



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

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Reference

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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 Membership Approval Procedure (MAP).

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.1331 [i.4] and ETSI ES 203 228 (the present document), 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"**, **"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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Executive summary

The present document aims to provide a better understanding of the energy efficiency of mobile networks. The focus of the present document is on the metrics and methods of assessing energy efficiency in operational networks.

The networks considered are those whose size and scale could be defined by topologic, geographic or demographic boundaries.

The present document explains how to extrapolate the measurements made on partial networks to the level of the total network. Such a simplified approach is proposed as a way of making approximate energy efficiency evaluations at the level of network elements and cannot therefore be considered sufficient for the entire network operation including, for example, transport.

Introduction

The present document deals with the definition of metrics and methods to measure energy performance of Mobile 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 cannot 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].

As the Energy Efficiency is a context-dependent metric, the present document provides the necessary clarification on the network classification (clause 4) and context of the network under assessment, as well as the implementation guidelines (clause 9) for such an assessment.

The present document provides also a method to extrapolate 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 also given in annex A.

It is acknowledged that energy efficiency, which is the scope of this recommendation, is only one aspect of environmental sustainability; in addition, sustainability also encompasses social and economic aspects, but they are not in the scope here.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5 and published by ITU and ETSI as Recommendation ITU-T L.1331 [i.4] and ETSI Standard ETSI ES 203 228 (the present document) respectively, which are technically equivalent.

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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 also the focus on the most energy consuming part, which 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, LTE and 5G New Radio (NR). 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, in particular considering the networks' evolution in different periods in time.

Aiming to consider also the slicing approach of the networks from 5G onwards the metrics are extended to the latency of the network itself related to the energy consumed, additionally to the metrics based on traffic and on coverage, already existing for legacy networks and still valid.

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 for which a measurement method is also recommended. The present document 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 referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the [ETSI docbox](#).

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 (3GPP TS 23.203 version 12.7.0 Release 12)".
- [6] [ETSI TS 136 314](#): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); 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 (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model".
- [10] [ISO/IEC 17025:2017](#): "General requirements for the competence of testing and calibration laboratories".
- [11] [ETSI EN 303 471](#): "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Network Function Virtualisation (NFV)".
- [12] [Recommendation ITU-R M.2410](#): "Minimum requirements related to technical performance for IMT-2020 radio interface(s)".
- [13] [ETSI TS 128 554](#): "5G; Management and orchestration; 5G end to end Key Performance Indicators (KPI) (3GPP TS 28.554)".
- [14] [ETSI TS 128 552 \(V16.6.0\)](#): "5G; Management and orchestration; 5G performance measurements (3GPP TS 28.552 version 16.6.0 Release 16)".
- [15] [ETSI TS 128 310](#): "LTE; 5G; Management and orchestration; Energy efficiency of 5G (3GPP TS 28.310)".
- [16] [ETSI TS 132 450](#): "Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Key Performance Indicators (KPI) for Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Definitions (3GPP TS 32.450)".

2.2 Informative references

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

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

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

- [i.1] ETSI TR 103 117: "Environmental Engineering (EE); Principles for Mobile Network level energy efficiency".
- [i.2] ETSI ES 202 706 (all parts): "Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment".
- [i.3] ETSI GS NFV 003: "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".

- [i.4] Recommendation ITU-T L.1331: "Assessment of mobile network energy efficiency".
- [i.5] FAO Soils Portal: "[Harmonized World Soil Database v 1.2](#)".
- [i.6] Jürgen Grieser, René Gommès, Stephen Cofield and Michele Bernardi: "Data sources for FAO worldmaps of Koeppen climatologies and climatic net primary production", 2006.
- [i.7] Recommendation ITU-T L.1350: "Energy efficiency metrics of a base station site".
- [i.8] Recommendation ITU-T L.1351: "Energy efficiency measurement methodology for base station sites".
- [i.9] Recommendation ITU-T L.1450: "Methodologies for the assessment of the environmental impact of the information and communication technology sector".
- [i.10] Recommendation ITU-T L.1333: "Carbon data intensity for network energy performance monitoring".
- [i.11] The Greenhouse Gas protocol: "[A Corporate Accounting and Reporting Standard](#)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

backhaul equipment: equipment used to connect base stations to the core network, or to other BSs

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 Remote Radio Heads (RRH) close to the antenna element and a central element connecting BS to network infrastructure

end-to-end latency: time that takes to transfer a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source to the moment it is successfully received at the destination

Energy Efficiency (EE): within ICT and especially for mobile networks, the relation between the useful output (similar to functional unit) and the energy consumption to realize that functionality

NOTE: For an electrical device, the EE is the percentage of total energy input consumed in useful work and not wasted as useless heat.

