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# Foreword

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

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5. It will be published respectively by ITU and ETSI as Recommendation ITU-T L.1330 and ETSI Standard ETSI ES 203 228, which are technically-equivalent.

Moreover the present document has been developed in collaboration with 3GPP SA5 and RAN3; GSMA has also given valuable suggestions and contributions.

# Modal verbs terminology

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# Introduction

The present document deals with the definition of metrics and methods to measure energy efficiency performance of Mobile Radio Access Networks and adopts an approach based on the measurement of such performance on small networks, for feasibility and simplicity purposes. Such simplified approach is proposed for approximate energy efficiency evaluations and can not be considered as a reference for planning evaluation purposes throughout the network operation process.The same approach was introduced also in ETSI TR 103 117 [i.1]; the measurements in testing laboratories of the efficiency of the Base Stations is the topic treated in ETSI ES 202 706 [i.2].

The measurement of this performance is useful for many reasons, and an implementation guidelines clause is given (clause 9) to help using the present document in the most convenient way.

The present document provides also an extrapolation method to extend the applicability of the assessment of energy efficiency to wider networks (clause 7).

The general outcome of the application of the method specified in the present document is based on the "Assessment report" introduced in clause 8. An example of application of the method is given for better readability and ease of use in annex A.

# 1 Scope

The present document is aimed at defining the topology and level of analysis to assess the energy efficiency of mobile networks. Within the scope of the present document there is the radio access part of the mobile networks, and namely there are radio base stations, backhauling systems, radio controllers and other infrastructure radio site equipment. The covered technologies are GSM, UMTS and LTE (including LTE-A). In particular the present document defines metrics for mobile network energy efficiency and methods for assessing (and measuring) energy efficiency in operational networks. The purpose of the present document is to allow better comprehension of networks energy efficiency.

The present document deals with both a homogeneous and heterogeneous "network" considering a network whose size and scale could be defined by topologic, geographic or demographic boundaries. For networks defined by topologic boundaries, a possible example of a network covered by the present document consists of a control node (whenever applicable), its supported access nodes as well as the related network elements. Networks could be defined by geographic boundaries, such as city-wide, national or continental networks and could be defined by demographic boundaries, such as urban or rural networks.

The present document applies to the so-called "partial" networks where energy efficiency is measured in standardized way. The specification extends the measurements in partial networks to wider so-called "total" networks energy efficiency estimations (i.e. the network in a geographic area, the network in a whole country, the network of a MNO, etc.).

Terminal (end-user) equipment is outside the scope of the present document and is not considered in the energy efficiency measurement.

# 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 reference document (including any amendments) applies.

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

[1] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".

[2] ETSI TS 136 104: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104)".

[3] ETSI TS 132 425 (V12.0.0): "LTE; Telecommunication management; Performance Management (PM); Performance measurements Evolved Universal Terrestrial Radio Access Network (E-UTRAN) (3GPP TS 32.425 version 12.0.0 Release 12)".

[4] ETSI TS 132 412 (V11.1.0): "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM) Integration Reference Point (IRP): Information Service (IS) (3GPP TS 32.412 version 11.1.0 Release 11)".

[5] ETSI TS 123 203 (V12.7.0): "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Policy and charging control architecture (Release 12)".

[6] ETSI TS 136 314: "LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Layer 2 - Measurements (3GPP TS 36.314)".

[7] ETSI TS 152 402 (V11.0.0): "Digital cellular telecommunications system (Phase 2+); Telecommunication management; Performance Management (PM); Performance measurements - GSM (3GPP TS 52.402 version 11.0.0 Release 11)".

[8] ETSI TS 132 405 (V11.1.1): "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM); Performance measurements; Universal Terrestrial Radio Access Network (UTRAN) (3GPP TS 32.405 version 11.1.1 Release 11)".

[9] ETSI ES 202 336-12: "Environmental Engineering; Monitoring and control interface for infrastructure equipment (power, energy and environmental parameters); Part 12: ICT Equipment power, energy and environmental parameters monitoring information model".

[10] ISO/IEC 17025 (2005): "General requirements for the competence of testing and calibration laboratories".

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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 TR 103 117: "Environmental Engineering (EE); Principles for Mobile Network level energy efficiency".

[i.2] ETSI ES 202 706: "Environmental Engineering (EE); Measurement method for power consumption and energy efficiency of wireless access network equipment".

[i.3] ETSI GS NFV 003: "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".

# 3 Definitions and abbreviations

## 3.1 Definitions

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

**backhaul equipment:** equipment used to connect base stations to the core network, or to other BSs (like X2 in LTE)

**Base Station (BS):** generic term used for network component which serves one cell or more cells and interfaces the user terminal (through air interface) and a radio access network infrastructure

**distributed RBS:** BS architecture which contains radio heads (RRH) close to the antenna element and a central element connecting BS to network infrastructure

**Energy Efficiency (EE):** relation between the useful output and energy/power consumption

**energy saving feature:** feature which contributes to decreasing the energy consumption compared to the case when the feature is not implemented

**integrated BS:** BS architecture in which all BS elements are located close to each other for example in one or two cabinets

NOTE: The integrated BS architecture may include TMA close to antenna.

**Mobile Network (MN):** set of equipment from the radio access network or sub-network that are relevant for the assessment of energy efficiency

**Mobile Network Coverage Energy Efficiency:** ratio between the area covered by the network in the Mobile Network under investigation and the energy consumption

**Mobile Network Data Energy Efficiency:** ratio between the performance indicator based on Data Volume and the energy consumption when assessed during the same time frame

**Mobile Network Energy Consumption:** overall energy consumption of equipment included in the MN under investigation

**Mobile Network Energy Efficiency:** Energy Efficiency of a Mobile Network

**Mobile Network Operator (MNO):** operator that manages one or more Mobile Networks

**Mobile Network Operator penetration ratio:** percentage of traffic served by an MNO in the area where it is active

**Mobile Network Performance Delivered:** performance indicator of the MN under investigation, defined as the data volume delivered by the mobile network under investigation during the time frame of the energy consumption assessment

**power consumption:** power consumed by a device to achieve an intended application performance

**radio access network:** telecommunications network in which the access to the network (connection between user terminal and network) is implemented without the use of wires and that is part of GERAN, UTRAN or E-UTRA networks defined by 3GPP

**Site Energy Efficiency (SEE):** metric used to determine the energy efficiency of a telecom site. SEE is defined by the ratio of "IT equipment energy" and "Total site energy", which generally includes rectifiers, cooling, storage, security and IT equipment. For datacenters, the "Total site energy" more globally includes building load, powering equipment (e.g. switchgear, uninterruptible power supply (UPS), battery backup), cooling equipment (e.g. chillers, computer room air conditioning unit (CRAC)) and IT equipment energy. SEE is the inverse of Power Usage Effectiveness (PUE), which is commonly used for datacenters." **telecommunication network:** network operated under a license granted by a national telecommunications authority, which provides telecommunications between Network Termination Points (NTPs)

**Comment [BMR1]:** To be revised

**Virtualized Network Function (VNF):** see [i.3] GS NFV 003

## 3.2 Abbreviations

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

| | |
|---|---|
| 3GPP | 3G (mobile) Partnership Project |
| BH | Backhaul |
| BS | Base Station |
| CoA | Coverage Area |
| CR | Coverage Ratio |
| CS | Circuit Switched |
| CS/PS | Circuit Switched/Packet Switched |
| DCA | Designed Coverage Area |
| DL | DownLink |
| DP | Dominant Penetration |
| DU | Dense Urban |
| DV | Data Volume |
| $DV_{MN}$ | Data Volume of the Mobile Network |
| EC | Energy Consumption |
| $EC_{MN}$ | Energy Consumption of the Mobile Network |
| $EE_{MN}$ | Energy Efficiency of the Mobile Network |
| E-UTRA | Evolved UMTS Terrestrial Radio Access Network |
| FAO | Food and Agriculture Organization |
| GERAN | GSM/EDGE Radio Access Network |
| GHG | GreenHouse Gas |
| GSM | Global System for Mobile communication |
| GSMA | GSM Association |
| ICT | Information Communications Technology |
| ITU | International Telecommunications Union |

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| | |
|---|---|
| ITU-T | International Telecommunications Union - Telecommunication |
| LTE | Long Term Evolution |
| MDT | Minimization of Drive Tests |
| MJ | MegaJoule |
| MN | Mobile Network |
| MNO | Mobile Network Operator |
| MP | Minor Penetration |
| NA | Not Applicable |
| NDP | Non Dominant Penetration |
| O&M | Operation & Maintenance |
| PDF | Probability Distribution Function |
| PS | Packet Switched |
| PSL | Packet Switched Large packages dominating |
| PSS | Packet Switched Small packages dominating |
| PUE | Power Usage Effectiveness |
| QCI | QoS Class Identifier |
| QoS | Quality of Services |
| RAB | Radio Access Bearer |
| RAT | Radio Access Technology |
| RC | Remote Controller |
| RF | Radio Frequency |
| RNC | Radio Network Controller |
| RRC | Radio Resource Control |
| RRH | Remote Radio Head |
| RU | Rural |
| SCH | Signalling Channel |
| SEE | Site Energy Efficiency |
| SI | Site Infrastructure |
| SINR | Signal to Interference plus Noise Ratio |
| SU | Sub Urban |
| TCH | Traffic Channel |
| TCO | Total Cost of Ownership |
| TMA | Tower Mounted Amplifier |
| U | Urban |
| UE | User Equipment |
| UE-BS | User Equipment to Base Station |
| UL | UpLink |
| UMTS | Universal Mobile Telecommunication Service |
| UN | United Nations |
| USA | United States of America |
| UTRAN | UMTS Terrestrial Radio Access Network |
| VNF | Virtualized Network Function |
| X2 | Interface allowing to interconnect eNBs with each other |

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# 4 Network under test definition

## 4.1 Introduction

The Mobile Radio Access Network (MN) under investigation shall include all the equipment that is necessary to run a radio access network or sub-network. Equipment to be included in the Mobile Network under investigation:

- Base Stations (see ETSI TS 125 104 [1] and ETSI TS 136 104 [2]):
  - Wide area BS.
  - Medium range BS.
  - Local Area BS.

