



**Environmental Engineering (EE);  
Measurement method for energy efficiency  
of wireless access network equipment;  
Dynamic energy efficiency measurement method of  
5G Base Station (BS)**

[ETSI TS 103 786 V1.2.1 \(2024-02\)](#)

<https://standards.iteh.ai/catalog/standards/etsi/e27763bc-e213-4cca-9a28-7987f6c276e7/etsi-ts-103-786-v1-2-1-2024-02>

---

**Reference**

RTS/EE-EEPS61

---

**Keywords**

5G, base station, energy efficiency, KPI, NR

**ETSI**

650 Route des Lucioles  
F-06921 Sophia Antipolis Cedex - FRANCE

---

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B  
Association à but non lucratif enregistrée à la  
Sous-Préfecture de Grasse (06) N° w061004871

---

**Important notice**

The present document can be downloaded from:  
<https://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format at [www.etsi.org/deliver](https://www.etsi.org/deliver).

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at  
<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:  
<https://portal.etsi.org/People/CommitteeSupportStaff.aspx>

If you find a security vulnerability in the present document, please report it through our  
Coordinated Vulnerability Disclosure Program:  
<https://www.etsi.org/standards/coordinated-vulnerability-disclosure>

---

**Notice of disclaimer & limitation of liability**

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use or inability to use the software.

---

**Copyright Notification**

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

---

## Contents

Intellectual Property Rights .....	5
Foreword.....	5
Modal verbs terminology.....	5
Introduction .....	5
1    Scope .....	7
2    References .....	7
2.1    Normative references .....	7
2.2    Informative references.....	8
3    Definition of terms, symbols and abbreviations.....	8
3.1    Terms.....	8
3.2    Symbols .....	9
3.3    Abbreviations .....	9
4    Assessment method .....	10
5    Reference configurations and Measurement requirements .....	10
5.1    Reference configurations.....	10
5.2    Measurement and test equipment requirements .....	11
5.3    BS Configuration.....	12
5.4    Transmit Signal and RF output power.....	12
5.5    UE Emulator requirements and settings .....	12
5.6    Environmental conditions.....	13
5.7    Power supply .....	13
6    Dynamic energy efficiency assessment.....	13
6.1    Overview energy efficiency .....	13
6.2    Energy efficiency measurement .....	14
6.2.1    Measurement lab setup .....	14
6.2.2    UE distribution.....	14
6.2.3    Data traffic model .....	15
6.2.4    Test Time Definition.....	16
6.2.5    Low traffic model .....	16
6.2.6    Medium traffic model .....	16
6.2.7    Busy-hour traffic model .....	16
6.2.8    Power and Energy Consumption Measurement.....	17
6.2.9    Energy Consumption measurement .....	17
6.2.10    Base Station Energy Efficiency KPI.....	18
6.2.11    UE quality of service KPI .....	18
7    Uncertainty .....	18
8    Measurement report.....	19
<b>Annex A (normative):      Test reports.....</b>	<b>20</b>
A.1    General information to be reported .....	20
A.2    Base Station (BS) energy efficiency report .....	20
<b>Annex B (normative):      Reference parameters for NR system .....</b>	<b>23</b>
<b>Annex C (normative):      Data Traffic Model .....</b>	<b>24</b>
C.1    Data Traffic Model.....	24
C.2    Measured data for BS Energy Efficiency KPI calculation .....	24
<b>Annex D (normative):      Uncertainty assessment .....</b>	<b>26</b>

D.1	General requirements .....	26
D.2	Components contributing to uncertainty .....	27
D.2.1	Contribution of the measurement system .....	27
D.2.1.1	Uncertainty Tree description.....	27
D.2.1.2	Measurement equipment.....	27
D.2.1.3	Attenuators, cables.....	27
D.2.1.4	UE emulator.....	27
D.2.1.5	Impact of environmental parameters.....	27
D.2.1.6	Impact of path loss.....	28
D.2.1.7	Data volume.....	28
D.2.1.8	Variance of device under test.....	28
D.3	Uncertainty assessment .....	28
D.3.1	Combined and expanded uncertainties .....	28
D.3.2	Cross correlation of uncertainty factors.....	29
D.3.3	Maximum expanded uncertainty .....	29
<b>Annex E (informative):</b>	<b>Bibliography.....</b>	<b>30</b>
History .....	.....	31

# iTeh Standards

## (<https://standards.iteh.ai>)

### Document Preview

[ETSI TS 103 786 V1.2.1 \(2024-02\)](#)

<https://standards.iteh.ai/catalog/standards/etsi/e27763bc-e213-4cca-9a28-7987f6c276e7/etsi-ts-103-786-v1-2-1-2024-02>

---

# Intellectual Property Rights

## Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

## Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

**DECT™, PLUGTESTS™, UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the **GSM** logo are trademarks registered and owned by the **GSM Association**.

