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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

The present document is part 2, sub-part 2 of a multi-part deliverable covering the Energy management; Operational infrastructures; Implementation of Global KPIs, as identified below:

ETSI EN 305 200-1: "General requirements";

ETSI TS 105 200-2: "Specific requirements":

Sub-part 1: "ICT Sites";

Sub-part 2: "Fixed broadband access networks";

Sub-part 3: "Mobile broadband access networks";

Sub-part 4: "Cable Access Networks";

ETSI TS 105 200-3: "ICT sites";

ETSI EN 305 200-4: "Design assessments".

NOTE: Part 2 of this series has also been produced as EN and ES.

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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Introduction

ICT energy needs and costs will continue to increase in the future, while new fixed generations will be deployed and will introduce new active dedicated equipment in the global network architecture.

In this context, and to reflect environmental aspects of sustainability, it is essential for telecommunications network operators to implement effective general engineering of fixed broadband networks and sites provisioning, managing or using those networks (i.e. ICT sites) in order to respond to critical issues of energy consumption. To guide this process, it is essential that metrics are defined that enable energy usage to be managed more effectively.

The Global Key Performance Indicators (KPIs) of the ETSI EN 305 200 series [1] address operational infrastructures and do not consider design or operation of individual components comprising those infrastructures.

The present document specifies the deployment of Global KPIs for energy management (KPI_{EM}) for the fixed access networks of broadband deployment specified in ETSI EN 305 200-2-2 [2].

The fixed access network described in ETSI EN 305 200-2-2 [2] includes all the active components or parts of the access network.

1 Scope

The reporting of Global KPIs in accordance with ETSI EN 305 200-2-2 [2] requires the collection of data to enable the calculation of the following aspects:

- Objective KPI relating to task efficiency (KPI_{TE}) based on *data_volume* and total energy consumption (KPI_{EC}).
- Objective KPI relating to the use of renewable energy (KPI_{REN}).

The present document supports the requirements of ETSI EN 305 200-2-2 [2] providing a framework for, and detailing, the implementation procedures including any necessary techniques for estimation of energy consumption together with clarification and treatment of different types of data volume.

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 305 200 series: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs".

[2] ETSI EN 305 200-2-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 2: Fixed broadband access networks".

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.

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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.

Not applicable.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI EN 305 200-2-2 [2] and the following apply:

Access Gateway (AG): gateway that interworks a significant number of analogue lines to a packet network

downstream: relative location in the fixed access network in the direction of Network Termination Point

fixed access network: access network provided by telecommunications operators providing direct connection (e.g. by metallic, optical fibre or fixed wireless or community WiFi) to customer premises where the User Equipment (UE) or the Access Gateway (AG) is connected directly by a fixed link

NOTE: This modifies and updates the definition of ETSI EN 305 200-2-2 [2].

Fixed Wireless Access (FWA): means of providing internet connectivity that uses wireless network technology rather than fixed lines

Management Information Base (MIB): database allowing management of ICT devices using Simple Network Management Protocol (SNMP)

Multi-access Edge Computing (MEC): network architecture that supports increases in data processing and storage at the edge of a fixed access network (closer to end-user) to reduce latency

Other Licensed Operator (OLO): provider of wireless communications services that owns or controls all the elements necessary to sell and deliver services to an end user including wireline network infrastructure, backhaul infrastructure, billing, customer care, provisioning computer systems and marketing and repair organizations

upstream: relative location in the fixed access network in the direction of an operator site

3.2 Symbols

For the purposes of the present document, the symbols given in ETSI EN 305 200-2-2 [2] apply.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI EN 305 200-2-2 [2] and the following apply:

AG	Access Gateway
ATM	Automated Teller Machine
FTTdp	Fiber To The distribution point
FWA	Fixed Wireless Access
FXS	Foreign eXchange Station
LL	Leased Line
MEC	Multi-access Edge Computing
MIB	Management Information Base
OLO	Other Licensed Operator
ONT	Optical Network Termination
PoS	Point of Sale
PSTN	Public Switched Telephone Network
SNMP	Simple Network Management Protocol
UPS	Uninterruptible Power Supply
VoIP	Voice over Internet Protocol

4 Global KPIs of ETSI EN 305 200-2-2

4.1 Fixed broadband access networks

The network schematic used in the present document is shown in Figure 1 (taken from of ETSI EN 305 200-2-2 [2]).

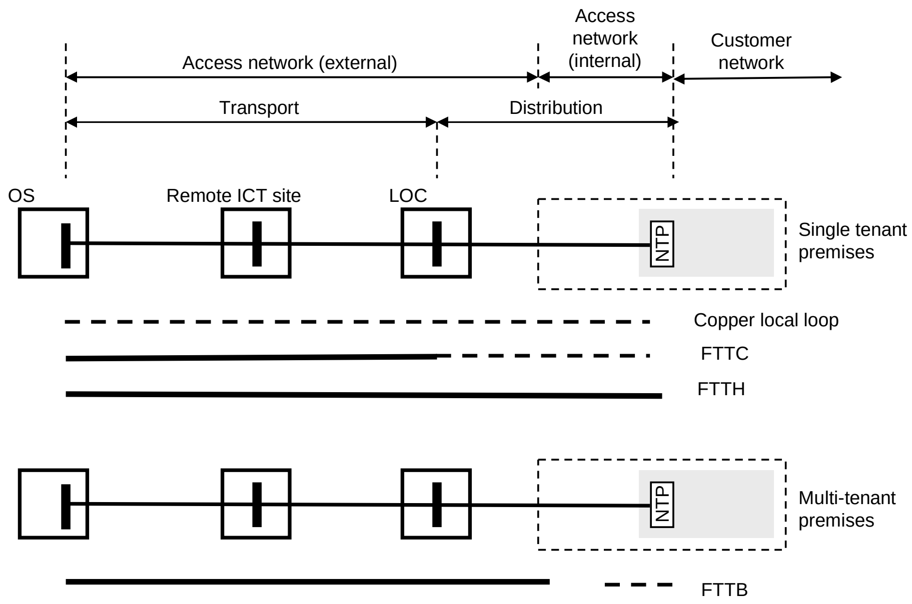


Figure 1: Fixed access network implementations

Within the Fixed Access Network (FAN), the term Network Distribution Node (NDN) is employed to describe a variety of aggregations of Network Telecommunications Equipment (NTE) at locations between the Operator Site (OS) and the Terminal Equipment (TE) in the Customer Premises (CP).

The Last Operator Connection point (LOC) is shown as a specific example of an NDN and is the closest NDN containing NTE to a CP.

Figure 1 shows certain NDNs within dashed boxes to indicate that they are:

- optional;
- not restricted in number to the configurations shown.

4.2 KPIs for energy management

4.2.1 Global KPI (KPI_{EM}) for fixed access networks

From ETSI EN 305 200-2-2 [2], KPI_{EM} is a combination of two separate KPIs, in a common assessment period, as follows:

1) the Objective KPI for task effectiveness expressed as KPI_{TE} (see clause 4.2.2.2);

2) the Objective KPI for renewable energy contribution expressed as KPI_{REN} (see clause 4.2.2.3);

and both of these Objective KPIs incorporate a third Objective KPIs for energy consumption expressed as KPI_{EC} (see clause 4.2.2.1).

From ETSI EN 305 200-2-2 [2], KPI_{EM} is defined as:

$$KPI_{TE} = \frac{data\_volume}{KPI_{EC}} \text{ in conjunction with } KPI_{REN}$$

The Global KPI, KPI_{EM}, and the underpinning Objective KPIs are primarily intended for trend analysis - not to enable comparison between fixed access networks.

4.2.2 Objective KPIs

4.2.2.1 Energy consumption (KPI_{EC})

4.2.2.1.1 General

The present document supports the evaluation of the energy consumption required to provide a given level of service as a primary objective.