- Home BS.

NOTE: Home BS (and WiFi access points) are not dealt with in the present document, being possibly considered for future versions.

- Site equipment (air conditioners, rectifiers/ batteries, fixed network equipment, etc.).
- Backhaul equipment required to interconnect the BS used in the assessment with the core network.
- Radio Controller (RC).

Power consumption and energy efficiency measurements of individual mobile network elements are described in several standards (for example ETSI ES 202 706 [i.2] for radio base stations). The present document describes energy consumption and MN energy efficiency measurements in operational networks.

As a complete and detailed energy consumption measurement of the complete network of a country or MNO is in most cases impossible or economically not viable, the total network is split into a small number of networks with limited size ("sub-networks").

These sub-networks are defined to represent some specific characteristics, for example:

- capacity limited networks representing urban and dense urban networks;
- sub-urban networks with high requirements for coverage and capacity;
- rural networks, which are usually coverage limited.

The size and scale of the sub-networks are defined by topologic, geographic or demographic boundaries. For networks defined by topologic boundaries, a possible example of a network covered by the present document consists of a Radio controller (whenever applicable), its supported access nodes as well as the related network elements. Networks could be defined by geographic boundaries, such as city-wide, national or continental networks and could be defined by demographic boundaries, such as urban or rural networks.

The sub-networks analyzed might consist of macro-only base stations or heterogeneous networks or whatever is actually implemented in real networks.

The tests defined in the present document for sub-networks provide the basis to estimate energy efficiency for large networks of one MNO or within an entire country, applying the extrapolation methods described in clause 7.

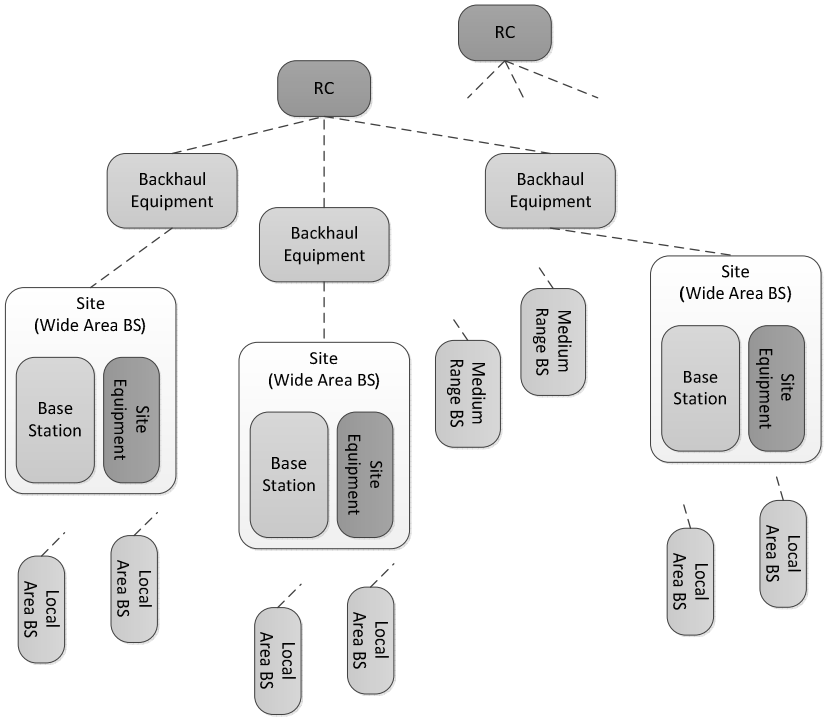


**Figure 1: Network under test definition**

## 4.2 Test parameter categorization

Metrics used for the energy efficiency assessment of mobile networks require the definition and collection of a range of parameters and variables. These are separated into two categories:

1) Parameters and variables required to calculate the network energy efficiency.

2) Parameters needed to allow network energy efficiency evaluation.

The first category describes a set of network variables as described in clause 5 (energy consumption, delivered bits, coverage) to be used to calculate the energy efficiency.

The second category includes parameters which are not directly required in the energy efficiency calculation. These parameters describe the network characteristics, such as geographical conditions, population density, coverage area, targeted data rates, climate zones, etc. and are used to interpolate from the measured sub-network to a larger network as described in clause 7. These parameters can be used to interpret variations in energy efficiency results of different networks.

**Table 1: Test parameter categorization**

| Category | Parameter | Remarks |
|---|---|---|
| 1 | $EC_{MN}$ | Measured network energy consumption |
| 1 | Capacity | As defined in clause 5.2 |
| 1 | Coverage area | As defined in clause 6.2.3 |
| 2 | Coverage ratio | As defined in clause 6.2.3 |
| 2 | Demography | Population density as defined in clause 4.3.1 |
| 2 | Topography | As defined in clause 4.3.2 |
| 2 | Climate zones | As defined in clause 4.3.3 |
| 2 | Informative classes | As defined in clause 4.3.4 |
| 2 | CS/PS data ratio | Describes the fraction of CS traffic vs. PS traffic in the network |

## 4.3 Network classification

### 4.3.0 Introduction of network classification

To allow an extrapolation from the measured sub-networks ("partial" networks) to a complete network ("total" or "overall" networks), the test areas shall be classified into different categories as defined by Network classification.

The environmental classes used for Network classification are: demography, topography and climate classes. These classes are described in the following clauses.

### 4.3.1 Demography

For the test purpose defined in the present document the mobile network shall be split into domains depending on the population density. The following population density values per domain categories shall be used, as reported in table 2.

**Table 2: Sub-network demography classes**

| Demography Class | Typical population density (inhabitants/km²) | Population range (inhabitants/km²) |
|---|---|---|
| Dense Urban (DU) | 20 000 | > 10 000 |
| Urban (U) | 2 000 | 1 000 - 10 000 |
| Sub-urban (SU) | 300 | 200 - 1 000 |
| Rural (RU) | 30 | 20 - 200 |
| Unpopulated | 0 | < 20 |

Some references to data bases where the demography distribution classes are reported can be found at:

- European Eurostat Reference to demographical distribution available at: http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/main-tables.
- UN Reference to demographical distribution available at: http://unstats.un.org/UNSD/demographic/sconcerns/popsize/size2.htm.
- USA Reference to demographical distribution available at: http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_VISF_P40&prodType=table.

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### 4.3.2 Topography

The following topography classes shall be used, as reported in table 3.

**Table 3: Dub-network topography classes**

| Topography classification | | Examples |
|---|---|---|
| ETSI class | Median Slope | |
| 1<br>Flat<br>(FAO 1-3) | 0 - 5 % | Denmark, Netherlands |
| 2<br>Rolling<br>(FAO 4-6) | > 5 - 30 % | France, Italy |
| 3<br>Mountainous<br>(FAO 7-8) | > 30 % | Norway, Switzerland |

Information on the median slope gradient distribution in the world can be found in FAO world median slope distribution information database at http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/.

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### 4.3.3 Climate zones

The following climate zones are identified as reported in table 4.

**Table 4: Sub-network climate classes**

| Climate Class | Sub-class | Explanation |
|---|---|---|
| *A: Tropical* | *Temperature of the coldest month: > 18 °C* | |
| | Af | No dry season, at least 60 mm of rainfall in the driest month |
| | Am | Monsoon type, short dry season but sufficient moisture to keep ground wet throughout the year |
| | Aw | Distinct dry season, one month with precipitation < 60 mm |
| *B: Dry* | *Arid regions where annual evaporation exceeds annual precipitation, marked dry season* | |
| | Bs | Steppe climate |
| | Bs | Desert |
| *C: Temperate* | *Average temperature of the coldest month < 18 °C and > -3 °C, and average temperature of warmest month > 10 °C* | |
| | Cw | Winter dry season, at least 10 times as much precipitation in wettest month of summer as in driest month of winter |
| | Cs | Summer dry season, at least three times as much rain in wettest month of winter as in driest month of summer, the latter having less than 30 mm precipitation |
| | Cf | At least 30 mm precipitation in the driest month, difference between wettest month and driest month less than for Cw and Cs |
| *D: Cold* | *Average temperature of the warmest month > 10 °C and that of coldest month < -3 °C* | |
| | Df | At least 30 mm of rain in the driest month, difference between wettest month and driest month less than for Cw and Cs |
| | Dw | At least 10 times as much precipitation in wettest month of summer as in driest month of winter |
| *E: Polar* | *Average temperature of the warmest month < 10 °C* | |
| | Et | Tundra, average temperature of warmest month > 0 °C |
| | Ef | No month with temperature > 10 °C |

The above reported climate classification is based on FAO Koeppen classification (FAO Koeppen Climate Zones, Jürgen Grieser, René Gommes, Stephen Cofield and Michele Bernardi, "Data sources for FAO worldmaps of Koeppen climatologies and climatic net primary production", 2006) available at: http://www.fao.org/nr/climpag/globgrids/KC_commondata_en.asp.