---

## Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

---

## 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).

"must" and "must not" are NOT allowed in ETSI deliverables except when used in direct citation.

---

## Introduction

Increasing of energy consumption and the related cost has been one of the key questions among the whole industry depending on energy and specially in our context the telecom operators while energy consumption cost is one of the main contributors to their OPEX. Despite the increasing of the OPEX, the environmental aspect in terms of CO<sub>2</sub> emission has been one of the most debated subjects within global warming discussions. Energy efficiency is one of the critical factors of the modern telecommunication systems.

In mobile telecom industry the energy consumption of the access network is the dominating part of a wireless telecom network energy consumption. Therefore, the core network and the service network are not considered in the present document. In a radio access network, the energy consumption of the Base Station is dominating.

In context of 5G, one is often talking about three classes of use cases: enhanced Mobile Broadband (eMBB), massive Machine-Type Communication (mMTC) and Ultra-Reliable and Low-Latency Communication (URLLC). eMBB corresponds to a more or less straightforward evolution of the mobile broadband services of today, enabling even larger data volumes and further enhanced user experience, higher end-user data rates while mMTC and URLLC correspond to services characterized by a massive number of devices and services with very low latency and extremely high reliability respectively.

The present document defines the dynamic measurement method for evaluation energy efficiency of 5G radio Base Stations with respect to only eMBB use case. Dynamic measurement method for evaluation energy efficiency of 5G radio Base Stations with respect to mMTC and URLLC is subjected for further study and will be handled in the later version of the present document. Due to the dynamic nature of eMBB service it may be very difficult or impossible to show gains of some Base Station features that improve energy efficiency using static method [8] alone. Compared to static method, the dynamic method strives to give more realistic estimates of Base Station's energy consumption and energy efficiency.

BS energy efficiency under dynamic traffic load conditions: the BS capacity under dynamic traffic load provided within a defined coverage area and the corresponding energy consumption are measured for given reference configurations.

# iTeh Standards

## (<https://standards.iteh.ai>)

### Document Preview

[ETSI TS 103 786 V1.2.1 \(2024-02\)](#)

<https://standards.iteh.ai/catalog/standards/etsi/e27763bc-e213-4cca-9a28-7987f6c276e7/etsi-ts-103-786-v1-2-1-2024-02>

---

# 1 Scope

The present document covers the following radio access technology:

- 5G NR

The methodology described in the present document is to measure Base Station dynamic energy efficiency. Within the present document, it is referred to dynamic measurement.

The results based on dynamic measurements of the BS provide energy efficiency information for BS with dynamic loads.

The present document covers only enhanced Mobile Broadband (eMBB) use case of 5G. Other use cases such as massive Machine-Type Communication (mMTC) and Ultra-Reliable and Low-Latency Communication (URLLC) will be subjected for future version of the present document.

Energy consumption of terminal (end-user) equipment is outside the scope of the present document however, how a User Equipment (UE) affects a Base Station energy performance will be considered for further study.

The scope of the present document is not to set and define target values for the power consumption nor the energy performance of equipment and neither for regulatory nor type approval purpose.

The results should only be used to assess and compare the energy efficiency of complete Base Stations.

Wide Area Base Stations are covered in the present document.

The present document only covers conducted testing, not OTA testing. In other words, the present document is applicable to BS type 1-C and BS type 1-H (at TAB connectors).

---

## 2 References

### 2.1 Normative references

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

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

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 EN 300 132-2](#): "Environmental Engineering (EE); Power supply interface at the input of Information and Communication Technology (ICT) equipment; Part 2: -48 V Direct Current (DC)".
- [2] [ETSI EN 300 132-1](#): "Environmental Engineering (EE); Power supply interface at the input to Information and Communication Technology (ICT) equipment; Part 1: Alternating Current (AC)".
- [3] [ETSI EN 300 132-3](#): "Environmental Engineering (EE); Power supply interface at the input of Information and Communication Technology (ICT) equipment; Part 3: Up to 400 V Direct Current (DC)".
- [4] [ETSI TS 138 211](#): "5G; NR; Physical channels and modulation (3GPP TS 38.211)".
- [5] [ETSI TS 138 104](#): "5G; NR; Base Station (BS) radio transmission and reception (3GPP TS 38.104)".

- [6] [ETSI TS 138 141-1](#): "5G; NR; Base Station (BS) conformance testing Part 1: Conducted conformance testing (3GPP TS 38.141-1)".
- [7] [IEC/ISO Guide 98-3](#) or equivalent GUM:2008/[JCGM 100:2008](#): "Evaluation of measurement data - Guide to the expression of uncertainty in measurement".
- [8] [ETSI ES 202 706-1](#): "Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power consumption - static measurement method".
- [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".

