



**Environmental Engineering (EE);  
Assessment of mobile network energy efficiency**

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Reference

DES/EE-EEPS005

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## Foreword

This final draft ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the ETSI standards Membership Approval Procedure.

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.

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## Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**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

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. 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.

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# 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.

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## 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.

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

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 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".

## 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 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".

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## 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

**telecommunication network:** network operated under a license granted by a national telecommunications authority, which provides telecommunications between Network Termination Points (NTPs)

## 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 <sub>MN</sub>	Data Volume of the Mobile Network
EC	Energy Consumption
EC <sub>MN</sub>	Energy Consumption of the Mobile Network
ECA	Effective Coverage Area
EE <sub>MN</sub>	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
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
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
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
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.

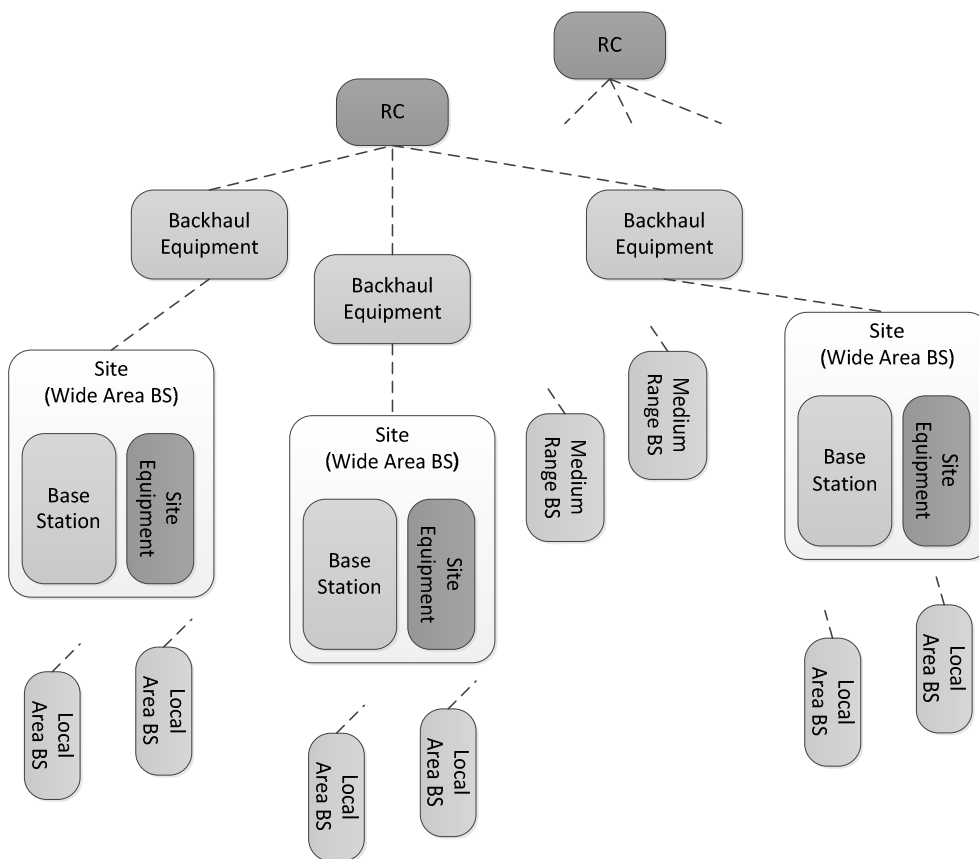


Figure 1: Network under test definition

## 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 <sub>MN</sub>	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/km <sup>2</sup> )	Population range (inhabitants/km <sup>2</sup> )
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/popsizesize2.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](http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_VISF_P40&prodType=table).

### 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 Flat (FAO 1-3)	0 - 5 %	Denmark, Netherlands
2 Rolling (FAO 4-6)	> 5 - 30 %	France, Italy
3 Mountainous (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/>.