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The indication based on the five main classes A to E is mandatory; the subclasses are optionally indicated.

### 4.3.4 Additional classification classes

In order to properly select the sub-networks operators penetration ratio and data traffic types could be reported for information. Table 5 reports the classification based on penetration classes, table 6 the classification based on data volume classes.

**Table 5: Sub-network penetration classes**

| Symbol | Operator penetration class | Range |
|---|---|---|
| DP | Dominant Penetration | > 30 % penetration |
| NDP | Non-Dominant Penetration | < 30 % penetration |
| MP | Minor Penetration | < 10 % penetration |

**Table 6: Sub-network data volume classes**

| Symbol | Traffic Class | Specific thresholds |
|---|---|---|
| CS | CS dominating | > 50 % of data volume is CS |
| PSS | PS - small packages dominating | > 50 % of data volume is PS,<br>>80 % of packages are small |
| PSL | PS - large packages dominating | > 50 % of data volume is PS,<br>< 80 % of packages are small |

# 5 Metrics for energy efficiency assessment

## 5.0 Introduction of clause

The following metrics shall be used to assess the mobile network energy efficiency.

## 5.1 Energy Consumption metrics

The Mobile Network Energy Consumption ($EC_{MN}$) is the sum of the energy consumption of equipment included in the MN under investigation (see clause 4). The network energy consumption is measured according to the assessment process defined in clause 6 such that individual metrics are provided per RAT and per MNO.

$$EC_{MN} = \sum_i \left( \sum_k EC_{BS_{i,k}} + EC_{SI_i} \right) + \sum_j EC_{BH_j} + \sum_l EC_{RC_l} \quad (1)$$

where:

EC is Energy Consumption.

BS refers to the Base Stations in the MN under measurement.

BH is the backhauling providing connection to the BSs in the MN under measurement.

SI is the site infrastructure (Rectifier, battery losses, climate equipment, TMA, tower illumination, etc.).

RC is the control node(s), including all infrastructure of the RC site.

*i* is an index spanning over the number of sites.

*j* an index spanning over the number of BH equipment connected to the *i* sites.

*k* is the index spanning over the number of BSs in the *i*-th site.

l is the index spanning over the control nodes of the MN.

$EC_{MN}$ shall be measured in Wh over the period of measurement T (see clause 6).

NOTE 1: If the control node(s) supports a larger MN than that which is assessed, only a proportional share of RC EC is considered, proportional to the RNC share of traffic that belongs to the MN being assessed.

In order to allow a more precise assessment of the energy consumption impact of local factors (like location specific site equipment) it is requested to measure and report into the parameter $EC_{SI_i}$ the site equipment consumption into two classes:

1. ICT equipment (equipment directly needed to perform the telecom service)

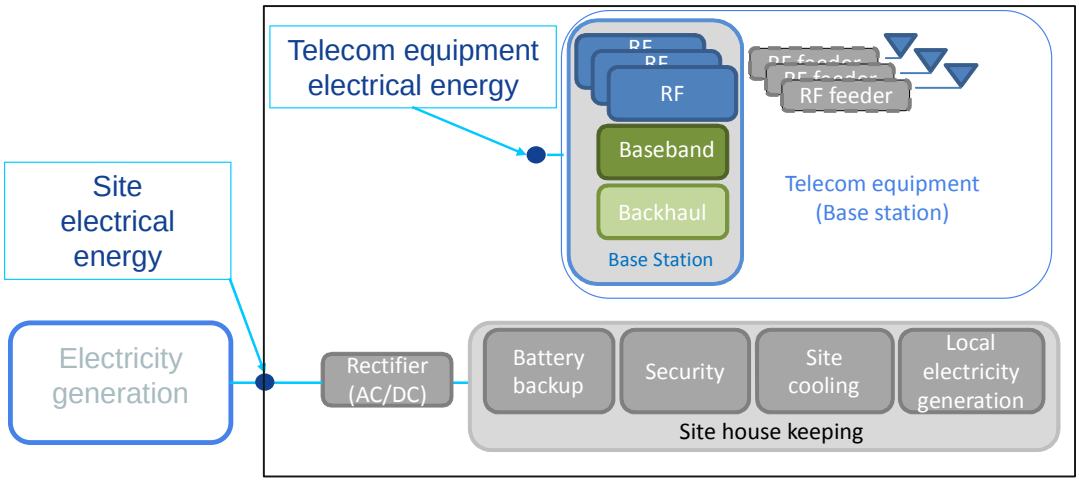
2. Support equipment (all equipment installed at the site which are needed to operate the particular site but which are not directly need for the telecom service, like air-conditioning, back-up power, lights, etc.)

Moreover, it is requested also to classify the site equipment according to operational temperature range.

Based on such a classification the following additional network KPI describing the energy consumption of the telecom equipment with reference to the total energy consumption shall be introduced:

$$EE_{site} = EC_{BSs} / (EC_{BSs} + EC_{SI})$$

The above KPI gives an indication of site efficiency in terms of how big fraction of energy is used for actual telecom equipment.



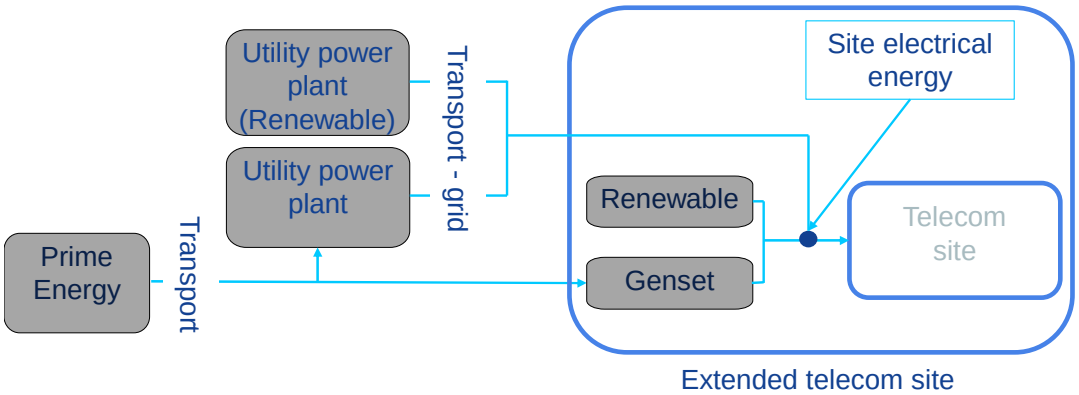

NOTE 2: Power generation is not part of MN energy efficiency, but reported for information, for use in TCO and GHG analysis.

In currently deployed sites, there is a wide mixture of equipment installed within one room with different cooling requirements. The maximum room temperature is determined by the equipment with the lowest acceptable operating temperature. However, base station equipment is often designed to be operated at much higher temperatures. The installed site equipment shall be classified in different environmental groups based on their operational temperature range. Such a classification would allow to assess the energy saving potential if the site would be split in areas for equipment which require cooling and others which can operate without.

**Comment [BMR2]:** Here we should introduce another classification, as well as the one on climate in chapter 4. Here we talk about the operational temperature range for equipment

| Environmental class | Temp. range | IC class |
|---|---|---|
| A | 0 … 28 deg. C | IP23 |
| B | -20 … 40 deg. C | IP45 |
| C | -40 … 55 deg. C | IP45 |

The Energy sources available in the sites (power grid, genset, etc.) shall be reported in the tables of clause 8.




The estimation of the environmental impact from the energy consumption requires additional parameters to calculate for example greenhouse gas emissions or impact on the power grid dimensioning.

Power consumption and power supply measurements / reports shall include:

- Total electrical energy consumption of the site
- Total electrical energy consumption of the ICT equipment
- Total electrical energy supplied from the grid
- Peak power delivered from the grid
- Total energy supplied in other from than electricity
- Total amount of energy generated at the site, separated between production type (genset, solar, wind, fuel cell, etc.
- Total site energy storage capacity
- Peak shaving features available at the site

## 5.2 Performance metrics

The Mobile Network performance metrics is derived from parameters of the MN under investigation (see clause 4) relevant for energy efficiency, in particular the total data volume ($DV_{MN}$) delivered by all its equipment and its global coverage area ($CoA_{MN}$).

For packet switched services, $DV_{MN}$ is defined as the data volume delivered by the equipment of the mobile network under investigation during the time frame T of the energy consumption assessment. The assessment process defined in clause 6 shall be used.

$$DV_{MN-PS} = \sum_{i,k} DV_{BS_{i,k}-PS} \quad (2)$$

where DV, measured in bit, is the performance delivered in terms of data volume in the network over the measurement period T (see clause 6). *i* and *k* are defined in formula (1).

For circuit switched services like voice, $DV_{MN\text{-}CS}$ is defined as the data volume delivered by the equipment of the mobile network under investigation during the time frame T of the energy consumption assessment.

$$DV_{MN-CS} = \sum_{i,k} DV_{BS_{i,k}-CS} \quad (3)$$

where DV, measured in bit, is the performance delivered in terms of data volume in the network over the measurement period T (see clause 6). *i* and *k* are like in formula (1).

Note that by "circuit switched", we mean here all voice, interactive services and video services managed by the MNOs, including CS voice, VoLTE and real-time video services delivered through dedicated bearers. The assessment process defined in clause 6 shall be used.