## 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 are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ISO/IEC 17025: "General requirements for the competence of testing and calibration laboratories".
- [i.2] IEC 62018: "Power consumption of information technology equipment - Measurement methods".
- NOTE: Equivalent to [CENELEC EN 62018](#).
- [i.3] Void.
- [i.4] ETSI TR 138 901 (V17.0.0): "5G; Study on channel model for frequencies from 0.5 to 100 GHz (3GPP TR 38.901 version 17.0.0 Release 17)".

<https://standards.iteh.ai/catalog/standards/etsv1-2-1-2024-02>

## 3 Definition of terms, symbols and abbreviations

### 3.1 Terms

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

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

**BS test control unit:** unit which can be used to control and manage BS locally in a lab

**busy-hour (load):** period during which occurs the maximum total load in a given 24-hour period

**distributed BS:** BS architecture which contains remote radio heads (i.e. RRH) close to antenna element and a central element connecting BS to network infrastructure

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

**Energy Efficiency:** Relation between the useful output (telecom service, etc.) and energy consumption of the BS

**NOTE:** In more details, the ratio between the produced task or work and the consumed power for producing this task or work over a time period is called energy efficiency. The task or work could be anything and in telecommunication it can for example be the delivered bits to a User Equipment (UE). In this case the unit could be for example [Mbits / kWh] or [bits / kWh] or [Mbits / Joules]. Since the electricity bills for operators are normally presented in kWh and the work can be expressed as delivering Mbits to a user it would be more convenient to express the unit as [Mbits / kWh].

**integrated BS:** BS architecture in which all BS elements are located close to each other; for example, in one single cabinet

**NOTE:** The integrated BS architecture may include Tower Mount Amplifier (TMA) close to antenna.

**low load:** lowest generated traffic during the dynamic measurement period

**medium load:** load between the lowest and busy-hour load generated during the dynamic measurement period

**power saving feature:** software/hardware feature in a BS which contributes to decrease power consumption

**static measurement:** power consumption measurement performed with different radio resource configurations with pre-defined and fixed load levels (ETSI ES 202 706-1 [8])

**UE group:** group of UEs whose path losses to the BS are identical

**Wide Area Base Station:** Base Station characterized by requirements derived from Macro Cell scenarios with a BS to UE minimum coupling loss equals to 70 dB and a rated output power (PRAT) above 38 dBm

**NOTE:** For example, for NR this PRAT is the mean power level per carrier according to ETSI TS 138 104 [5].

## 3.2 Symbols

Void.

## 3.3 Abbreviations

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

AC	Alternating Current
BS	Base Station
BSEE	Base Station Energy Efficiency
DC	Direct Current
DL	DownLink
DUT	Device Under Test
eMBB	enhanced Mobile BroadBand
GUM	Guide to the expression of Uncertainty in Measurement
HW	HardWare
KPI	Key Performance Indicator
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
mMTC	massive Machine-Type Communications
NIST	National Institute of Standards and Technology
NR	New Radio
NSA	Non-StandAlone
OPEX	Operating Expense
OTA	Over The Air
PBCH	Packet Broadcast Control Channel
PCM	Pulse Code Modulation
PRAT	Power RATed
PRB	Physical Resource Block
PSS	Primary Synchronizing Signal
RF	Radio Frequency

RMSI	Remaining Minimum System Information
RRH	Remote Radio Head
RX	Receiver
SA	StandAlone
SDH	Synchronous Digital Hierarchy
SIB	System Information Block
SS	Synchronization Signals
SSB	Synchronization Signal Block
SSS	Secondary Synchronizing Signal
SW	SoftWare
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TMA	Tower Mount Amplifier
TX	Transmitter
UE	User Equipment
UL	UpLink
URLLC	Ultra-Reliable Low-Latency Communication

## 4 Assessment method

The assessment method is covering the BS equipment dynamic energy efficiency for which the present document defines reference BS equipment configurations and reference load levels to be used when measuring BS energy efficiency.

The assessment procedure contains the following tasks:

- 1) Identification of equipment under test:
  - 1.1 Identify BS basic parameters (table A.1 in annex A).
  - 1.2 List BS configuration (annex A and annex B).
  - 1.3 List traffic load(s) for measurements (annex C).
  - 1.4 List of used power saving features and capacity enhancement features.
- 2) Energy efficiency measurement under dynamic load conditions, Measure BS equipment delivered task in terms of bits and the consumed energy under required conditions (see clause 6).
- 3) Collect and report the energy efficiency measurement results.