### 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	<i>Temperature of the coldest month: &gt; 18 °C</i>	
	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	<i>Arid regions where annual evaporation exceeds annual precipitation, marked dry season</i>	
	Bs	Steppe climate
	Bs	Desert
C: Temperate	<i>Average temperature of the coldest month &lt; 18 °C and &gt; -3 °C, and average temperature of warmest month &gt; 10 °C</i>	
	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	<i>Average temperature of the warmest month &gt; 10 °C and that of coldest month &lt; -3 °C</i>	
	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	<i>Average temperature of the warmest month &lt; 10 °C</i>	
	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 Gomme, 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](http://www.fao.org/nr/climpag/globgrids/KC_commondata_en.asp).

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, >80 % of packages are small
PSL	PS - large packages dominating	> 50 % of data volume is PS, < 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.

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

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

## 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,  $DV_{MN-CS}$  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:

$$EE_{MN,CoA} = \frac{\text{coverage area}}{EC_{MN}} \quad (6)$$

where  $EE_{MN,CoA}$  is expressed in  $m^2/J$  and  $EC_{MN}$  is the yearly energy consumption.

## 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.

### 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.

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.:

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

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 95<sup>th</sup> 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

### 6.2.3.0 Introduction

Coverage area ( $CoA_{MN}$ ) 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.

The coverage area shall be described by two distinct methods:

- 1) Calculated coverage area derived from network design, planned service and geographical data.
- 2) Measured network coverage based on UE reporting.

#### 6.2.3.1 Geographic coverage area

The geographic network coverage area is the total two dimensional area intentionally covered by the selected sub-network. This area is defined by an MNO defined network service plans (minimum granted data rate/typical data rate, etc.) for the selected test area. The area is based on base station power, propagation conditions in the selected area and accepted outage criteria.

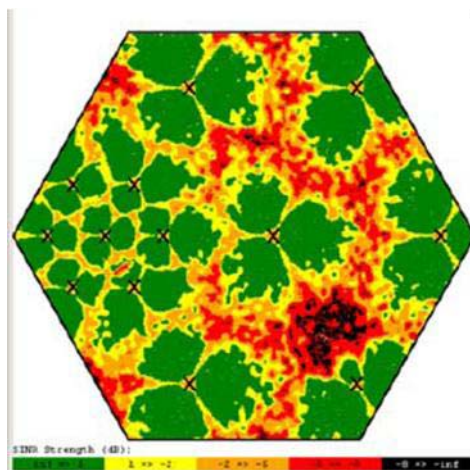
#### 6.2.3.2 Coverage ratio/effective coverage area

The actual coverage area might differ from the originally planned coverage area (i.e. coverage holes within the considered area). The coverage ratio is a measure to estimate the actually covered fraction of the planned total coverage area. User equipment reports such as signal strength and failed call attempts shall be used to more accurately determine the covered fraction. Drive tests and similar additional measurement campaigns should be avoided.

The coverage ratio/effective coverage area 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 2 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 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 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 coverage 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 the coverage ratio.

The coverage ratio (CR) for a base station is defined using the effective coverage area (ECA) and the designed coverage area (DCA) as:

$$CR = ECA / DCA \quad (10)$$

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

$$CR = 1 - \text{"percentage of users/sessions with coverage failure"} \quad (11)$$

The following indicators shall be used to calculate the coverage failure:

- 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 ratio is defined as follows:

$$CR = 1 - (1 - \text{RRC setup failure ratio}) (1 - \text{RAB setup failure ratio}) (1 - \text{RAB release failure ratio}) \quad (12)$$

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 = Failed RRC connection establishments/Attempted RRC connection establishments.
- RAB setup failure ratio = RAB setup failure/RAB setup attempted.
- RAB release failure ratio = RAB release failure/RAB release attempted.