The overall data volume is computed as follows:

$$DV_{MN} = DV_{MN-PS} + DV_{MN-CS} \quad (4)$$

$DV_{MN}$ can be derived from standard counters defined in ETSI TS 132 425 [3] and ETSI TS 132 412 [4] for LTE or equivalent used for 2G and 3G, multiplying by the measurement duration T. The counters (in ETSI TS 132 425 [3] and ETSI TS 132 412 [4]) account also for QoS being reported in QoS Class Identifier (QCI) basis (see ETSI TS 123 203 [5]).

NOTE 1: $DV_{MN}$ includes data volumes for DL and UL.

NOTE 2: BH supervision and control data volumes are not considered (in order to include only the payload).

$DV_{MN}$ is computed in bit.

Coverage area ($CoA_{MN}$) is also considered as a mobile network performance metric in the MN designed primarily for coverage goals (and hence especially in RU environments). The assessment process defined in clause 6 shall be used. CoA is computed in $m^2$.

## 5.3 Mobile Network Energy efficiency metrics

Mobile Network data Energy Efficiency ($EE_{MN,DV}$) is the ratio between the performance indicator ($DV_{MN}$) and the energy consumption ($EC_{MN}$) when assessed during the same time frame.

$$EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}} \quad (5)$$

where $EE_{MN,DV}$ is expressed in bit/J.

Mobile Network coverage Energy Efficiency ($EE_{MN,CoA}$) is the ratio between the area covered by the MN under investigation (see clause 4) and the energy consumption when assessed during one year. $EE_{MN,CoA}$ is mainly used to complement $EE_{MN,DV}$ for MNs handling low data volumes, in particular in rural or deep rural areas. The area covered shall be assessed using rules (i.e. derived from geographic data or propagation models) defined in clause 6:

$$EE_{MN,CoA} = \frac{\mathrm{CoA_des_{MN}}}{EC_{MN}} \quad (6)$$

where $EE_{MN,CoA}$ is expressed in m²/J and $EC_{MN}$ is the yearly energy consumption and $\mathrm{CoA_des_{MN}}$ is the "coverage area" as defined in clause 6.2.3.

# 6 Measurement of energy efficiency

## 6.0 Introduction of clause

The measurement of the $EE_{MN}$ in the MN under investigation shall be based on the separate measurement of the performance (in terms of capacity and coverage) and energy, according to the metrics defined in clause 5.

## 6.1 Time duration of the measurement

The time duration of the measurement, denoted as T, shall be one of the alternatives:

- Weekly measurement: T equal to 7 days.
- Monthly measurement: T equal to 30 days.
- Yearly measurement: T equal to 365 days.

The minimum duration is therefore one week: monthly and yearly measurements are extensions of the basic week test. For the CoA metric the Energy Consumption shall be always extrapolated to 1 year time.

**Comment [BMR3]:** SA5 understand "time duration of the measurement" as the duration between when the measurement starts and when it ends; it can be either 7 days, or 30 days, or 365 days. In addition to this, SA5 PM IRP uses the "granularity period", i.e. the time between the initiation of two successive gatherings of measurement data, and the "reporting period", i.e. the time between two successive reportings of measurement data. SA5 understanding is that, in the context of 203 228, "time duration of the measurement" is equal to "granularity period" and to "reporting period".

Has ETSI EE the same understanding?

**Comment [BMR4]:** The time duration of the measurement is the actual time during which measures are collected. It's a long time period (probably much longer that those mentioned by SA5) in order to catch all the energy consumptions effect typical of some days or of some periods in the weeks. So the time duration is NOT equal to granularity or reporting periods. ETSI does not request to specify a granularity and a reporting period, but they could be gathered as optional in the reporting tables

## 6.2 Measurement procedures

### 6.2.1 Measurement of Energy Consumption

The Energy Consumption of the MN can be measured by means of metering information provided by utility suppliers or by mobile network integrated measurement systems. Moreover, sensors can be used to measure site and equipment energy consumption, following the requirements set by ES 202 336/12.

The $EC_{MN}$ is based on site granularity and includes therefore all the equipment that is on the MNO sites (including the network controllers whenever applicable). The $EC_{MN}$ shall be differentiated per MNO providing service to the MN; in case of shared infrastructure the $EC_{MN}$ of the shared sites shall be computed per each MNO sharing those sites in a proportional ratio. In case of separate metering per MNO the respective part of the $EC_{MN}$ shall be assigned to each MNO.

The $EC_{MN}$ shall be based on a per RAT estimation. If in the site there are BS of different RATs the $EC_{MN}$ shall be measured per each RAT.

The list of equipment operating in the MN sites under investigation shall be reported in the assessment report, including cooling, power conversion, etc. For a site with multi RAT equipment the energy consumption of that equipment shall be split between each RAT proportionally to the configured RF power transmitted by each RAT; further details on the multi RAT will be issued according to the development of multi RAT measurement in ETSI ES 202 706 [i.2].

The reporting frequency of the $EC_{MN}$ should be aligned with the energy provider settings and mobile network performance assessment settings. It shall be reported in the assessment report.

NOTE: When a mobile network integrated measurement system according to ETSI ES 202 336-12 [9] is available, it should be used in addition to the utility provided $EC_{MN}$, allowing a more precise estimation of the consumption per RAT and per MNO.

### 6.2.2 Measurement of capacity

The $DV_{MN}$ shall be measured using network counters for data volume related to the aggregated traffic in the set of BS considered in the MN under test.

For PS traffic, the data volume is considered as the overall amount of data transferred to and from the users present in the MN under test. Data volume shall be measured in an aggregated way per each RAT present in the MN and shall be measured referring to counters derived from vendor O&M systems.

For CS traffic (e.g. CS voice or VoLTE), the data volume is considered as the number of minutes of communications during the observation period multiplied by the data rate of the corresponding service and the call success rate. The call success rate is equal to 1 minus the sum of blocking and dropping rates, i.e.:

$$Call\ Success\ Rate = (1 - blocking\ rate)(1 - dropping\ rate) \times 100\ [\%] \quad (7)$$

The blocking rates are computed using the O&M counters. They are composed of traffic channel (TCH) and signalling channels (SCH) blocking rates:

$$1 - \text{blocking rate} = (1 - \text{TCH blocking rate})(1 - \text{SCH blocking rate}) \quad (8)$$

The dropping includes the intra-cell call failure and the handover failure:

$$1 - \text{dropping rate} = (1 - \text{intracell failure rate})(1 - \text{handover failure rate}) \quad (9)$$

In order to include reliability in the measurement the aggregated data volume shall be provided together with the 95th percentile of the cumulative distribution, for each RAT in the MN.

NOTE 1: It is not possible for data services to determine a user related QoS, i.e. to identify for each data connection if a target throughput has been reached using counters. Such a computation would need the usage of probes that is out of scope of the present document.

NOTE 2: As soon as the MDT related measurements in [6] are available the data volume may be measured according to the specification given therein (especially referring to clause 4.1.8 in [6]). In this case, the per-user information about QoS can be obtained for data services and only connections with good QoS should be considered.

### 6.2.3 Determination of coverage area

*Note: this section is updated after EEPS48002r1 Change Request; integration with the other sections will be implemented in next draft version*

#### 6.2.3.0 Introduction

The Coverage area is subject to network planning and intended services delivered within a certain geographic area. These parameters vary according to an MNO strategy and might therefore differ from MNO to MNO but also within the network of one MNO for different geographical area. For the sake of energy efficiency assessment, drive tests and similar additional measurement campaigns are not required.

The coverage area shall be described by the following parameters:

1. The total geographical area of a country (CoA_geo). This includes the total geographical area which falls into the network operators responsibility (total network and/or sub-area under investigation). A network might

**Comment [BMR5]:** Is call success rate relevant in the calculation of data volume for CS traffic? SA5 thinks that, in case a call has not been successful, this is already reflected in the number of minutes of communication.
Please confirm.

**Comment [BMR6]:** Ok, we can remove (1-blocking rate) and keep (1-dropping rate) to indicate that some of these minutes were not "useful" due to dropping of the call (bad quality). Call attempts that fail do not generate minutes

**Comment [BMR7]:** Is "observation period" same as "time duration of the measurement" (cf. Section 6.1)?

**Comment [BMR8]:** yes

**Comment [BMR9]:** It's the rate of dropping calls due to all the causes not related to handover

**Comment [10]:** efinition of "intracell

**Comment [11]:** inition of "intracell

**Comment [12]:** ition of "intracell failure

**Comment [13]:** ion of "intracell failure

**Comment [14]:** n of "intracell failure

**Comment [15]:** of "intracell failure

**Comment [16]:** "intracell failure rate"

cover the geographical area only to a certain fraction (often defined by the license agreements, for example area coverage of a complete countrt or of a region).

2. The designated coverage area (CoA_des). This area defines the area in which a network coverage is provided by the selected sub-network and it's derived by planning models from network design, planned service and geographical data.
3. A coverage quality factor (CoA_Qdes). This factor takes into account measured feedback from user equipment (as described in table 7). This coverage quality factor signifies that networks might experience false coverage issues (e.g. inside buildings), load congestions or high interference issues.

List of abbreviations (to be moved to 3.2):

CoA_geo: total geographical area under investigation and within the operators license agreement

CoA_des: designated coverage area as designed by network planning

CoA_Qdes: quality factor describing how well users are covered withing the coverage area

#### 6.2.3.1 Geographic coverage area

The geographic coverage area is the total two dimensional area of a country, region or city were the MNO under test provides its service according to the license agreement. This area might be not completely covered by the network. A license agreement might include geographic coverage area (for example >90% of the country area shall be covered) and an additional population coverage area (for example 98% of the population shall be covered).