## 5 Reference configurations and Measurement requirements

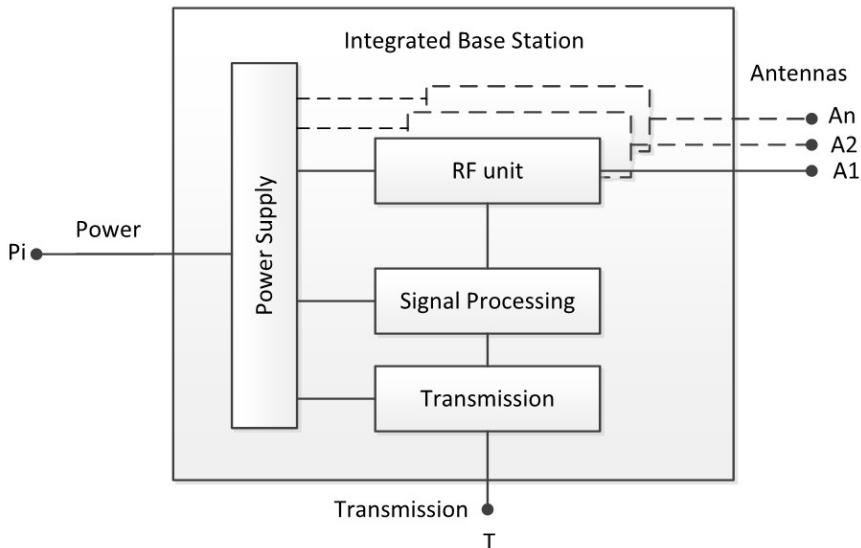
### 5.1 Reference configurations

The BS equipment is a network component which serves a number of user equipment within a specific coverage area over an air interface. A BS interfaces user equipment (through air interface) and a wireless network infrastructure.

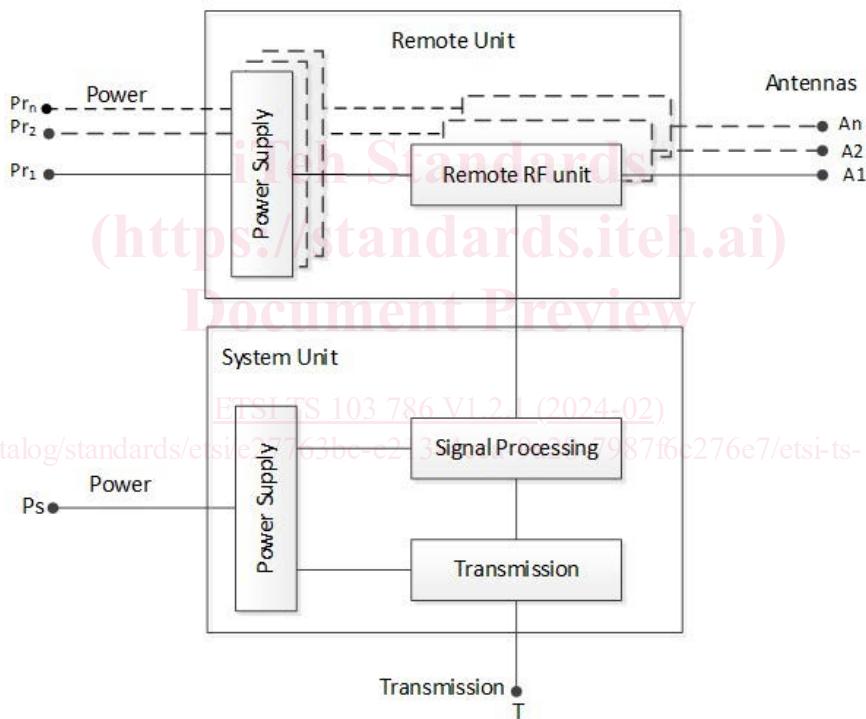
Reference configurations are defined in annex B.

These configurations include integrated and distributed BS, mast head amplifiers, remote radio heads, RF feeder cables, number of carriers, number of sectors, power range per sector, frequency range, diversity, MIMO.

The BS shall be tested with its intended commercially available configuration at temperatures defined in clause 5.6. It shall be clearly reported in the measurement report if the BS cannot be operated without additional air-conditioning at the defined temperatures.



**Figure 1: Integrated BS model (Example)**



**Figure 2: Distributed BS model (Example)**

## 5.2 Measurement and test equipment requirements

The measurement of the power consumption shall be performed by either measuring the power supply voltage and true effective current in parallel and calculate the resulting power consumption (applicable only for DC) or with a wattmeter (applicable for both AC and DC). The measurements can be performed by a variety of measurement equipment, including power clamps, or power supplies with in-built power measurement capability.

All stand-alone measurement equipment such as power measurement instruments, shall be calibrated and shall have data output interface to allow long term data recording and calculation of the complete power consumption over a dedicated time.

The below requirements are not applied to any internal measurement mechanism build in a Base Station [9]. The below requirements shall be applied to stand-alone equipment such as power measurement instrument.