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

Parameter	Function	Counter name
Failed RRC connection establishments	Radio resource control	RRC.ConnEstabFail.sum
Attempted RRC connection establishments	Radio resource control	RRC.ConnEstabAtt.sum
RAB setup failure	Initial context setup attempt	RAB.EstabInitFailNbr.sum
RAB setup attempted	Initial context setup attempt	ERAB.EstabInitAttNbr.sum
RAB release failure	RAB release	RAB.RelFailNbr.sum
RAB release attempted	RAB release	ERAB.RelAttNbr.sum

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

$$CR_{MN} = \sum_{i,k} CR_{BS_{i,k}} DCA_{BS_{i,k}} / \sum_{i,k} DCA_{BS_{i,k}} \quad (13)$$

where:

- BS refers to the Base Stations in the MN under measurement;
- $i$  is an index spanning over the number of sites;
- $k$  is the index spanning over the number of BSs in the  $i$ -th site.

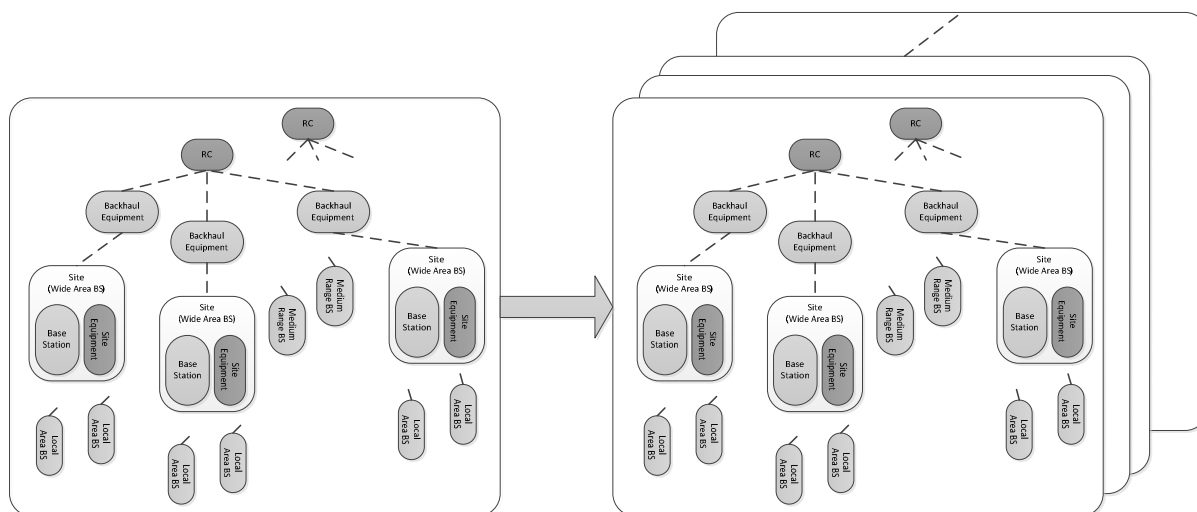
## 7 Extrapolation for overall networks

### 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:

$$EE_{class,av} = \frac{\sum_k EE_{MN,k}}{K} \quad (14)$$

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:

$$EE_{total} = \frac{\sum_m PofP_m EE_{class,av,m}}{\sum_m PofP_m} \quad (15)$$

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

Table 8 the reporting extrapolation method based on demography is summarized.

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

Demography Classification	Percentage of presence (PofP) in the total Network area of the class	EEMN in the class	
		EEMN,DV	EEMN,CoA
Dense Urban (DU)	PofP <sub>DU</sub> [%]	$EE_{DU,av}$	$EE_{DU,av}$
Urban (U)	PofP <sub>U</sub> [%]	$EE_{U,av}$	$EE_{U,av}$
Sub-urban (SU)	PofP <sub>SU</sub> [%]	$EE_{SU,av}$	$EE_{SU,av}$
Rural (RU)	PofP <sub>RU</sub> [%]	$EE_{RU,av}$	$EE_{RU,av}$
Unpopulated	PofP <sub>Unp</sub> [%]	$EE_{Unp,av}$	$EE_{Unp,av}$
<b>Total EE</b>		$EE_{total,DV}$	$EE_{total,CoA}$

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

Table 9 the reporting extrapolation method based on topography is summarized.

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

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

## 7.2.3 Reporting extrapolation based on Climate zones

Table 10 the reporting extrapolation method based on climate zones is summarized.