#### 6.2.3.2 Designated coverage area

The designated coverage area is the area to be covered based on network planning and presents the actual geographic are where the operator officially promises coverage. This area is defined by the MNO's network service plan 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 hardly comparable).

The designated coverage are 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

**Comment [17]:** intracell failure rate"

**Comment [18]:** tracell failure rate"

**Comment [19]:** acell failure rate" would

**Comment [20]:** ell failure rate" would

#### 6.2.3.4 Coverage quality

The actual coverage area where UEs can be served might differ from the originally planned 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. User equipment reports such as failed call attempts (table 7) 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) like shown in figure **Error! Reference source not found.** could be used the determine the fraction of the total area were a signal quality above a certain minimum value is achieved. However, such maps require a large amount of measurements and usually drive tests.

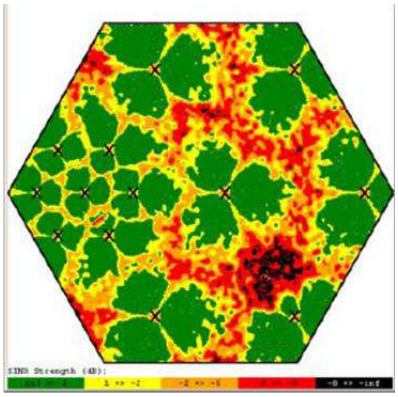


**Figure 2: Typical SINR distribution of a mobile network**

For the sake of an energy efficiency assessment it is not required to have the knowledge of the detailed network conditions such as the actual coverage hole locations. From an Energy Efficiency assessment point of view it is important to know how many users/sessions or served users/sessions experienced problems because of lack of sufficient quality in relation to the total number of users/sessions or served users/sessions within the considered area.

This allows a number of simplifications and an indirect determination of a quality factor.

The coverage quality factor (QF) for a base station is based on network failure reports of the UE.

The coverage quality factor shall be measured based on coverage failures reported by the appropriate network counters:

QF = 1 - "percentage of users/sessions with coverage failure" (10)

**Comment [21]:** l failure rate" would be

**Comment [22]:** failure rate" would be

**Comment [23]:** ilure rate" would be hel

The following indicators shall be used to calculate the coverage failure (details see table 7):

1) RRC setup failure ratio (Call setup failure ratio).

2) RAB setup failure ratio (UE-BS radio interface failure).

3) RAB release failure ratio (UE-BS radio interface failure).

A further factor which can indicate a coverage issue is the handover drop ratio. However, a handover drop can have multiple reasons (cell overload, UE speed, etc.). Furthermore, the handover drop rate depends on the network structure (number of neighbour cells). Its calculation requires several additional network parameters and complicates the data collection and analysis significantly. This factor is therefore omitted.

The coverage quality factor for a site is defined as follows:

$$QF_S = (1 - \text{RRC setup failure ratio})\,(1 - \text{RAB setup failure ratio})\,(1 - \text{RAB release failure ratio}) \qquad (11)$$

The needed parameters are specified by 3GPP standards and the results can be obtained from the network management and supervision.

The failure ratios are the fraction of failures of the total amount of attempts:

- RRC setup failure ratio = ($\Sigma_k$ Failed RRC connection establishments$_k$)/($\Sigma_k$ Attempted RRC connection establishments$_k$).
- RAB setup failure ratio = ($\Sigma_k$ RAB setup failure$_k$)/ ($\Sigma_k$ RAB setup attempted$_k$).
- RAB release failure ratio = ($\Sigma_k$ RAB release failure$_k$)/ ($\Sigma_k$ RAB release attempted$_k$).

where *k* is the index spanning over the number of BSs in the considered site.

**Table 7: Measurement parameters required for coverage qualitycalculation (refer to [7], [8] and [3] for 2G, 3G and 4G definition/source reference respectively)**

Comment [24]: ure rate" would be hel

| | | |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Comment [25]: e rate" would be hel

Measurement for LTE

| Parameter | Function | Counter name |
|---|---|---|
| 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* |

Measurements for UMTS:

| Parameter | Function | Counter name |
|---|---|---|
| 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*,<br>RAB.FailEstabCSQueuing.*sum* |
| | RAB setup for PS domain | RAB.FailEstabPSNoQueuing.*sum*<br>RAB.FailEstabPSQueuing.*sum* |
| RAB setup attempts | RAB setup for CS domain | RAB.AttEstabCS.Conv.<U><D><br>RAB.AttEstabCS.Strm<br>RAB.AttEstabCS.Intact<br>RAB.AttEstabCS.Bgrd |
| | RAB setup for PS domain | RAB.AttEstabPS.Conv<br>RAB.AttEstabPS.Strm.<U><D><br>RAB.AttEstabPS.Intact<br>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* |

Measurement fro GSM:

| Parameter | Function | Counter name |
|---|---|---|

| | | |
|---|---|---|
| Immediate assignment success | IMMEDIATE ASSIGNMENT | succImmediateAssingProcs |
| Immediate assignment attempts | IMMEDIATE ASSIGNMENT | attImmediateAssingProcs |

The following averaging procedure is then used to obtain an average coverage quality factor of the partial network under test:

$$\mathrm{CoA_Qdes_{MN}} = \sum_i \mathrm{QF_{S_i}} \mathrm{DCA_{S_i}} / \sum_i \mathrm{DCA_{S_i}} \quad (12)$$

where:

- S refers to the sites in the MN under measurement;
- *i* is an index spanning over the number of sites.

To avoid overcounting, the sites designed coverage areas should be defined as the area where the signals from the cells of the site are stronger (Best Server). It holds true that:

$$\mathrm{CoA_des_{MN}} = \sum_i \mathrm{DCA_{S_i}} \leq \mathrm{CoA_geo} \quad (13)$$

where:

- S refers to the sites in the MN under measurement;
- *i* is an index spanning over the number of sites.

**Comment [26]:** te" would be hel

**Comment [29]:** would be hel

# 7 Extrapolation for overall networks

## 7.0 Extrapolation approach

The EE measured according to clauses 5 and 6 can be used to extrapolate to larger networks. When such an extrapolation is made, it shall be performed following the method presented in this clause.

The sub-network data shall be extrapolated to overall/total networks according to demography, topography and climate classifications, as described in clause 4.

The extrapolation shall be done according to statistical information that indicates how recurrent is the sub-network within the total network to be addressed.

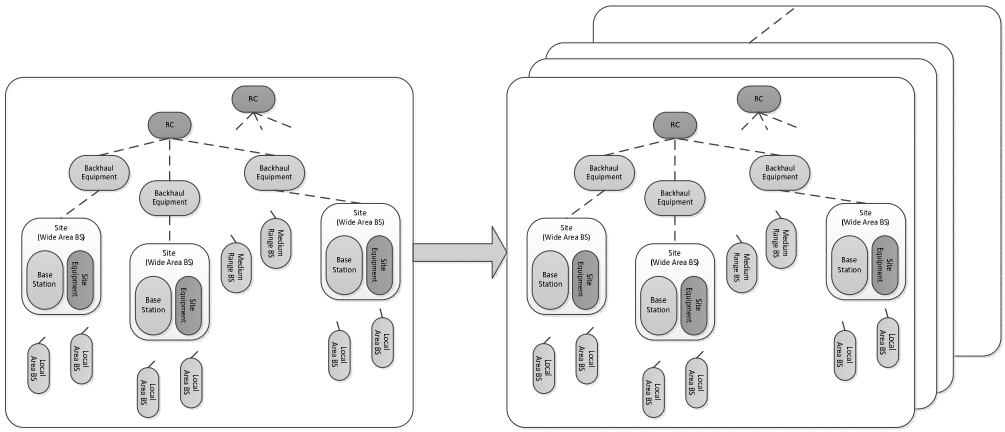



**Figure 3: Extrapolation from one sub-network to a set of sub-networks ("total" network)**

# 7.1 Extrapolation method

## 7.1.0 Introduction of extrapolation method

In case the overall/total network to be addressed is not completely known in terms of demographical, topographical or climatological composition, or if the measurements of clause 5 and 6 are executed only in some and not all the sub-networks constituting the total network, then the results shall be presented according to the tables in clause 8.

In such a case it shall be indicated for each sub-network what is its percentual recurrence with respect to the global one, in terms of demographical, topographical and climatological composition. Otherwise, if the exact composition of the total network is completely known, then the extrapolation shall be made to achieve the information valid for the whole total network.

- The extrapolation procedure shall be based on the demography information classes as reported in table 2. It is optional to make extrapolation also based on topography classes (table 3) or on climate classes (table 4) or on a combination of demography, topography and climate zones.
- The extrapolation shall be based on a demography number of classes sufficient to represent at least the 75 % of the entire total network area demographical distribution.

Next clauses show how to obtain data on the statistical distribution of demography, topography and climate zones classes in the networks under test at total level. This information is given to be used as a reference for every network area where the present specification will be used.

## 7.1.1 Statistical information about Demography

An example of demographical information for Europe can be found in ETSI TS 132 425 [3], to classify the sub-network under test under a demography class as in table 2.

Another example referring to UN information is in ETSI TS 132 412 [4]. Still another example for USA can be found in ETSI TS 123 203 [5].

## 7.1.2 Statistical information about Topography

An example of topography information can be found at the FAO world median slope distribution information, to classify the sub-network under test under a demography class as in table 3.

