



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

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Contents

Intellectual Property Rights	5
Foreword.....	5
Modal verbs terminology.....	5
Introduction	5
1 Scope	6
2 References	6
2.1 Normative references	6
2.2 Informative references.....	7
3 Definitions and abbreviations.....	7
3.1 Definitions.....	7
3.2 Abbreviations	8
4 Network under test definition.....	9
4.1 Introduction	9
4.2 Test parameter categorization.....	10
4.3 Network classification.....	11
4.3.0 Introduction of network classification	11
4.3.1 Demography	11
4.3.2 Topography.....	12
4.3.3 Climate zones.....	12
4.3.4 Additional classification classes	13
5 Metrics for energy efficiency assessment.....	13
5.0 Introduction of clause.....	13
5.1 Energy Consumption metrics.....	13
5.2 Performance metrics.....	14
5.3 Mobile Network Energy efficiency metrics.....	14
6 Measurement of energy efficiency	15
6.0 Introduction of clause.....	15
6.1 Time duration of the measurement.....	15
6.2 Measurement procedures.....	15
6.2.1 Measurement of Energy Consumption	15
6.2.2 Measurement of capacity	15
6.2.3 Determination of coverage area.....	16
6.2.3.0 Introduction.....	16
6.2.3.1 Geographic coverage area	16
6.2.3.2 Coverage ratio/effective coverage area	16
7 Extrapolation for overall networks	18
7.0 Extrapolation approach.....	18
7.1 Extrapolation method	19
7.1.0 Introduction of extrapolation method	19
7.1.1 Statistical information about Demography	19
7.1.2 Statistical information about Topography.....	19
7.1.3 Statistical information about Climate zones	19
7.2 Extrapolation reporting tables	19
7.2.0 Introduction of extrapolation reporting tables.....	19
7.2.1 Reporting extrapolation based on Demography.....	20
7.2.2 Reporting extrapolation based on Topography	20
7.2.3 Reporting extrapolation based on Climate zones.....	20
8 Assessment report	21
8.0 Introduction of assessment report.....	21
8.1 Report of Network Area under test	21
8.2 Report of sites under test	23

8.3	Report of Site measurement	24
9	Implementation guidelines	24
Annex A (informative): Implementation examples		26
A.1	Implementation examples.....	26
A.2	Examples of reporting data.....	26
	History	31

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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.

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.

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.

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

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.

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".

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 _{MN}	Data Volume of the Mobile Network
EC	Energy Consumption
EC _{MN}	Energy Consumption of the Mobile Network
ECA	Effective Coverage Area
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
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

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.

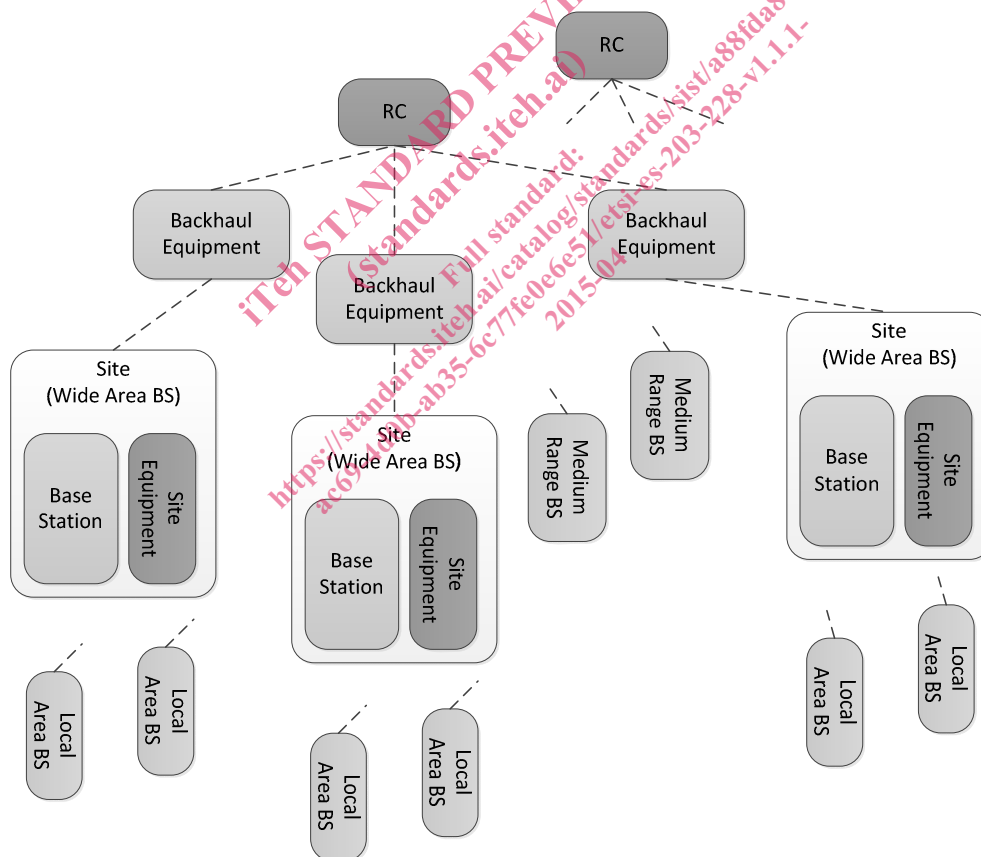


Figure 1: Network under test definition

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/km ²)	Population range (inhabitants/km ²)
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.