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

energy 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, E-UTRA or 5G NR networks defined by 3GPP

Site Energy Efficiency (SEE): metric used to determine the energy efficiency of a telecommunication site

NOTE: 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 datacentres, 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.

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

Virtualised Network Function (VNF): See ETSI GS NFV 003 [i.3].

3.2 Symbols

Void.

3.3 Abbreviations

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

3GPP	3G (mobile) Partnership Project
AAOP	Accessibility and Availability Obligation Profile
BH	BackHaul
BS	Base Station
CC	Central Cloud
CoA	Coverage Area
CoA _{des}	designated coverage area as designed by network planning
CoA _{geo}	total geographical area under investigation and within the operator's license agreement
CoA _{Qdes}	quality factor describing how well users are covered within the coverage area
CoA _{MN}	Coverage Area Mobile Network
COP	Coverage Obligation Profile
CRAN	Cloud Radio Access Network
CS	Circuit Switched
CS/PS	Circuit Switched/Packet Switched
DC	Data Center
DCA	Designed Coverage Area
DL	DownLink
DP	Dominant Penetration
DU	Dense Urban
DV	Data Volume
DV _{MN}	Data Volume of the Mobile Network
E2E	End To End
EC	Energy Consumption
EC _{MN}	Energy Consumption of the Mobile Network

EC _{SI}	Energy Consumption of the Site
EDC	Edge Cloud
EDGE	Enhanced Data rates for GSM Evolution
EE _{MN}	Energy Efficiency of the Mobile Network
EF	Emission Factor
eMBB	enhanced Mobile BroadBand
eNB	evolved Node B, the LTE logical base station
E-RAB	E-UTRAN Radio Access Bearer
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FAO	Food and Agriculture Organization
FWA	Fixed Wireless Access
GERAN	GSM/EDGE Radio Access Network
GHG	GreenHouse Gas
gNB	next-generation Node B, the 5G NR logical base station
GSM	Global System for Mobile communication
GSMA	GSM Association
HARQ	Hybrid Automatic Repeat Request
ICT	Information Communications Technology
IP	Ingress Protection
ITU	International Telecommunications Union
ITU-T	International Telecommunications Union - Telecommunication
KPI	Key Performance Indicator
LC	Local Cloud
LTE	Long Term Evolution
MBB	Mobile BroadBand
MDT	Minimization of Drive Tests
MMTC	Massive Machine Type Communication
MN	Mobile Network
MNO	Mobile Network Operator
MP	Minor Penetration
NA	Not Applicable
NDP	Non Dominant Penetration
NR	New Radio
O&M	Operation & Maintenance
PDCP	Packet Data Control Protocol
PDF	Probability Distribution Function
PofP	Point of Presence
PPA	Power Purchase Agreement
PS	Packet Switched
PSL	Packet Switched Large packages dominating
PSS	Packet Switched Small packages dominating
QCI	QoS Class Identifier
QoS	Quality of Services
RA	Radio Access
RAB	Radio Access Bearer
RAN	Radio Access Network
RAP	Radio Access Point
RAT	Radio Access Technology
RC	Remote Controller
RF	Radio Frequency
RNC	Radio Network Controller
RRC	Radio Resource Control
RRH	Remote Radio Head
RU	Rural
SDU	Service Data Unit
SE	Switching Equipment
SEE	Site Energy Efficiency
SI	Site Infrastructure
SINR	Signal to Interference plus Noise Ratio
SU	Sub Urban

TCO	Total Cost of Ownership
TE	Telco Equipment
TMA	Tower Mounted Amplifier
TTI	Time Transmission Interval
U	Urban
UE	User Equipment
UE-BS	User Equipment to Base Station
UL	UpLink
UP	User Plane
UMTS	Universal Mobile Telecommunication Service
UN	United Nations
URLLC	Ultra Reliable Low Latency Communications
USA	United States of America
UTRAN	UMTS Terrestrial Radio Access Network
VNF	Virtualised Network Function
VNFS	Virtualised Network Function Servers
VoLTE	Voice over LTE
VoNR	Voice over NR
Wh	Watt-hour

4 Network under test definition

4.1 Introduction

The Mobile Network (MN) under investigation shall include all the equipment that is necessary to run the 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 Wi-Fi 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.).
- Multi-Access EDGE equipment.
- Backhaul equipment required to interconnect the BS used in the assessment with the core network.
- Radio Controller (RC).
- Gateways to connect to the Cloud.

Energy consumption and energy efficiency measurements of individual mobile network elements are described in several standards (for example ETSI ES 202 706-1 [i.2] and ETSI ES 202 706-2 [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;