From ETSI EN 305 200-2-2 [2], KPI_{EC}, for a given assessment period, is defined mathematically as:

$$KPI_{EC} = \sum_{i=1}^{N} C_{OS_i} + \sum_{j=1}^{M} C_{NDN_j}$$

where, for the assessment period:

i = index of OS

j = index of NDN sites

N = total number of OS

M = total number of NDN sites

C_{OS_i} = energy consumption of all the fixed access network NTE at OS_i

NOTE 1: C_{OS} includes the energy consumption of the supporting infrastructure at OSs where all the NTE is under common governance.

C_{NDN_j} = energy consumption of all the fixed access network NTE at NDN_j supplied from the utility, from upstream sources or generated on-site

NOTE 2: C_{NDN} includes the energy consumption of the supporting infrastructure at NDNs where all the NTE is under common governance.

The note text in the explanations of the parameters are taken from ETSI EN 305 200-2-2 [2]. However, it should be noted that network and location sharing (see clause 5.2.1.5) implies that not all NTE at OS and NDN sites is under common governance and the present document refines the approach taken in such situations.

The above formula and terms do not take account of equipment that is powered by third parties including Access Gateways (AG), Fiber To The distribution point (FTTdP) equipment (G-FAST) and Optical Network Termination (ONT) equipment powered by the end-user. This is not addressed in ETSI EN 305 200-2-2 [2] and the inclusion of such equipment requires a modification to the above formula (see clause 4.2.2.1.2).

It has to be considered that a fixed access network is complex and consists of a large number of distributed sites accommodating ultra-broadband equipment. A typical Operator has many thousand sites, up to tens of thousands. The number of sites is predicted to increase further with the development of higher speed networks such as G-FAST and of Fixed Wireless Access (FWA).

KPI_{EC} can be either measured or estimated:

- $KPI_{EC\text{-}measured}$ is the energy consumption obtained through direct measurement by the MNO or electricity supplier, or provided by another MNO if equipment is co-located in the OS or the NDN;

- $KPI_{EC\text{-}estimated}$ is the energy consumption obtained through direct measurement by the MNO or electricity supplier, or provided by another MNO if equipment is co-located in the OS or the NDN.

NOTE 3: This is applied in mixed, "access/core", network sites where equipment of other network segments is present (core, fixed access, etc.) and the energy split is not made through continuous measurement. Estimation is also needed for the energy consumed by network equipment in small cells, powered from CP as described in clause 4.2.2.1.2.

4.2.2.1.2 CP-powered equipment within the calculation of KPI_{EC}

4.2.2.1.2.1 General

The presence of CP-powered equipment within the fixed access network requires an amendment of the formula for KPI_{EC} of clause 4.2.2.2.1 as follows:

$$KPI_{EC} = \sum_{i=1}^{N} C_{OS_i} + \sum_{j=1}^{M} C_{NDN_j} + C_{CP}$$

with:

$$C_{CP} = \sum_{k=1}^{P} C_{CP}$$

where, for the assessment period:

k = index of AG, FTTdp and ONT equipment

P = total number of AG, FTTdp, ONT equipment under consideration

C_{CP_k} = energy portion of the consumption of CP-powered AG, FTTdp, FTTH ONT or FWA equipment k (see clauses 4.2.2.1.2.2, 4.2.2.1.2.3, 4.2.2.1.2.4, 4.2.2.1.2.5 and 4.2.2.1.2.6 respectively)

4.2.2.1.2.2 AG FXS VoIP

The progressive trend towards the dismission of legacy narrowband platforms (the digital switches) should be considered.

The digital switches represent the majority of the energy consumption of many operators. They are coming of age as they were installed in the early "nineties". Furthermore, the progressive use of broadband services, of Voice over IP (VoIP) and of mobile telephony for voice calls has drastically reduced the number of customers to these legacy services. Switching off the digital switches can produce huge reduction in energy use of fixed access networks.

Although drastically reduced, Public Switched Telephone Network (PSTN) is still widely used (elderly people, Point of Sale (PoS) equipment, alarms, etc.). It is then normal to replace the original service from the digital switch with VoIP delivery via the Foreign eXchange Service (FXS) port of an AG. Such provision of the PSTN service needs the following considerations:

- the AG needs to be always on. It cannot be switched off when broadband service is not in use;
- the energy to support such service is provided by the customer (legacy equipment was powered by the operator);
- "lifeline" service can be a problem. Need to install an opportune power backup (e.g. UPS) at the AG in case lifeline service needs to be guaranteed.

The consumption of such equipment even if it is not directly accounted for by the operator, has an integral role in providing the fixed access network services and should be part of the KPI_{EC}.

The AG module dedicated to the delivery of VoIP via FXS needs to remain active at all times and its consumption can be estimated as 25 % of the maximum AG energy consumption (as specified in the equipment's technical specification).

4.2.2.1.2.3 Access Gateway support of WiFi community service

Among the services fixed (or converged fixed-mobile) network operators are giving to their customers is the WiFi community service. It allows subscribing customers to connect to other hotspots of the same community when they are outside their home, or even abroad. Typically, a subscribing customer accepts to share a part of the bandwidth of their fixed broadband access with the other members of the same community, on a second Wi-Fi signal (WiFi community SSID), in exchange for the right to use other members' hotspots.

The AG module dedicated to WiFi community support need to remain active at all times and its consumption can be estimated as 25 % of the maximum AG energy consumption (as specified in the equipment's technical specification).

4.2.2.1.2.4 CP-powered distribution points

In order to deliver very high speeds, in excess of 250 Mb/s, without incurring is the costs and network development issues of the FTTH, modern transmission technologies are being introduced with Fiber To The distribution points (FTTdp), acting as LOCs, to accommodate G-FAST DSLAMs and, typically, serving only a very limited number of users based on very short loop lengths.

Given their very high number, powering such equipment is problematic and would imply excessive infrastructural costs. So, the trend is to feed them through "reverse powering" from the CP providing power to the G-FAST DSLAMs in the distribution point using the same copper pair(s) used to convey the broadband signal to the CP.

The FTTdp equipment can be deployed in different places such as:

- hanging on poles;
- underground in maintenance chambers;
- in basements of multi-dwelling units.

The consumption of the G-FAST DSLAMs, when all ports are in active condition, has to be considered within the calculation of KPI_{EC}.

The estimation of this consumption of FTTdp powered by the CP can be made by multiplying the quantity of such equipment by its maximum energy consumption.

4.2.2.1.2.5 FTTH ONT

FTTH service is increasingly used as it allows virtually unlimited bit rate capabilities. FTTH normally requires the installation of an Optical Network Termination (ONT) at the customer premises to terminate the optical access network operation and maintenance functions.

The consumption of the ONT, when in active condition, has to be considered within the calculation of KPI_{EC}.

4.2.2.1.2.6 Fixed Wireless Access

Among the services of operators, FWA is typically used to deliver high-speed broadband in a cost-effective way where deployment of telecommunications cabling (optical or copper) would be impractical. The consumption of the TE of FWA services (that can be integrated in the antenna) needs to be accounted for.

4.2.2.1.3 Measurement (and estimation) of total energy consumption

As indicated above KPI_{EC} (as either $KPI_{EC\text{-}measured}$ or $KPI_{EC\text{-}estimated}$) is the arithmetic sum of the consumption of all the NTE of the fixed access network, together with the energy consumed by their supporting infrastructure where all the NTE is under common governance. The supporting infrastructure considers powering; cooling; lighting and any further ancillary equipment in the fixed access network sites.

As described in detail in clause 5.2.1, the consumption information sources can be:

- the utility meter, through the fiscal energy billing;
- a sensor and metering network installed by the fixed operator;
- energy consumption estimation;

- consumption of CP-powered equipment (see clause 4.2.2.1.2).

Although the primary objective of present document is the evaluation of KPIs of a fixed access network only, in some cases it could prove difficult to apportion the consumption of mixed-use sites, that are hosting both access and core network equipment and even offices for the operator's employees. This could lead to extensive need to split by estimation of the shares due to the various network segments (see clause 5.2.1.5).

This complexity is going to increase as the Multi-access Edge Computing (MEC) equipment is going to spread across the access network sites. In such a case, in addition to NTE, other infrastructures composed of ITE will be present in the ICT site. In order to simplify the task for the operator and to improve dependability of the data, it could then be acceptable that the consumption of the MEC ITE equipment, up to that of the whole fixed network is used as KPI_{EC}. The approach chosen on the network boundaries considered will have to be declared in the reporting template.