## 7.1.3 Statistical information about Climate zones

An example of topography information can be found in FAO Koeppen classification, to classify the sub-network under test under a demography class as in table 4.

## 7.2 Extrapolation reporting tables

### 7.2.0 Introduction of extrapolation reporting tables

Table 8 indicates how to report the data for extrapolation towards total EE based on demography only. This is the mandatory approach when extrapolation data are computed. Not all the classes shall be measured, but only those classes that allow to cover at least 75 % of the whole demographical distribution of the total area under measurement.

For all the sub-networks the results of EE are reported according to clause 8 tables and the relative class shall be indicated. For all the same class measurement an average of EE measurements shall be reported in table 8; this shall be done both for Data Volume EE and for Coverage Area EE, whichever metric is used.

For each class then an average EE shall be computed as follows:

$$EE_{class,av} = \frac{\sum_k EE_{MN,k}}{K} \tag{14}$$

where "class" stands for one of the Demography Classes (DU, U, SU, RU or Unpopulated), *k* is an index that runs over the number K of sub-networks per each class.

The Total EE shall be computed as a weighted sum of all the averages available, the weights being the percentage of each demography class versus the sum of the available classes percentages. These percentages shall be derived from the information according to the examples of clause 7.1.

The Total EE shall be then computed as follows:

$$EE_{total} = \frac{\sum_m PofP_m EE_{class,av,m}}{\sum_m PofP_m} \tag{15}$$

where $PofP_m$ is the percentage of presence of the m-th demography class in the network under test, *m* is an index spanning over the number of classes and $EE_{class,av,m}$ is the m-th average as computed in (14).

### 7.2.1 Reporting extrapolation based on Demography

The reporting extrapolation method based on demography is summarized in table 8.

**Table 8: Reporting extrapolation Table based on Demography**

| Demography Classification | Percentage of presence (PofP) in the total Network area of the class | $EE_{MN}$ in the class | |
|---|---|---|---|
| | | $EE_{MN,DV}$ | $EE_{MN,CoA}$ |
| Dense Urban (DU) | $PofP_{DU}$ [%] | $EE_{DU,av}$ | $EE_{DU,av}$ |
| Urban (U) | $PofP_{U}$ [%] | $EE_{U,av}$ | $EE_{U,av}$ |
| Sub-urban (SU) | $PofP_{SU}$ [%] | $EE_{SU,av}$ | $EE_{SU,av}$ |
| Rural (RU) | $PofP_{RU}$ [%] | $EE_{RU,av}$ | $EE_{RU,av}$ |
| Unpopulated | $PofP_{Unp}$ [%] | $EE_{Unp,av}$ | $EE_{Unp,av}$ |
| **Total EE** | | $EE_{total,DV}$ | $EE_{total,CoA}$ |

Demography table is the mandatory extrapolation representation. In case also the Topography and Climate Zone classification is available for the sub-networks measured according to clause 8 also table 9 and table 10 are to be reported.

### 7.2.2 Reporting extrapolation based on Topography

The reporting extrapolation method based on topography is summarized in table 9.

**Table 9: Reporting extrapolation Table based on Topography**

| Topography classification | Percentage of presence (PofP) in the total Network area of the class | $EE_{MN}$ in the class | |
|---|---|---|---|
| | | $EE_{MN,DV}$ | $EE_{MN,CoA}$ |
| 1 Flat (FAO 1-3) | $PofP_{Flat}$ [%] | $EE_{Flat,av}$ | $EE_{Flat,av}$ |
| 2 Rolling (FAO 4-6) | $PofP_{Roll}$ [%] | $EE_{Roll,av}$ | $EE_{Roll,av}$ |
| 3 Mountainous (FAO 7-8) | $PofP_{Mount}$ [%] | $EE_{Mount,av}$ | $EE_{Mount,av}$ |
| **Total EE** | | $EE_{total,DV}$ | $EE_{total,CoA}$ |

### 7.2.3 Reporting extrapolation based on Climate zones

The reporting extrapolation method based on climate zones is summarized in table 10.

**Table 10: Reporting extrapolation Table based on Climate zones**

| Climate zone classification | Percentage of presence (PofP) in the total Network area of the class | $EE_{MN}$ in the class | |
|---|---|---|---|
| | | $EE_{MN,DV}$ | $EE_{MN,CoA}$ |
| A Tropical | $PofP_{Trop}$ % | $EE_{Trop,av}$ | $EE_{Trop,av}$ |
| B Dry | $PofP_{Dry}$ % | $EE_{Dry,av}$ | $EE_{Dry,av}$ |
| C Temperate | $PofP_{Temp}$ % | $EE_{Temp,av}$ | $EE_{Temp,av}$ |
| D Cold | $PofP_{Cold}$ % | $EE_{Cold,av}$ | $EE_{Cold,av}$ |
| E Polar | $PofP_{Polar}$ % | $EE_{Polar,av}$ | $EE_{Polar,av}$ |
| **Total EE** | | $EE_{total,DV}$ | $EE_{total,CoA}$ |

# 8 Assessment report

## 8.0 Introduction of assessment 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 report shall include tables defined in clauses 8.1 to 8.3. Items in italics can be considered optional.

Further guidelines on the test report can be found in clause 5.10 of ISO/IEC 17025 [10].

## 8.1 Report of Network Area under test

Table 11 reports the details of the Network Area under test, representing a sub-network where the measurements are conducted. The Network Area is the area encompassing all the sites under measurement; the $CoA_des_{MN}$ is instead computed starting from the area covered by each site (as per clause 6) and aggregating for all the sites in the Network Area under test.

For each site reported in table 11 the details shall be included in table 3. Table 4 reports the measurements results for each site.

**Table 11: Report of Network Area under test**

| **Network Area under test** | | |
|---|---|---|
| Demography class<br>[Dense Urban, Urban, Suburban, Rural, Sparse] [table 2] | | |
| Topography class [table 3] | | |
| Climate zone [table 4] | | |
| Informative classification [tables 5 and 6] | | |
| Network Area definition<br>[by Demography, by Geography, by Topology] | | |
| | *Number of inhabitants in the Network area*<br>*[estimate]* | |
| | Network Area dimensions<br>[estimate, km²] | |
| | Number of sites in the Network Area<br>[same radio controller?] | |
| Type of sites in the Network Area | | |
| | Number of Wide Area BS sites | |
| | Number of Medium Range BS sites | |
| | Number of other sites/equipment<br>(Local Area BS, relay nodes, etc.) | |
| Sites categorization | | |
| | Number of sites in an MNO<br>local exchange premise | |
| | Number of sites in buildings not owned by MNO | |
| | Number of sites in a shelter | |
| | *Number of any other sites* | |
| Multi-MNO sites | | |
| | Number of "single MNO" sites | |
| | Number of co-located multi-MNOs sites | |
| | Number of sites in "Network Sharing" mode | |
| Multi-technology sites | | |
| | Number of 2G only sites | |
| | Number of 3G only sites | |
| | Number of LTE only sites | |
| | Number of 2G+3G sites | |
| | Other options [indicate] | |
| Backhauling information | | |
| | Predominant type of backhauling<br>[wireless, fibre, copper…] | |
| | Number of backhauling links per type | |
| Energy efficiency in the Network Area | | |
| | $EE_{MN,DV}$ [b/J] | |
| | $EE_{MN,CoA}$ [$m^2$/J] | |
| Energy efficiency top-down approach results (see note) | | |
| NOTE: In case any alternative EE approach has been conducted on the network under test (i.e. measuring the aggregated energy consumption and the aggregated data volume or coverage area) the results of the evaluation shall be reported here for comparison purposes. | | |

## 8.2 Report of sites under test

**Table 12: Report of sites under test**

| **Site(s) under test in the Network Area (one table per site type to be measured in the Network Area)** | | |
|---|---|---|
| Measurement duration | | |
| | Time duration of the measurement [T] | |
| | *Measurement start date and time* | |
| | *Measurement finish date and time* | |
| Type of site | | |
| | Site "layer"<br>[Wide Area, Medium Range, other]<br>In case of Wide Area, indicate number of sectors and carriers per sector | |
| | Site "technology"<br>[2G, 3G, 2G+3G, LTE only, 2G+3G+LTE, other] | |
| | Site "MNOs"<br>[single MNO, co-location, network sharing, other] | |
| *Site and equipment age*<br>• *Initial commission date of the site*<br>• *Commission date of the current equipment in the site* | | |
| *Temperature*<br>• *Average temperature [over period T]*<br>• *Minimum temperature*<br>• *Maximum temperature* | *Internal °C* | *External °C* |
| *Environmental class Temp. range IC class*<br>*A 0 … 28 deg. C IP23*<br>*B -20 … 40 deg. C IP45*<br>*C -40 … 55 deg. C IP45* | | |
| Site infrastructure | | |
| | Site location<br>[local exchange premise, building, shelter, other] | |
| | Site composition | |
| | • Air conditioners | |
| | • Rectifiers/batteries | |
| | • Fixed network equipment consumption | |
| | • Other | |
| | *Estimated percentage of infrastructure consumption in the site ($EC_{si}$)* | |

