of cell size, propagation losses, user location and UE receiver performance which has a direct impact on the need RF transmit power of the base station.

Further UE reporting parameters for network coverage quality assessment (like call drop rates) are already required (see clause 7.2).

The required data is summarized in Table 2. The parameters of Table 2 can be used for further network energy efficiency evaluation (KPIs are ffs).

Table 2: Required UE data

Parameter	Function	Remarks
IMEI code	UE identifier	Only first 8 digits required
UE category	UE DL capability	
RSSI/RSRP	RF signal strength at UE	See ETSI TS 136 214 [8]
Call drop rates	See clause 7.2	

8 Measurement report

The results of the assessments shall be reported accurately, clearly, unambiguously and objectively, and in accordance with any specific instructions in the required method(s).

The following shall be reported for the BS site under assessment:

- $KPI_{EE-capacity}$;
- $KPI_{EE-coverage}$ and CoA_{Qdes} ;
- $KPI_{EE-site}$.

In addition, the following shall be reported for an extended BS site under assessment:

- $KPI_{REN-tot}$;
- $KPI_{REN-onsite}$.

A list of reference parameters, measurement conditions, test results, and derived calculation results which are to be reported is given in Table A.3.

Further guidelines on the test report can be found in clause 5.10 of ISO/IEC 17025 [i.5].

Annex A (normative): Test reports

A.1 General information to be reported

The information in Table A.1 shall be reported separately for each BS or BS site under consideration.

Table A.1: Site(s) under test in the Network Area

General heading	Specific information	Reported value	
Measurement duration	Time duration of the measurement [<i>T</i>]		
	Measurement start date and time		
	Measurement finish date and time		
	Repetition time		
	Granularity of measurements		
Type of site	Site "layer" [Wide Area, Medium Range, other] For Wide Area, indicate number of sectors and carriers per sector		
	Site "technology" [2G, 3G, 2G+3G, LTE only, 2G+3G+LTE, other]		
	Site "MNOs" [single MNO, co-location, network sharing, other]		
Site and equipment age	Initial commissioning date of the site		
	Commission date of the current equipment in the site		
Internal temperature [during period <i>T</i>]	Average temperature [°C]		
	Minimum temperature [°C]		
	Maximum temperature [°C]		
External temperature [during period <i>T</i>]	Average temperature [°C]		
	Minimum temperature [°C]		
	Maximum temperature [°C]		
Environmental class according to ETSI ES 203 228 [1] (for each equipment in the site)			
		Temperature	IP class
	A	from 0 °C to 28 °C	
	B	from -20 °C to 40 °C	
	C	from -40 °C to 55 °C	
Site location	[local exchange premise, building, shelter, other]		
Site composition	Air conditioners		
	Rectifiers/batteries		
	Fixed network equipment consumption		
	Other		

General heading	Specific information	Reported value
Estimated infrastructure consumption in the site	Energy consumption of NTE equipment E_{BS} [Wh]	
	Energy consumption of support equipment E_{SI} [Wh]	
	Energy consumption of BS site	
	- Total electrical energy supplied from the grid	
	- Peak power delivered from the grid	
	- Total site energy storage capacity	
	- Peak shaving features available at the site	
	Energy saving features affecting the site equipment during the test	
	Capacity enhancement features affecting the site equipment during the test	
Estimated percentage of presence of this site type in the Network Area		

A.2 Energy consumption report

Table A.2: Site measurement report

General heading	Specific information	Reported value
Measurement duration	Time duration of the measurement [T]	
	Measurement start date and time	
	Measurement finish date and time	
	Repetition time	
	Granularity of measurements	
Environmental data [during period T]	Temperature class	
	Average internal temperature [$^{\circ}\text{C}$]	
	Average external temperature [$^{\circ}\text{C}$]	
Energy consumption in the site	Method of measurement [energy bills/counters, sensors, equipment information, other]	
Measured BS energy consumption E_{BS} [Wh or multiples]	Week energy consumption [per week data/graph]	
	Month energy consumption [if T allows]	
	Year energy consumption [if T allows]	
Measured BS site energy consumption [Wh or multiples]	Week energy consumption [per week data/graph]	
	Month energy consumption [if T allows]	
	Year energy consumption [if T allows]	
Measured traffic volume DV [bits or multiples]	Week traffic [per week data/graph]	
	Month traffic [if T allows]	
	Year traffic [if T allows]	
Coverage of the site [data to be reported per each radio access technology present in the site]	CoA _{des} : [km ²]	
	CoA _{Qdes} :	
	Failed RRC connection establishments	
	Attempted RRC connection establishments	
	RAB setup failure	
	RAB setup attempted	
	RAB release failure	
RAB release attempted		

A.3 KPI report

Table A.3: Calculated KPIs to be reported for site efficiency

General heading	Specific information	Reported value
Measured energy consumption E_{BS} [Wh or multiples]	Week energy consumption [per week data/graph]	
	Month energy consumption [if T allows]	
	Year energy consumption [if T allows]	
Measured traffic volume DV [bits or multiples]	Week traffic [per week data/graph]	
	Month traffic [if T allows]	
	Year traffic [if T allows]	
	<i>KPIEE-capacity</i>	
Coverage of the site [data to be reported per each radio access technology present in the site]	CoA_{geo} : [km ²]	
	CoA_{des} : [km ²]	
	CoA_{Qdes} :	
	Failed RRC connection establishments	
	Attempted RRC connection establishments	
	RAB setup failure	
	RAB setup attempted	
	RAB release failure	
RAB release attempted		
	<i>KPIEE-coverage</i>	
Measured BS site energy consumption [Wh or multiples]	Week energy consumption [per week data/graph]	
	Month energy consumption [if T allows]	
	Year energy consumption [if T allows]	
	<i>KPIEE-site</i>	

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V1.1.1	October 2018	Publication