KPI_{EC} is expressed in kWh; the unit for consumption of electricity which is the main source of energy in fixed access networks. Nevertheless, other energy vectors can be part of the total energy consumption such as: diesel oil used in gen-sets that power off-grid, remote sites, natural gas used in high efficiency CHP co/tri-generators. The additional use of energy from different sources than electricity has to be converted from the original form into kWh.

Requirements or recommendations in relation to the improvement of the energy consumption of the NTE and support infrastructures are not within the scope of the present document.

It is desirable that the actual energy consumption of all relevant NTE and supporting infrastructure equipment is measured and used to calculate the KPI. However, in situations where direct measurement of the consumption is not possible, the maximum consumption of the equipment contained within the vendors technical specifications may be used. This latter approach will result in a generally higher value of KPI_{EC}. This will encourage the implementation of methodologies to enable the direct measurements to be made.

4.2.2.2 Task effectiveness (KPI_{TE})

4.2.2.2.1 General

The present document supports the evaluation of the task effectiveness as a primary objective.

KPI_{TE} is a measure of the data volume transported across the fixed access network per unit of energy consumed by the entire network.

An improvement of KPI_{TE} reflects a reduction of the overall energy consumption required to deliver a given data volume (which is noted by a reduction in KPI_{EC}) and/or an increase in the data volume provided for a given level of energy consumption.

From ETSI EN 305 200-2-2 [2], KPI_{TE}, for a given assessment period, is defined mathematically as:

$$KPI_{TE} = \frac{\sum_{i=1}^{N} data\_volume_i}{KPI_{EC}}$$

where, for the assessment period:

KPI_{EC} =	total of $KPI_{EC\text{-measured}}$ and $KPI_{EC\text{-estimated}}$
i =	index of the site
N =	total number of sites
$data\_volume_i$ =	total data volume at the site i (which can be measured at the highest hierarchical level which provides clear and unambiguous data)

In order to obtain the total data volume, it is not necessary to measure the data traffic at each site as an aggregated view of data volume can be obtained by measurement at the core level or other location in the network where data are aggregated.

This represents a wider interpretation to that given in ETSI EN 305 200-2-2 [2].

4.2.2.2.2 Measurement of data volumes

The measurement of the total data volume transported across the fixed network could be made at different probing points, from each NDN, up to the core network. Nevertheless, measuring at each NDN is quite complex both due to the quantity of equipment involved and the lack of such probing points in legacy equipment. Practical reasons favour the measurement at high level network points (towards the boundaries between access and core network) as they are significantly less numerous and, anyway, in today's network architecture all the data traffic is crossing them. The introduction of MEC will introduce new paths for the data flow as a relevant part of the data served to customers will not cross the core network anymore, but will be limited to the extreme downstream part of the access network. In order to ensure that the data traffic of these future fixed services is accounted for, each MEC installation shall be provided with data flow measurement features.

Some legacy technologies are expressing the traffic in other terms than bit rate. PSTN and ISDN voice traffic, as an example, is expressed in minutes of call. To determine the data traffic contribution of such technologies it is then needed to convert the minutes of calls using the following formulas:

$$Traffic_{voicePSTN} = 72 \text{ [kbits/s]} \times 60 \text{ [s/minutes]} \times CALL_{million\ minutes} \times 2 \text{ (bi-directional data flow)}$$

where:

$Traffic_{voice}$ = data volume equivalent (Gbit) of total call time of the FAN

$CALL_{million\ minutes}$ = total call time (in millions of minutes) over the FAN

NOTE: The "72 [kbit/s]" values comprises the bit rate for the call itself + an additional bit rate for the signalling and framing overhead.

Among the services of the operator there are LL. Their data traffic has to be counted but the actual amount of traffic of the LL is not known as the operator knows only its nominal bit rate which is the maximum data rate such interface could transport. It is not reasonable to count the maximum theoretical as no data interface is used at 100 % of its capabilities. To the objectives of the present document, a utilization factor of 5 % is considered.

A broad number of types of LL has been created along the time and it would be impractical to perform a detailed and exhaustive calculation so, to simplify the evaluation by operators, a grouping of families of LL is applied:

1) analogic or digital (less than 64 kbit/s) - in this case, an average value of 32 kbit/s is considered for the calculation);

2) N × 64 kbit/s - in this case, the average value assigned to N is 2: this category includes the connections towards the Automated Teller Machines (ATM);

3) 2 Mbit/s (these connections, together with the N × 64 kbit/s, are the most numerous);

4) 34 Mbit/s;

5) 155 Mbit/s;

6) 1 Gbit/s (this class contains optical fibre LL).

Considering K as a class for a given rated speed of a LL, the annual traffic of a group of such LLs is given by the following formula:

$$LLTraffic_K = Rated\ speed_K \times 0{,}05 \times 31\ 536 \times LL_K$$

where:

$LLTraffic_K$ = annual traffic expressed in Gbps for class K

$Rated\ speed_K$ = rated speed for class K

LL_K = no. of leased lines of class K

4.2.2.3 Renewable energy (KPI_{REN})

4.2.2.3.1 General

From ETSI EN 305 200-2-2 [2], KPI_{REN} , for a given assessment period, is defined mathematically as:

$$KPI_{REN} = \frac{\sum_{i=1}^{N} C_{OS_i} \times R_{OS_i} + \sum_{j=1}^{M} C_{NDN_j} \times R_{NDN_j}}{KPI_{EC}}$$

where, for the assessment period:

- i = index of OS
- j = index of NDN sites
- N = total number of OS
- M = total number of NDN sites
- C_{OS_i} = energy consumption of all the fixed access network NTE at OS_i
- C_{NDN_j} = energy consumption of all the fixed access network NTE at NDN_j supplied from the utility, from upstream sources or generated on-site
- R_{OS_i} = ratio of renewable energy generated on-site at OS_i
- R_{NDN_j} = ratio of renewable energy generated on-site at NDN_j

KPI_{REN} is the ratio of energy consumption from renewable sources to the total energy consumption of clause 4.2.2.1. It is a dimensionless number.

Equipment powered by the CP (as described in clause 4.2.2.1.2) are not considered within calculations of KPI_{REN} unless the energy source is under the control of the operator.

4.2.2.3.2 Measurement of renewable energy consumption

ETSI EN 305 200-2-2 [2] and the present document support the use of renewable energy as a primary objective.

KPI_{REN} is the ratio of energy consumption from renewable sources to the total energy consumption of clause 4.2.2.1. It is a dimensionless number.

Only the sources contributing to KPI_{EC} will be taken into account, whether dedicated or shared.

KPI_{REN} takes account of renewable energy that is produced by:

a) sources dedicated to and directly serving an NDN;

b) sources under common governance with the NDNs they serve and from which it is conveyed by the utility (grid) serving an NDNs in the group defined for the application of the KPI_{EM}.

In the case of b):

- the renewable energy shall not be included within KPI_{REN} of the recipient site if it is already included in the proportion of "green" energy within the energy mix of the utility (grid) supplied to the NDN as defined in European standards or other international schemes;

NOTE: Any proportion in the mix of utility electricity supplies certified as "renewable" (e.g. based on the carbon footprint of the energy source) by electricity suppliers or in accordance with nationally recognized schemes is not recognized by the present document.

- the portion of such energy allocated to the recipient NDN added to other NDN consumptions shall not exceed the overall energy consumption by the NDN.

5 Collection of data

5.1 General

The data collection provides the input for KPI calculation. Data are obtained from different sources at the sites or equipment comprising the fixed access network as described in clause 4.

This clause describes the origin of the data and the way they could be collected.

It is not within the scope of the present document to provide a detailed view of FAN equipment. However, some basic information is required to allow the calculation of the Objective KPIs.

Information related to energy consumption can be collected from different sources as described in clause 5.2.1.1. Once the data are collected by the operator, they will have to be stored in a database to be analysed and sorted for providing the KPIs and help stakeholders in the management and improvement of their energy usage.