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 <sub>MN</sub> in the class	
		EE <sub>MN,DV</sub>	EE <sub>MN,CoA</sub>
A Tropical	PofP <sub>Trop</sub> %	<i>EE<sub>Trop,av</sub></i>	<i>EE<sub>Trop,av</sub></i>
B Dry	PofP <sub>Dry</sub> %	<i>EE<sub>Dry,av</sub></i>	<i>EE<sub>Dry,av</sub></i>
C Temperate	PofP <sub>Temp</sub> %	<i>EE<sub>Temp,av</sub></i>	<i>EE<sub>Temp,av</sub></i>
D Cold	PofP <sub>Cold</sub> %	<i>EE<sub>Cold,av</sub></i>	<i>EE<sub>Cold,av</sub></i>
E Polar	PofP <sub>Polar</sub> %	<i>EE<sub>Polar,av</sub></i>	<i>EE<sub>Polar,av</sub></i>
<b>Total EE</b>		<i>EE<sub>total,DV</sub></i>	<i>EE<sub>total,CoA</sub></i>

## 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 (Coverage Area) is instead computed starting from the area covered by each site 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 [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 [by Demography, by Geography, by Topology]		
	Number of inhabitants in the Network area [estimate]	
	Network Area dimensions [estimate, km <sup>2</sup> ]	
	Number of sites in the Network Area [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 (Local Area BS, relay nodes, etc.)	
Sites categorization		
	Number of sites in an MNO 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 [wireless, fibre, copper...]	
	Number of backhauling links per type	
Energy efficiency in the Network Area		
	EE <sub>MN,DV</sub> [b/J]	
	EE <sub>MN,CoA</sub> [m <sup>2</sup> /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" [Wide Area, Medium Range, other] In case of 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 <ul style="list-style-type: none"> <li>Initial commission date of the site</li> <li>Commission date of the current equipment in the site</li> </ul>		
Temperature <ul style="list-style-type: none"> <li>Average temperature [over period T]</li> <li>Minimum temperature</li> <li>Maximum temperature</li> </ul>	Internal °C	External °C
Site infrastructure		
	Site location [local exchange premise, building, shelter, other]	
	Site composition <ul style="list-style-type: none"> <li>Air conditioners</li> <li>Rectifiers/batteries</li> <li>Fixed network equipment consumption</li> <li>Other</li> </ul>	
	Estimated percentage of infrastructure consumption in the site ( $EC_{si}$ )	
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]	
	<i>Measurement start date and time</i>	
	<i>Measurement finish date and time</i>	
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]	
	<ul style="list-style-type: none"> <li>• Week energy consumption [per week data/graph]</li> <li>• <i>Month energy consumption [if T allows]</i></li> <li>• <i>Year energy consumption [if T allows]</i></li> </ul>	
Traffic offered in the site		
	Method of measurement [operational counters, backhauling data, MDT, other]	
	Measured traffic volume DV[bit or multiples]	
	<ul style="list-style-type: none"> <li>• Week traffic [per week data/graph]</li> <li>• <i>Month traffic [if T allows]</i></li> <li>• <i>Year traffic [if T allows]</i></li> </ul>	
Coverage of the site [data to be reported per each RAT present in the site]		
	Designed coverage area CoA [km <sup>2</sup> ]	
	Coverage Ratio [%]	
	Effective coverage area CoA [km <sup>2</sup> ]	
	<ul style="list-style-type: none"> <li>• Failed RRC connection establishments</li> <li>• Attempted RRC connection establishments</li> <li>• RAB setup failure</li> <li>• RAB setup attempted</li> <li>• RAB release failure</li> <li>• RAB release attempted</li> </ul>	
Site Energy efficiency		
	Measured Energy Efficiency $EE_{MN}$ [bit/J] and [m <sup>2</sup> /J]	
	<ul style="list-style-type: none"> <li>• Weekly Energy Efficiency [per week data/graph]</li> <li>• <i>Monthly Energy Efficiency [if T allows]</i></li> <li>• <i>Yearly Energy Efficiency [if T allows]</i></li> </ul>	

## 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.



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 present 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.