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| | | |
|---|---|---|
| Energy consumption of ICT equipment in the site [Wh] | | |
| Energy consumption of all the support equipment in the site [Wh] | | |
| Energy efficiency in the site equipment (Energy_ICTequipment / Energy_Total_network) | | |
| - Total electrical energy supplied from the grid<br>- Peak power delivered from the grid<br>- Total site energy storage capacity<br>- Peak shaving features available at the site | | |
| Energy Efficiency Enhancement methods affecting the site equipment during the test | | |
| *Estimated percentage of presence of this site type in the Network Area* | | |
| Electricity sources used in the site | | |
| | Electricity [%] | |
| | Genset [%] | |
| | Solar [%] | |
| | Renewables [%] | |
| | Others (indicate) | |

## 8.3 Report of Site measurement

**Table 13: Report of Site measurement**

| **Site measurement** | | |
|---|---|---|
| Measurement duration | | |
| | Time duration of the measurement [T] | |
| | *Measurement start date and time* | |
| | *Measurement finish date and time* | |
| Temperature class and average temperature during the test | | |
| Energy consumption in the site | | |
| | Method of measurement [energy bills/counters, sensors, equipment information, other] | |
| | Measured energy consumption $EC_{MN}$ [Wh or multiples] | |
| | • Week energy consumption [per week data/graph] | |
| | • *Month energy consumption [if T allows]* | |
| | • *Year energy consumption [if T allows]* | |
| Traffic offered in the site | | |
| | Method of measurement [operational counters, backhauling data, MDT, other] | |
| | Measured traffic volume DV[bit 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 RAT present in the site] | | |
| | CoA_geo: [$km^2$] | |
| | CoA_des: [$km^2$] | |
| | CoA_Qdes: | |
| | • Failed RRC connection establishments<br>• Attempted RRC connection establishments<br>• RAB setup failure<br>• RAB setup attempted<br>• RAB release failure<br>• RAB release attempted | |
| Site Energy efficiency | | |
| | Measured Energy Efficiency $EE_{MN}$ [bit/J] and [$m^2$/J] | |
| | • Weekly Energy Efficiency [per week data/graph] | |
| | • *Monthly Energy Efficiency [if T allows]* | |
| | • *Yearly Energy Efficiency [if T allows]* | |

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# 9 Implementation guidelines

The present document is based on the Mobile Network Area definition under test as described in clause 4, where measurements have to be done according to the metrics as defined in clause 5 and following the procedures as defined in clause 6. In this way the network under test is evaluated in terms of energy efficiency and the results obtained therein are to be filled in the tables reported as an essential part of the specification in clause 8.

Extrapolation of sub-network results can be used for the assessment of larger networks, in particular when measurement over the whole total network is not possible due to its dimensions. In this case, the extrapolation approach defined in clause 7 shall be used.

Attention has to be paid to the selection of the sub-networks where to make the measurements, to ensure that the results are technically sound and, even if this is not the primary goal, comparable. Of course results measured in very different environments (different in terms of demography or climatology or topography, but also different due to the goal and function of the network) are hardly comparable and, as said, the purpose of the specification is not to make comparable what is not. But the important issue is to introduce a method to make tests that can represent a common reference whenever a test of mobile network energy efficiency is performed over a radio access network.

In case one network is tested against itself in different time periods a comparison could be sensible only considering with the due attention all the parameters listed in the Tables of Clause 8, especially referring to temperatures and environmental conditions to be aware of the possible reasons for change in the energy efficiency. Of course when considering these parameters the accuracy of the measurements has to be reported as well, in order to ensure the utmost consistency of measurements made in different periods.

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If in given regions there are regulation constraints that impose some rules in the deployment of networks this has to be kept in mind when making any comparison. In such cases only comparison of networks with the same constraints are sensible.

Regarding the time duration T of the measurements campaigns, the period of the measurements has to be chosen in the most sensible way in terms of particular foreseeable traffic conditions, weather impacts, and so on.

An essential part of this common base method is represented by the tables in clause 8. Even in very different scenarios these tables are to be filled in completely in order to have the measurement accepted and standard-based. In such a way even if the measurements are done in very different scenarios the details of the scenarios are reported in the tables and only considering not only the final Energy Efficiency results but also how they have been obtained the test will be considered standard compliant.

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# Annex A (informative): Implementation examples

## A.1 Implementation examples

Considering the Implementation guidelines reported in clause 9 a set of examples on how to implement the present document is given in this clause.

As an example, a possible application of the present document is to provide National Authorities a commonly accepted procedure to estimate at national, regional or city level the efficiency of a Radio Access Technology or a set of RATs deployed by an MNO or a set of MNOs. This assessment can be stand alone, just to know what is the efficiency reasonably achievable, or can be estimated towards a given threshold, to ensure that hopefully better efficiency is achieved (as an example after the introduction of new energy savings procedures, or new hardware solutions).

As another example, the present document could be used to test the efficiency of a network year over year or in any case against a given time roadmap. The test can be performed over the same sub or total network, depending on the requirements, and over the network of the same MNO, in different period of time, i.e. year over year or in any case so as to emphasize a time evolution of the EE performances. Of course, even in this case, the full completion of the information in tables in clause 8 is mandatory to check under which conditions the tests have been performed.

As a final example, the present document could be used also without any extrapolation phase (as described in clause 7) whenever the purpose is to evaluate network functionalities that impact energy efficiency in a small network under test. In such a case the prsent document indicates a way how to proceed to compare such small networks when the mentioned functionalities are activated with respect to the baseline case, when the functionalities are not active.

## A.2 Examples of reporting data

In this clause an example of data to be filled in into tables of clause 8 and clause 7 is given. This example is for explanation purposes only and the data reported therein are not to be considered real or binding in any possible way.

Table A.1 is table 11 filled in with example data.

**Table A.1**

| **Network Area under test (Partial network #1)** | | |
|---|---|---|
| Demography class<br>[Dense Urban, Urban, Suburban, Rural, Sparse] [table 2] | Dense Urban | |
| Topography class [table 3] | Flat | |
| Climate zone [table 4] | Temperate | |
| Informative classification [tables 5 and 6] | DP, PSL | |
| Network Area definition<br>[by Demography, by Geography, by Topology] | Demography | |
| | *Number of inhabitants in the Network area*<br>*[estimate]* | 150 000 |
| | Network Area dimensions<br>[estimate, km²] | 15 $km^2$ |
| | Number of sites in the Network Area<br>[same radio controller?] | 30, of the same RC |
| Type of sites in the Network Area | | |
| | Number of Wide Area BS sites | 25 |
| | Number of Medium Range BS sites | 3 |
| | Number of other sites/equipment<br>(Local Area BS, relay nodes, etc.) | 2 |
| Sites categorization | | |
| | Number of sites in an MNO<br>local exchange premise | 5 |
| | Number of sites in buildings not owned by MNO | 20 |
| | Number of sites in a shelter | |
| | *Number of any other sites* | 5 |
| Multi-MNO sites | | |
| | Number of "single MNO" sites | 20 |
| | Number of co-located multi-MNOs sites | 8 |
| | Number of sites in "Network Sharing" mode | 2 |
| Multi-technology sites | | |
| | Number of 2G only sites | 0 |
| | Number of 3G only sites | 10 |
| | Number of LTE only sites | 5 |
| | Number of 2G+3G sites | 10 |
| | Other options [indicate] | 5 2G+3G+LTE |
| Backhauling information | | |
| | Predominant type of backhauling<br>[wireless, fibre, copper…] | Fibre, copper |
| | Number of backhauling links per type | 20 fibre, 10 copper |
| Energy efficiency in the Network Area | | |
| | $EE_{MN,DV}$ [b/J] | 180 b/J |
| | $EE_{MN,CoA}$ [$m^2$/J] | 3 $m^2$/MJ |
| Energy efficiency top-down approach results | | |
| | 100 bit/J | |

Table A.2 reports an example of a site in the Partial network #1 described in table A.1.

**Table A.2**

| **Site(s) under test in the Network Area (one table per site type to be measured in the Network Area)** | | |
|---|---|---|
| Measurement duration | | |
| | Time duration of the measurement [T] | 2 weeks |
| | *Measurement start date and time* | 2014/07/07 |
| | *Measurement finish date and time* | 2014/07/20 |
| Type of site | | |
| | Site "layer"<br>[Wide Area, Medium Range, other]<br>In case of Wide Area, indicate number of sectors and carriers per sector | Wide Area,<br>3 sectors<br>2 carriers each sector |
| | Site "technology"<br>[2G, 3G, 2G+3G, LTE only, 2G+3G+LTE, other] | 3G |
| | Site "MNOs"<br>[single MNO, co-location, network sharing, other] | Single MNO |
| *Site and equipment age*<br>*Initial commission date of the site*<br>*Commission date of the current equipment in the site* | | 2005/11/05 initial<br>2013/07/22 current equipment |
| *Temperature*<br>*Average temperature [over period T]*<br>*Minimum temperature*<br>*Maximum temperature* | *Internal °C*<br>*24,2 °C*<br>*18,8 °C*<br>*30,6 °C* | *External °C*<br>*28,3 °C*<br>*19,6 °C*<br>*36,4 °C* |
| Site infrastructure | | |
| | Site location<br>[local exchange premise, building, shelter, other] | Outdoor cabinet |
| | Site composition | |
| | • Air conditioners | Yes, 2 kW average power |
| | • Rectifiers/ batteries | Yes, both; 250 W average power |
| | • Fixed network equipment consumption | |
| | • Other | |
| | *Estimated percentage of infrastructure consumption in the site ($EC_{si}$)* | 50 % |
| Energy Efficiency Enhancement methods affecting the site equipment during the test | Traffic related power off of the second carrier | |
| *Estimated percentage of presence of this site type in the Network Area* | 33 % | |
| Electricity sources used in the site | | |
| | Mains/power grid [%] | 80 % |
| | Genset [%] | - |
| | Solar [%] | 20 % |
| | Other Renewables [%] | - |
| | Others (indicate) | - |

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Table A.3 reports the measurement in the site described in table A.2.