A certain level of basic information is required to calculate the different indicators (see clause 4.2.2). Partial information, or a too high level of extrapolation will not give a realistic view of the energy consumption, KPI_{EC}, task efficiency, KPI_{TE}, and renewable energy usage, KPI_{REN}. This will also falsify the results of the global indicator KPI_{EM}.

Figure 2 is a schematic view of data collection and storage which excludes any contribution of energy provided from CPs.

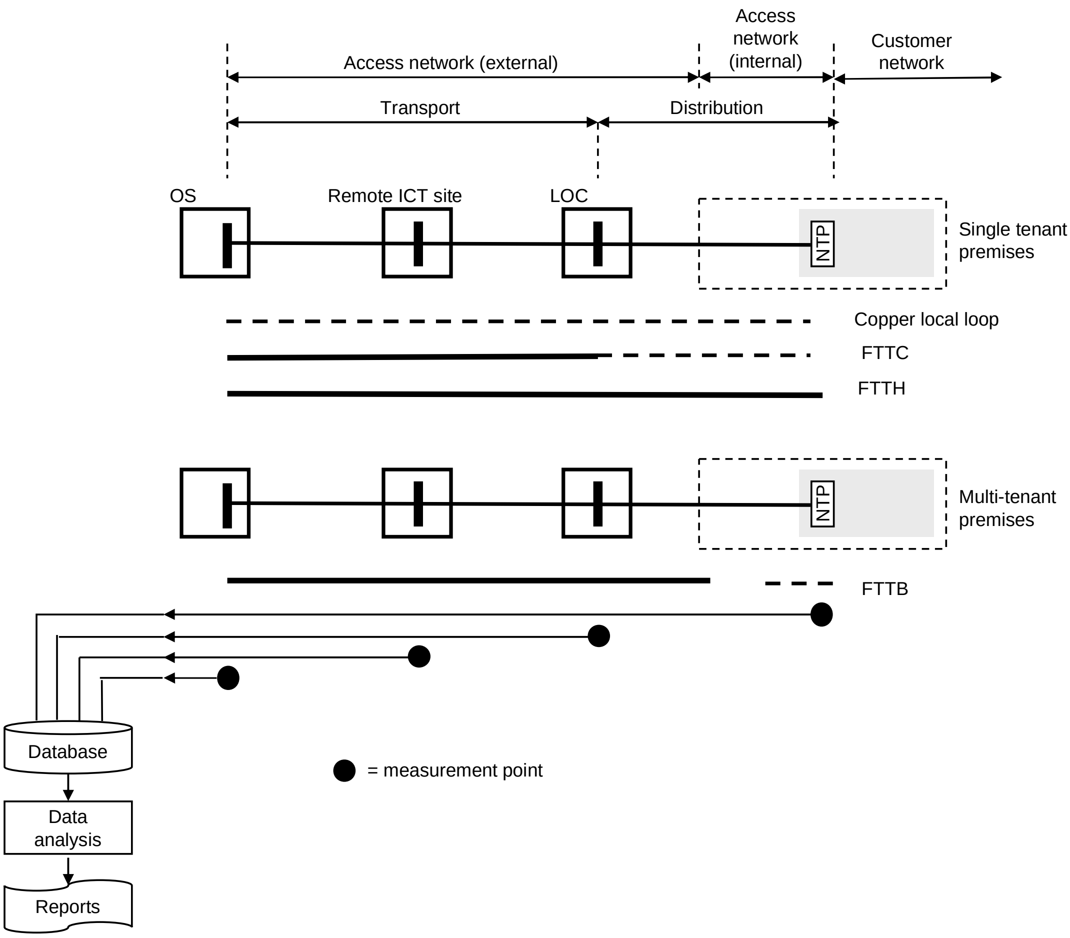


Figure 2: Data collection architecture

Figure 3 is a schematic view of the several steps to produce reporting for the KPIs.

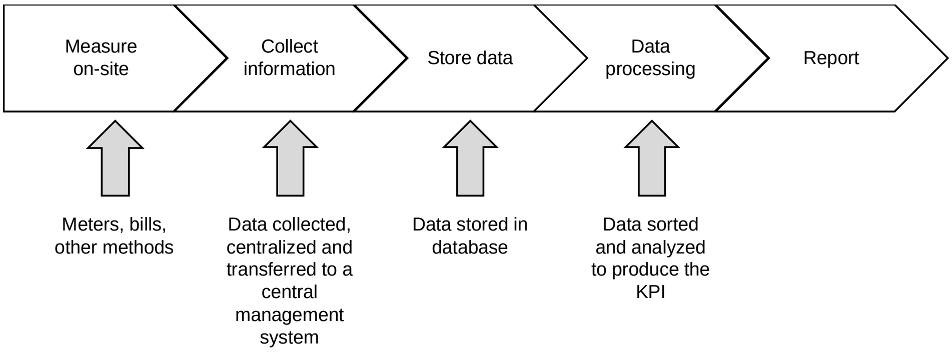


Figure 3: Data processing and reporting architecture

Clause 7 describes a reporting template for the fixed access network KPIs.

5.2 Estimation of energy consumption and renewable content

5.2.1 Energy consumption

5.2.1.1 Overview

The estimation of the energy consumption is given by the KPI_{EC} indicator.

For a fixed access network, composed of thousands of remote sites, the KPI_{EC} for global access network will be the arithmetic sum of all KPI_{EC}, estimated or measured, for each site (OS or NDN). This is the same for the objective KPI_{REN}.

For example, KPI_{REN} will be the quantity of renewable energy which is locally generated at all the sites which are fully or for a part-powered with renewable energy (solar, wind or other).

NOTE 1: Any proportion in the mix of utility electricity supplies certified as "renewable" (e.g. based on the carbon footprint of the energy source) by electricity suppliers or in accordance with nationally recognized schemes is not recognized by the present document.

Figure 4 is a schematic from ETSI EN 305 200-2-2 [2] which has been modified to include the concept of powering of sites from CPs.

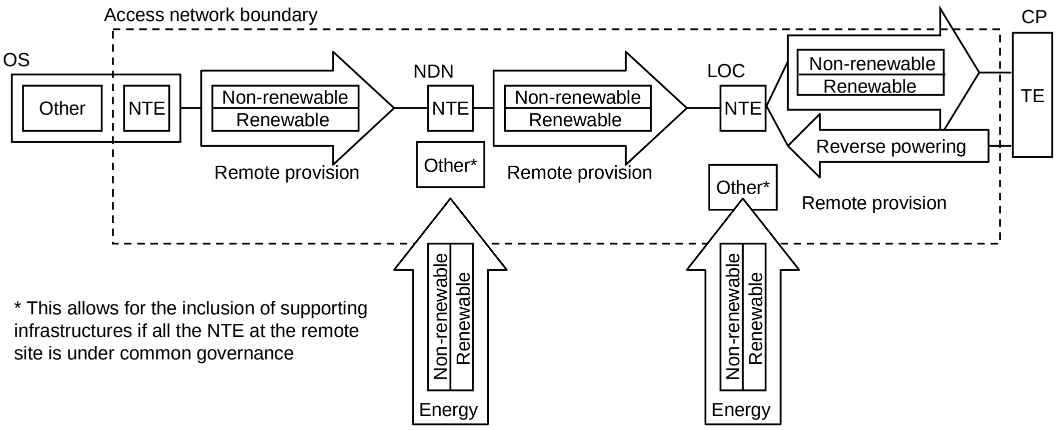


Figure 4: Schematic of fixed access network energy consumption

For an Operator, the large number of sites make it difficult to collect the data to estimate their individual site consumption and efficiency since the deployment of a smart metering solution on each site is very costly.

This clause describes the origin of the data giving some elements in order to evaluate the energy consumption. For the energy use, data can be collected from different sources such as:

- energy bills from the electricity/gas/fuel supplier (see clause 5.2.1.2);
- proprietary meters installed on sites at different levels in the access network (see clause 5.2.1.3);

NOTE 2: This solution ideally enables full coverage of all sites but the complexity and costs of monitoring the many thousands of sites in a typical fixed access network often force the Operator to only cover a sample of the sites.