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### 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 [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 [by Demography, by Geography, by Topology]	Demography	
	<i>Number of inhabitants in the Network area [estimate]</i>	150 000
	Network Area dimensions [estimate, km <sup>2</sup> ]	15 km <sup>2</sup>
	Number of sites in the Network Area [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 (Local Area BS, relay nodes, etc.)	2
Sites categorization		
	Number of sites in an MNO local exchange premise	5
	Number of sites in buildings not owned by MNO	20
	Number of sites in a shelter	
	<i>Number of any other sites</i>	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 [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 <sup>2</sup> /J]	3 m <sup>2</sup> /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**

<b>Site(s) under test in the Network Area</b> <b>(one table per site type to be measured in the Network Area)</b>		
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" [Wide Area, Medium Range, other] In case of Wide Area, indicate number of sectors and carriers per sector	Wide Area, 3 sectors 2 carriers each sector
	Site "technology" [2G, 3G, 2G+3G, LTE only, 2G+3G+LTE, other]	3G
	Site "MNOs" [single MNO, co-location, network sharing, other]	Single MNO
Site and equipment age		
Initial commission date of the site		2005/11/05 initial
Commission date of the current equipment in the site		2013/07/22 current equipment
Temperature	Internal °C	External °C
Average temperature [over period T]	24,2 °C	28,3 °C
Minimum temperature	18,8 °C	19,6 °C
Maximum temperature	30,6 °C	36,4 °C
Site infrastructure		
	Site location [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)	-

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 <sub>MN</sub> [Wh or multiples]	
	<ul style="list-style-type: none"> <li>Week energy consumption [per week data/graph]</li> </ul>	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
	<ul style="list-style-type: none"> <li>Month energy consumption [if T allows]</li> </ul>	NA
	<ul style="list-style-type: none"> <li>Year energy consumption [if T allows]</li> </ul>	NA
Traffic offered in the site		
	Method of measurement [operational counters, backhauling data, MDT, other]	Operational counters
	Measured traffic volume DV [bit or multiples]	
	<ul style="list-style-type: none"> <li>Week traffic [per week data/graph]</li> </ul>	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
	<ul style="list-style-type: none"> <li>Month traffic [if T allows]</li> </ul>	NA
	<ul style="list-style-type: none"> <li>Year traffic [if T allows]</li> </ul>	NA
Coverage of the site [data to be reported per each RAT present in the site]		
	Designed coverage area CoA [km <sup>2</sup> ]	0,5
	Effective coverage area CoA [km <sup>2</sup> ]	0,42
	Coverage Ratio [%]	84 %
	<ul style="list-style-type: none"> <li>Failed RRC connection establishments</li> <li>Attempted RRC connection establishments</li> <li>RAB setup failure</li> <li>RAB setup attempted</li> <li>RAB release failure</li> <li>RAB release attempted</li> </ul>	658 13 118 322 4 998 294 4 998
Mobile Network Energy efficiency		
	Measured Energy Efficiency [bit/J]	
	<ul style="list-style-type: none"> <li>Weekly Energy Efficiency [per week data/graph]</li> </ul>	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
	<ul style="list-style-type: none"> <li>Monthly Energy Efficiency [if T allows]</li> </ul>	NA
	<ul style="list-style-type: none"> <li>Yearly Energy Efficiency [if T allows]</li> </ul>	NA

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	EEMN in the class	
		EEMN,DV	EEMN,CoA
Dense Urban (DU)	42 %	200 b/J	2,7 m <sup>2</sup> /MJ
Urban (U)	20 %	40 b/J	19 m <sup>2</sup> /MJ
Sub-urban (SU)	15 %	8 b/J	38 m <sup>2</sup> /MJ
Rural (RU)	13 %	2 b/J	115 m <sup>2</sup> /MJ
Unpopulated	10 %	NA	NA
<b>Overall/total EE</b>		<b>103,8 b/J</b>	<b>28,4 m<sup>2</sup>/MJ</b>

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

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

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

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).

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## History

<b>Document history</b>			
V1.0.0	January 2015	Membership Approval Procedure	MV 20150328: 2015-01-27 to 2015-03-30