**Table A.3**

| **Site measurement** | | |
|---|---|---|
| Measurement duration | | |
| | Time duration of the measurement [T] | 2 weeks |
| | *Measurement start date and time* | 2014/07/07 |
| | *Measurement finish date and time* | 2014/07/20 |
| Temperature class and average temperature during the test | | |
| Class C, average internal temperature 24,2 °C | | |
| Energy consumption in the site | | |
| | Method of measurement [energy bills/counters, sensors, equipment information, other] | Sensors |
| | Measured energy consumption $EC_{MN}$ [Wh or multiples] | |
| | • Week energy consumption [per week data/graph] | *Introduce a graph of the kWh in the site, or a table of values, per each week, according to the time granularity of the available data* |
| | • *Month energy consumption [if T allows]* | NA |
| | • *Year energy consumption [if T allows]* | NA |
| Traffic offered in the site | | |
| | Method of measurement [operational counters, backhauling data, MDT, other] | Operational counters |
| | Measured traffic volume DV [bit or multiples] | |
| | • Week traffic [per week data/graph] | *Introduce a graph of the Gb in the site, or a table of values, per each week, according to the time granularity of the available data* |
| | • *Month traffic [if T allows]* | NA |
| | • *Year traffic [if T allows]* | NA |
| Coverage of the site [data to be reported per each RAT present in the site] | | |
| | CoA_geo: [$km^2$] | 0,5 |
| | CoA_des: [$km^2$] | 0,42 |
| | CoA_Qdes: | 84 % |
| | • Failed RRC connection establishments<br>• Attempted RRC connection establishments<br>• RAB setup failure<br>• RAB setup attempted<br>• RAB release failure<br>• RAB release attempted | 658<br>13 118<br>322<br>4 998<br>294<br>4 998 |
| Mobile Network Energy efficiency | | |
| | Measured Energy Efficiency [bit/J] | |
| | • Weekly Energy Efficiency [per week data/graph] | *Introduce a graph of the bit/J in the site, or a table of values, per each week, according to the time granularity of the available data* |
| | • *Monthly Energy Efficiency [if T allows]* | NA |
| | • *Yearly Energy Efficiency [if T allows]* | NA |

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Table A.4 reports an example of computation results of a total Mobile Network Energy Efficiency assessment. The EE values are in the format of tables for Partial network 1, and other values are considered in other Partial networks in the same partial network area (not reported in this example) to come to the average values in the EE columns. The Total EE is evaluated in the measurement period T timeframe (2 weeks) for the DV case, while EC is extrapolated to 1 year as required for CoA EE metric.

**Table A.4**

| Demography Classification | Percentage of presence (PofP) in the total Network Area of the class | $EE_{MN}$ in the class | |
|---|---|---|---|
| | | $EE_{MN,DV}$ | $EE_{MN,CoA}$ |
| Dense Urban (DU) | 42 % | *200 b/J* | *2,7 $m^2$/MJ* |
| Urban (U) | 20 % | *40 b/J* | *19 $m^2$/MJ* |
| Sub-urban (SU) | 15 % | *8 b/J* | *38 $m^2$/MJ* |
| Rural (RU) | 13 % | *2 b/J* | *115 $m^2$/MJ* |
| Unpopulated | 10 % | *NA* | *NA* |
| **Overall/total EE** | | ***103,8 b/J*** | ***28,4 $m^2$/MJ*** |

In order to better clarify the example in table A.4 the following equations explain how to compute the Total EE in the cases mentioned above.

$$EE_{total,DV} = \frac{PofP_{DU} * EE_{DU,av} + PofP_U * EE_{U,av} + PofP_{SU} * EE_{SU,av} + PofP_{Unp} * EE_{Unp,av}}{PofP_{DU} + PofP_U + PofP_{SU} + PofP_{Unp}}$$
$$= \frac{42 * 200 + 20 * 40 + 15 * 8 + 13 * 2}{42 + 20 + 15 + 13} = 103{,}8\ b/J$$

$$EE_{total,CoA} = \frac{PofP_{DU} * EE_{DU,av} + PofP_U * EE_{U,av} + PofP_{SU} * EE_{SU,av} + PofP_{Unp} * EE_{Unp,av}}{PofP_{DU} + PofP_U + PofP_{SU} + PofP_{Unp}}$$
$$= \frac{42 * 2{,}7 + 20 * 19 + 15 * 38 + 13 * 115}{42 + 20 + 15 + 13} = 28{,}4\ m^2/MJ$$

Note that in the CoA case the extrapolation has been made from T = 14 days to 1 year dividing by 26 the results during period T (365/14~26).

# Annex B (informative): Cloud RAN energy efficiency

The objective of this annex is to provide the minimum information on definitions and principles to be used for the assessment of energy efficiency of Cloud RAN (CRAN) networks. Further details on the CRAN architecture and implementation of EECRAN assessment are still under investigation (e.g. SooGreen EU research project) and can be provided in future revisions of this international standard as appropriate.

## B.1 Generic CRAN architecture layout and definitions

As far as energy efficiency assessment is concerned, the generic architecture of CRAN can be divided in 3 domains: central cloud, edge cloud and radio access. The generic layout design is defined in Figure 4.

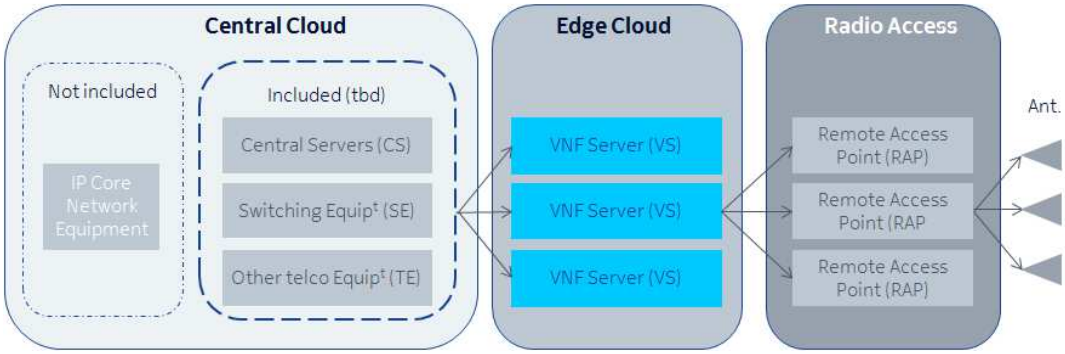


**Figure 4: Generic CRAN architecture layout**

The Radio Access (RA) domain is consisting of the Remote Access Points (RAP) dedicated to the CRAN under investigation. A typical RAP would include the radio, baseband and optical transport equipment. It would perform real time eNB tasks (e.g. Scheduler). It is installed near the transmitting antennas (e.g. within 1 m to 1 km). The density of RAP's deployed for CRAN would vary with different implementations but would be typically be of a few RAP units per 10 km². A typical value of RAP energy efficiency is: SEERAP = 90%.

The Edge Cloud (EDC) domain is consisting of small datacenters dedicated to telecom functions, including Virtualized Network Functions (VNF) Servers (VNFS) used by the CRAN under investigation. A typical EDC datacenter would perform non-real time eNB tasks, such as Operations, Administration and Maintenance (OAM). The density of EDC datacenters deployed for CRAN would vary with different network configurations but would typically be of a few units per 100 km². A typical value of Edge Cloud site energy efficiency is: SEEEDC = 75%.

The Central Cloud (CC) domain is consisting of a multi server datacenter (DC) including Central Servers (CS), Switching Equipment (SE) and other Telco Equipment (TE) if needed. IP Core network equipment should not be taken into account in the assessment of CRAN energy consumption. Central Cloud datacenters are usually very far from most of the served EDC. Their density would vary with different network configurations but would be typically be of a few units per 100,000 km². A typical value of Central Cloud site energy efficiency is: SEECC = 65%.

## B.2 Energy consumption and efficiency assessment

The following formulas should be used in the EE assessment:

- Data Volume

$$DV_{CRAN} = \sum_{RAP} (DV_{RAP-DL} + DV_{RAP-UL})$$

where $DV_{RAP-DL}$ and $DV_{RAP-UL}$ are the datavolume of the RAP for downlink (DL) and uplink (UL) respectively.

- Energy consumption:

$$EC_{CRAN} = \sum_{CC\ sites}\left(\sum_{site}(EC_{CS} + EC_{SE} + EC_{TE})\right)\Big/SEE_{CC} \cdot + \sum_{EDC\ sites}\left(\sum_{Site} EC_{VNFS}\right)\Big/SEE_{EDC} + \sum_{RAP} EC_{RAP}/SEE_{RAP}$$

- Energy efficiency:

$$EE_{CRAN} = DV_{CRAN}/EC_{CRAN}$$

# History

| Document history | | |
|---|---|---|
| V1.0.0 | January 2015 | Membership Approval Procedure MV 20150328: 2015-01-27 to 2015-03-30 |
| V1.1.1 | April 2015 | Publication |
| V1.1.2 | November 2015 | Added a new clause 6.2.3 |
| V1.1.3 | January 2016 | Added site impact assessment |
| V1.1.4 | May 2016 | Added Annex B and modified site assessment |
| | | |