- the equipment itself, if it is equipped with the appropriate mechanism to record data on energy consumption (see clause 5.2.1.4). All equipment at the site, including that for the ancillary services, has to be equipped with such features.

The Operator has to provide the consumptions related to the different points of measurement, for all sites or equipment connected to the grid, and for the renewable part, the global amount of energy generated by the production source.

The information detailed above is meaningful only for dedicated ICT sites since supporting infrastructure consumption is included for KPI_{EC} in such locations. Clause 5.2.1.5 addresses network and location sharing.

5.2.1.2 Energy bills

Most sites connected to the grid are equipped with a meter provided by the electricity supplier. This meter allows the supplier to collect (manually or automatically) the energy consumed during a certain period (typically monthly). The collected information on the consumption are used by the supplier to invoice the customer. The collection, storage and analysis of information given by the bill is generally made by Operator and provides a clear and dependable view of the entire energy consumption of all sites which are connected to the grid.

Similarly, if the site produces energy based on renewable sources and feeds energy to the electricity supplier, this will be separately recorded by the meter used for the Feed-in Tariff. Clause 4.2.2.3.2 specifies how such renewable energy may be included in KPI_{REN} at other sites under common ownership.

5.2.1.3 Meters installed by the operator (smart metering)

Some operators, for various reasons, have deployed their own meters on some, or all, of their sites, together with a software platform to analyse data and produce detailed reporting.

This solution, even if it is the best to know clearly where energy is consumed, is very costly because it needs to deploy, instead of primary meters at the site entrance, some sub-meters in all parts of the sites, for cooling, racks, equipment, etc.

To cover the whole fixed access network, this implies the deployment of thousands of meters and probes. Generally, the Operator limits these solutions to their main ICT sites and a sample of other typical access network sites. They then extrapolate to the entire range of access network sites. For such reasons it is normally considered not a practical solution to obtain a dependable information on the exact overall energy consumption of the network.

5.2.1.4 Energy consumption provided by the equipment

Certain equipment such as servers and even NTEs, is now able to collect internally information on its own energy consumption and store this information in a Management Information Base (MIB).

NOTE: Older equipment does not implement such features and this option is of limited value for legacy installations.

The MIB can be collected through the network and be managed by a software platform to provide any KPI as defined by the Operator.

This method can be valid to keep track of the consumption of more modern equipment, but is not available for older NDNs and not, normally, for the consumption of the ancillary equipment.

5.2.1.5 Network and location sharing

Fixed infrastructure sharing means the process by which operators share their infrastructure to deliver a fixed service to end users.

In the case of the fixed access network, a challenge will be to be to split the consumption between several stakeholders, knowing that part of the network and the sites could be shared with one or more Other Licenced Operator (OLO). Usually, the energy meter provided by the electricity company gives a global consumption for the whole site.

Sharing the fixed access network is a widespread policy, in particular as, since the "nineties", the incumbent operators got obligation to set in their sites (the central offices), rooms and technical capabilities (e.g. powering and cooling) to host access equipment of other OLOs.

The way the energy consumption is apportioned among those present by the site owner and the way the energy cost is subdivided is normally defined in the contract between the site owner and the OLO.

The higher levels of sharing (core network elements and service platforms) are not considered in the present document.

5.2.2 Renewable energy

Two different methods are possible to collect data for renewable energy:

- measure the total of energy generated from renewable sources in a site;
- measure the renewable energy consumption of the site (which may differ form that produced at the site).

5.3 Data related to traffic

For KPI_{TE}, (related to measure the data volume transported across the fixed access network per unit of energy consumed by the entire network), the energy consumption depends on two parts.

The first is related to the infrastructure and it is the "fixed" part, typically responsible for major part (70 % to 80 %) of the energy consumption, the other part is linked to the load of the network activity. This amount of energy consumption depends on the traffic and data-volumes generated at the different levels of the network and linked to the type of communication and service offered.

Data volumes are obtained via monitoring probes that can be placed over suitable interfaces within the fixed network. Depending on their position, these probes allow to data volumes to be captured with various levels of granularity. Probes may take measurements at different levels of the network such as:

- core network (charging and policy servers, gateways);
- core and metro network routers;
- ICT site (Central Office, NDN, etc.).

The present document focusses on the measurement of the total aggregated information and there is no requirement for the collection of data from each OS or NDN. However, the introduction of MEC will require each MEC site to be provided with the capability to measure their individual data flow in order to ensure the correct data volume is accounted for.

5.4 Clarification of data

There are two different types of data which are basic to KPI_{TE} calculation:

- energy consumption: all data containing information on the energy consumed or any energy generated by renewable sources;
- data-traffic: all data containing information on the volumes of information (uplink and downlink) exchanged on the network between the customer and the access network.

5.5 Treatment of data types

Each type of data refers to one or more objectives indicators (KPI_{EC}, KPI_{TE}, KPI_{REN}). The data will have to be identified to provide the appropriate information for the calculation method of the KPIs:

- data related to energy consumption as input for KPI_{EC};
- data related to renewable energy generated as input for KPI_{REN};
- data related to traffic volumes as input for KPI_{TE}.

6 Trend analysis

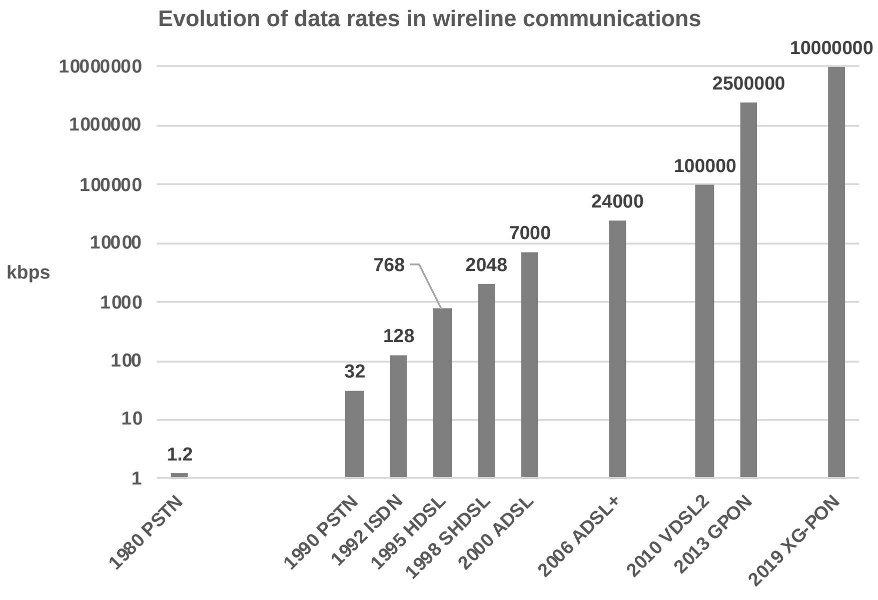
6.1 Overview

Fixed access networks have developed significantly over recent years and offer data-oriented services that include, in addition to voice communications, multimedia communication, online gaming, high-quality video streaming, and many other future services needing increasing bandwidth and generating substantial growth of traffic on the fixed access network. Although the net number of subscriptions to fixed telecommunications has decreased in the last decades, following the shift of voice calls to VoIP and to mobile, the demand for ever higher data rates of fixed subscribers has drastically increased forcing Operators to deploy newer transmission technologies to serve the demand.

Each new generation of network requires a new infrastructure to be deployed. The number of network components to be exchanged in such a programme together with the new features provided by equipment increases the energy consumption of the network, unless legacy platforms such as PSTN and ISDN are passed through a port compacting (to get rid of unused ports), or are discontinued at all (switched-off).

NOTE: For a period of time, the existing and new networks co-exist to maintain legacy service provision which can further increase energy consumption.

However, this increase is balanced by the effectiveness of the new equipment in terms of ratio of kbps/W which has been multiplied by more than 1 000 000 over the last thirty years (see figure 5).



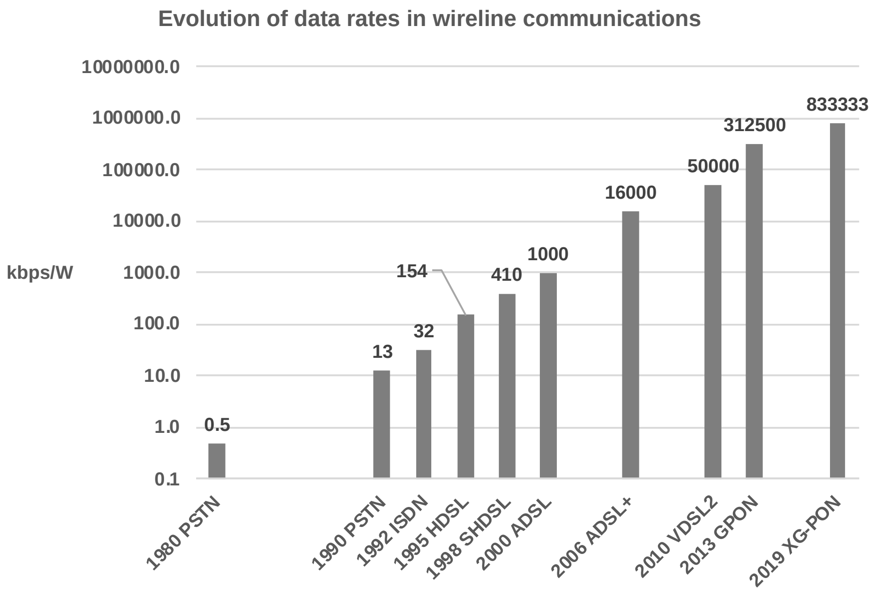


Figure 5: Growth of traffic data rate per W

Considering that each new fixed generation is associated with an increase of the total energy needs to guarantee the service. Each new generation of fixed access network exhibits an improved efficiency and can affect positively the KPI_{TE} by offering a higher ratio of kbps/W.

The energy consumption of the fixed access networks can be reduced by one of more of the following:

1) the use of more energy efficient hardware - reducing KPI_{EC} and increasing KPI_{TE} of NTE equipment;

2) the increased adoption of renewable energy systems as main power sources for NTEs, where relevant - increasing KPI_{REN};

3) the intelligent management of the network elements in operation, management and deployment, based on traffic load variations and geographical considerations;

4) compacting the user lines of legacy technologies where the number of clients is diminishing (e.g. PSTN, ISDN) to a limited set of modules, allowing removing the unused ones.

6.2 Renewable energy sources

Fixed access network sites could be supplied in part or in full using the renewable energy. Different ways to generate renewable energy are presented in Annex A.

Currently, the most important part of renewable energy in fixed access network is the use of solar photovoltaic panels for energy generation. This has the advantage of being easy to deploy in many different countries and regions.

Some electricity suppliers propose to acquire via the grid energy with a guarantee of "green" renewable sources. Both ETSI EN 305 200-2-2 [2] and the present document do not consider this aspect.

Renewable energy power is a relevant solution for the fixed access network in the following conditions:

- "off-the-grid" areas;
- regions that suffer from frequent power cuts;
- optimal climatic conditions for solar and wind energy generation;
- proximity of a river, torrent, sea current, tides for hydraulic energy generation;

NOTE 1: This solution is generally at an experimental state but will certainly become more deployed in the future due to their potential yield.

- possibility to obtain vegetal or animal wastes, generally in rural areas for energy generation from biomass.

NOTE 2: This solution is generally at an experimental state but will certainly become more deployed in the future due to their potential yield.

Renewable energy sources can only produce electricity when some conditions are respected. To avoid power cuts, it is usually coupled with a backup source (grid or generator) or in most cases, batteries which can assume the service continuity during non-production hours or days.

6.3 Intelligent management

The fixed access network should operate in an "energy aware" way, so to minimize its energy consumption while delivering the service requested by the customer. During the periods of lower customer traffic it should apply, as far as possible, applicable standby and sleep modes so to aim at an energy consumption behaviour that is linearly related with the volume of service delivered.

6.4 Summary of possible actions to improve KPI_{EM}

Table 1 summarizes the different techniques to improve KPI_{EM} by the reduction of energy consumption.

Table 1: Techniques for improvement of KPI_{EM}

Approach	Energy savings	Advantages	Considerations
Use of ICT equipment having wide temperature and humidity operating range	Up to 30 %.	Significant savings when fresh air cooling can be used for most of (or all) the year.	High capital expenditure to replace legacy equipment.
Replacing older equipment with more modern equivalent and compacting legacy ones	Up to 50 %.	Easy to implement. East to test.	Replacing older PSTN/xDSL with more efficient ones will save further space in the site.
Switching off legacy narrowband services and VoIP delivery through the FXS port of an Access Gateway	Up to 80 %.	Low implementation costs. Big savings. Real estate advantages. Dismission of old cooling and powering equipment.	The Access Gateways need to be always on. The energy to provide such service is provided by the customer. Lifeline service can be a problem.
Renewable energy	Dependent on location and climatic conditions.	Green energy. Decreased carbon footprint. All energy produced reduces Opex.	Capital expenditure. Location of sites. Meteorological conditions.

KPI_{EM} can also be improved by the use of renewable energy which also reduces carbon footprint and operating expenditure. The opportunity for this depends upon climatic/meteorological conditions at the location of the ICT site and the type of renewable energy source but can involve high capital expenditure.

6.5 Reporting of trend data

KPI_{EM} represented by the combination of KPI_{TE} *or* KPI_{REN} is a measure of the energy management across an entire fixed access network. Operators can demonstrate their commitment to improving the energy management by highlighting trends in the measured values of KPI_{TE} *or* KPI_{REN}.

However, certain operational decisions can mask the true energy performance of the network by effectively "outsourcing" energy consumption to third party.

An example of this would be a move towards the use of shared infrastructures at ICT sites and NDNs. This could produce a significant improvement in KPI_{TE} which could overwhelm both smaller improvements, or even reductions, in energy performance elsewhere.

See clause 7 for reporting requirements.

7 Reporting templates

As specified in the ETSI EN 305 200-2-2 [2] the following values shall be reported for the sites within the fixed access network for which the KPI_{EM} has been determined using the template of Table 2:

- T_{KPI}: the period of time over which Objective KPIs are assessed;
- T_{REPEAT}; the time between which the Objective and Global KPIs are assessed to determine relevant trend information;
- Δt: the maximum time variation between measurement points of the different Objective KPIs within a given Global KPI.

Table 2: Template for fixed network report

Fixed network	**Name, designation, etc.**
Assessment date	**End date of assessment**
Foundations	**Value**
Δt	To be determined by the operator
T_{REPEAT}	To be determined by the operator
T_{KPI}	To be determined by the operator
N (total number of OS)	To be determined by the operator
M (total number of NDN)	To be determined by the operator
P (total number of CP powered equipment)	To be determined by the operator
Baseline data	**Value**
KPI_{EC} as either $KPI_{EC\text{-}measured}$ or $KPI_{EC\text{-}estimated}$ or $KPI_{EC\text{-}power}$	Calculated
C_{OS} (energy consumption of the NTE at all the OSs)	Calculated
C_{NDN} (energy consumption of the NTE at all the NDNs supplied from the utility, from upstream)	Calculated
C_{CP} (total energy consumption of all the equipment supplied from downstream CPs)	Calculated
Total data volume	Calculated
KPI results	**Value**
KPI_{REN}	Calculated
KPI_{TE}	Calculated

In view of the two options for the assessment of energy consumption the KPI_{EC} shall be reported as either:

- $KPI_{EC\text{-}power}$: Objective KPI of energy consumption if any OS or NDN measurements are based on power rather than energy; or
- KPI_{EC}: Objective KPI for energy consumption (indicated as either $KPI_{EC\text{-}measured}$ or $KPI_{EC\text{-}estimated}$).

In addition, the existence of equipment being powered by CP requires the separate reporting of the total energy consumption C_{CP} (see clause 4.2.2.1.2) in addition to its inclusion in $KPI_{EC\text{-}power}$.

The report shall also include any relevant business information which serves to explain any trends in the Global KPI (as either KPI_{TE} *or* KPI_{REN}) which the report highlights. Such information includes, for example, a significant move towards shared infrastructure which improves KPI_{TE} as described in clause 6.5.

Annex A (informative): Fixed Access Networks and Energy

A.1 Network energy consumption and supply

The fixed access network delivers communications between the NTEs and the CP and includes the following equipment:

- OSs;
- NDNs;
- NTEs over metallic, optical or fixed wireless access;
- backhaul links;
- other active equipment such as repeaters, etc.

As shown schematically in Figure 1, the legacy generations of fixed access networks (PSTN, ISDN), were usually located on the same centralized sites, both in outdoor and indoor sites, same as for first generations of broadband equipment (ADSL, HDSL, SHDSL). Higher speed technologies still operating over metallic loops (VDSL and G-FAST) need much shorter loop lengths and imply a great number of remote sites spread in the vicinity to the customer. On the contrary, the development of fully optical broadband, thanks to the longer reach of such interfaces, enables shrinking the network equipment to a reduced set of sites, centralized into a reduced number of OSs.

The energy consumed by the great majority of urban and rural sites is provided by the grid. Operators or third-party stakeholders providing facilities and accommodation for sites are searching to introduce renewable energy solutions in order to decrease operating expenditure by generating a part of the energy needed.

Table A.1 presents some existing solutions of renewable energy sources that are or could be used to supply energy for the access network. Some of them are already deployed by operators in part of their networks, some others are currently experimental solutions, but could be relevant solutions for the future.

Table A.1: Renewable energy source solutions

Renewable energy sources	Yield	Location	Types of ICT sites or equipment	Type of supply
Solar (photovoltaic) panels	Dependent on solar conditions	Urban or rural areas	NDN, sensors	Primary, backup
Windmills	Dependent on wind conditions	Urban or rural areas	OS, NDN	Primary, backup
Fuel cells	24h/24	Urban or rural areas	OS, NDN	Primary, backup
Hydraulic turbines	Possibly 24h/24 dependent on location	Rural areas	NDN	Primary
Gas turbines (methane)	Possibly 24h/24 dependent on location	Rural areas	OS	Primary
Primary batteries (non-rechargeable)	24h/24	Urban or rural areas	Sensors	Primary

A.2 Energy consumption trends

The data collected by means of the annual reports and other information obtained during the processing of that data will generate the set of KPIs defined in present document. In addition to presenting the information in tabular form, it can be useful to represent them in graphical form so to enable visual trend analysis.

Examples for such representations are given in Figure A.1 to Figure A.6. These Figures are provided as pure guidance only and should not be considered as having any implication for the FAN operators that will apply the present document.

The historical data in Figures A.1 to A.6 come from trend information FAN operators such as sustainability reports and conference papers. The data for the 2020-2030 periods are based public internet traffic forecasts and network development trends. They are included for guidance for possible evolution due to the appearance of new technologies (e.g. 5G) or to the removal of legacy ones (e.g. PSTN and ISDN). Discontinuing the support of PSTN will lead to extensive use of POTS port replication within AGs. The impact on the consumption at the CPs has been taken into account, together with the other FAN-related loads defined in clause 4.2.2.1.2.

Figure A.1 shows the exponential growth of data volumes. The share due to PSTN/ISDN voice calls has drastically decreased both due to the progressive transition of calls to the mobile platforms and also to the reduction of PSTN/ISDN lines. Public switched traffic is due to disappear as the PSTN and ISDN platforms have come of age and are will be removed in the next decade. The remaining voice traffic of FANs will be originated at the AG and will be conveyed through the broadband network as VoIP.

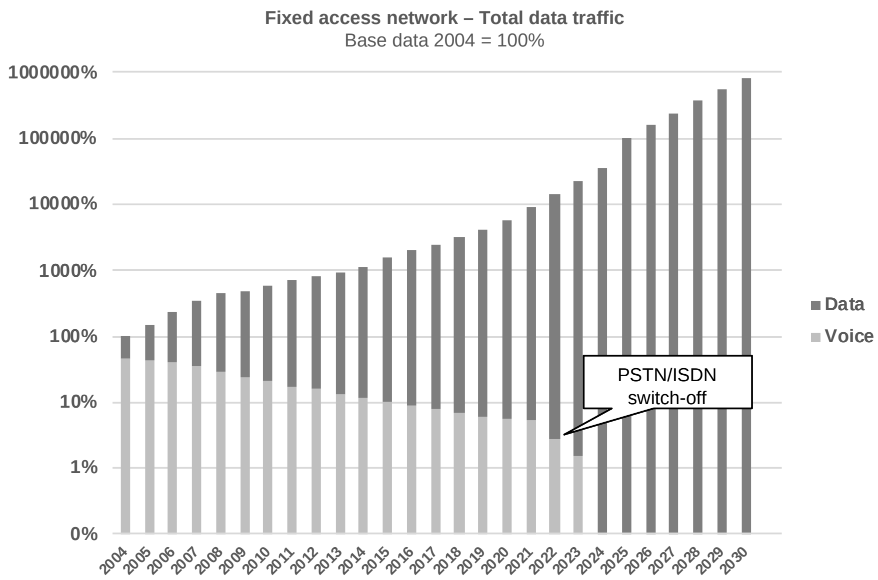


Figure A.1: Trends in data volume

Figure A.2 shows the historical, non-regular, behaviour of the yearly increase of the data volume. Such irregularity is due to the various phases of development of broadband networks (ADSL, VDSL2, etc.) and to the advent of more data-hungry services, such as video streaming.

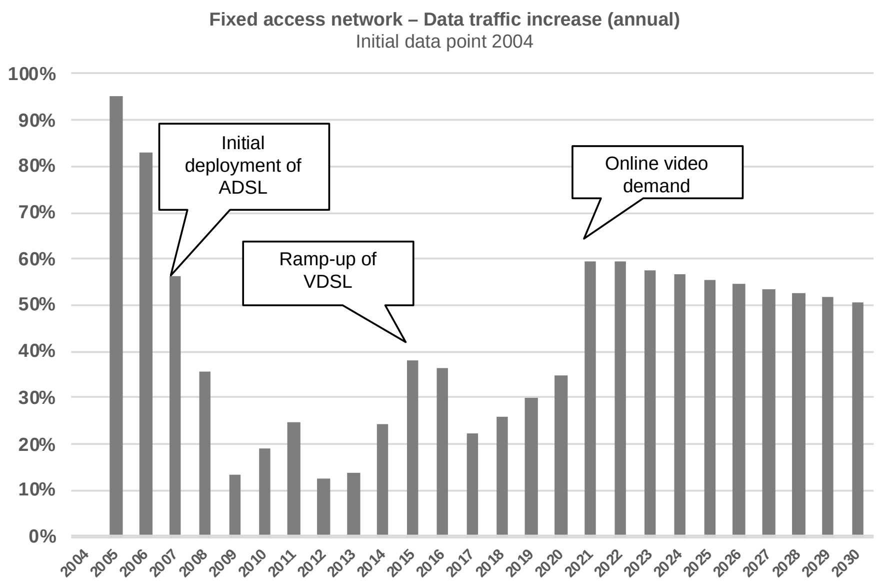


Figure A.2: Trends in data volume increase (annual)

The energy consumption of FANs has always been dominated by the load due to the legacy switched network platforms (PSTN/ISDN) and their stricter requirements on cooling that keep the need for energy-hungry active cooling.

ADSL broadband networks deployment represented an additional load, but the operators continuously ran efficiency programmes on the legacy platforms and successfully achieved a net reduction of overall amount of energy used. In recent years, the boost in the deployment of VDSL2 has driven a growth of the consumption. This trend is likely to be inverted due to development of less per-capita energy-hungry technologies such as FTTH and, more importantly, to the switch-off of the switched network platforms, of the ADSL and the abandonment of most central offices as no more long-distance services over metallic cabling are expected to be used.

As shown in Figure A.3, while the direct energy demand of the FAN NTE equipment is expected to fall, the TE at (or NTE near) the customer premises is going to grow significantly.

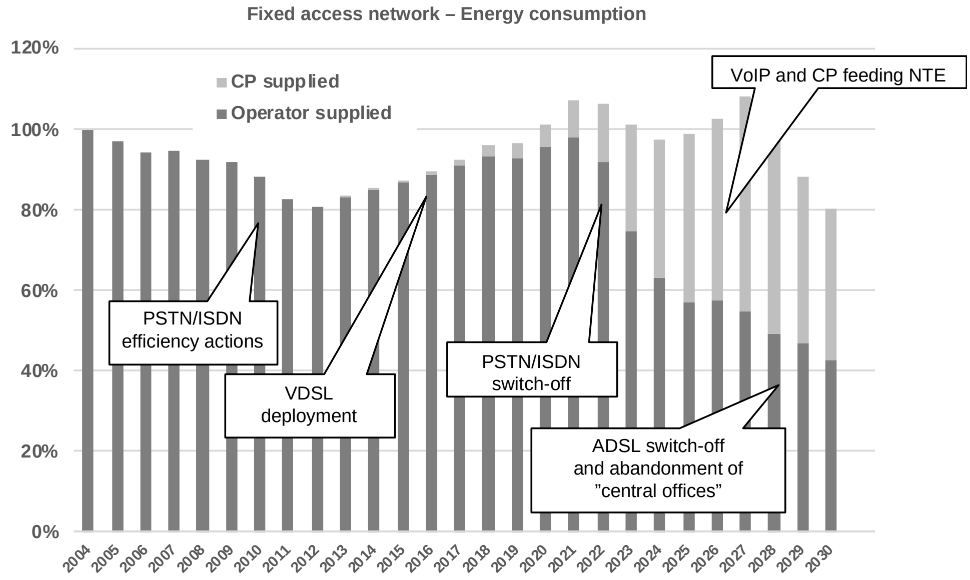


Figure A.3: Trends in energy consumption and sourcing

As shown in Figure A.4, in the past, only a small fraction of the energy consumption of the FAN was estimated as nearly all the connections to the electrical grid were metered. Things are expected to change in the future as the load of network terminations at (or near) the customer premises is going to grow significantly which cannot be metered.

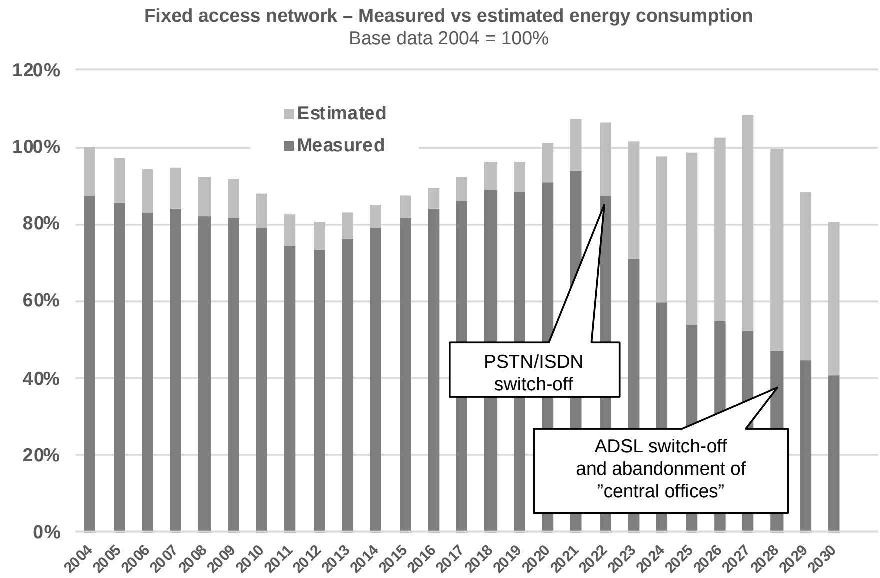


Figure A.4: Trends in energy consumption and sourcing

As shown in Figure A.5, the dramatic increase in the amount of data delivered, while the energy consumption has remained nearly constant, has produced an enormous growth of KPI_{TE}. Such trend is expected to be maintained in the next decade also.

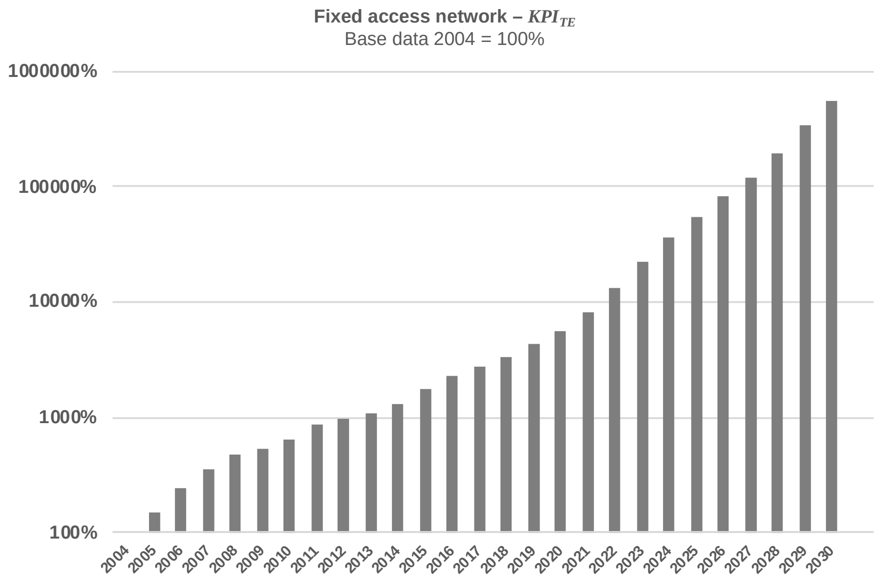


Figure A.5: Trends in *KPI_{TE}*

As shown in Figure A.6, the yearly progress of KPI_{TE}. is expected to generally follow the incremental rate of the data traffic.

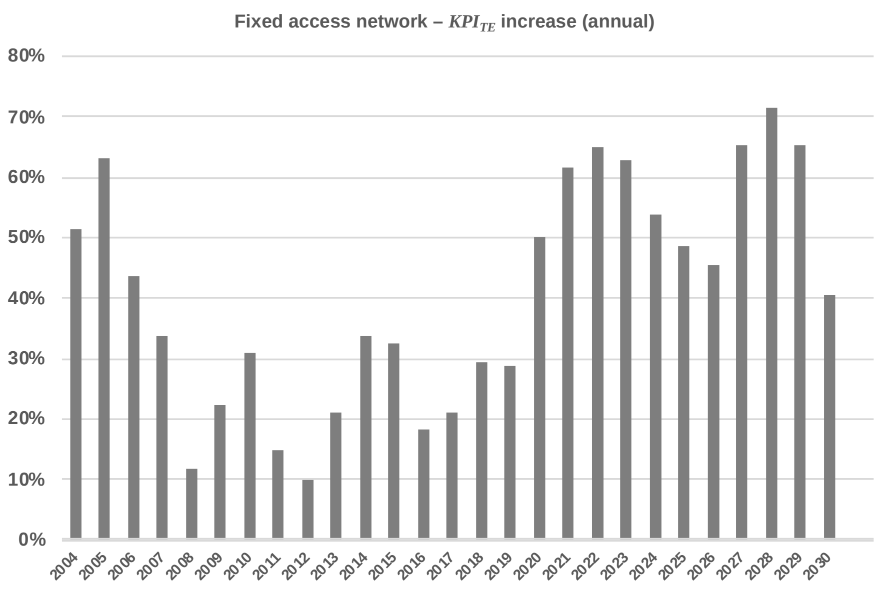


Figure A.6: Trends in KPI_{TE} increase (annual)

Annex B (informative): Change History

Date	Version	Information about changes
06-2019	0.0.1	First formal WD for circulation and comment
07-2019	0.0.2	Second formal WD for circulation and comment
29/07/2019	0.0.3	Stable draft

History

Document history		
V1.1.1	May 2018	Publication as ETSI ES 205 200-2-2
V1.2.1	August 2018	Publication as ETSI EN 305 200-2-2
V1.3.1	December 2019	Publication