EN 303 471 V0.0.2 (2017-01)

Energy efficiency measurement method and KPIs of Network Functions Virtualization (NFV) applications in ICT networks

SKELETON DRAFT 2

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Reference
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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 - NAF 742 C
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Contents

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Foreword

This European Standard (EN) has been produced by ETSI Technical Committee Environmental Engineering (EE).

The present document is

National transposition dates	
Date of adoption of this EN:	1 October 2014
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The present document specifies the method and metrics to determine the energy efficiency of Network Function Virtualization (NFV) applications and their associated infrastructure.

The present document extends the Objective KPIs of EN 305 200-2-2 (fixed access), EN 305-200-2-3 (mobile access) and EN 3050 200-2-4 (cable access networks) to assess the impact of NFV when applied to those networks as described in ETSI GS 003 [i.1].

1 Scope

The present document specifies the method and metrics to determine the energy efficiency of Network Functions Virtualization (NFV) applications.

The present document extends the Objective KPIs of EN 305 200-2-2 (fixed access) and EN 305-200-2-3 (mobile access) when NFV is applied and to define the "boundaries" of such NFV implementations.

KPIs are also defined to determine the performances, in terms of energy efficiency, for the NFV applications..

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customer premises (CP): ??

fibre node (FN): [from EN 305 200-2-4]

ICT equipment: equipment providing data storage, processing and transport services
NOTE: a combination of Information Technology Equipment and Network Telecommunications Equipment

ICT site: site containing structures or group of structures dedicated to the accommodation, interconnection and operation of ICT equipment together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability

Information Technology Equipment (ITE): equipment providing data storage, processing and transport services for subsequent distribution by network telecommunications equipment (NTE)

local head-end (HE): [from EN 305 200-2-4]

last operators connection point (LOC): interface to the fixed access transport networks of one or more operators from which cabling is routed to a customer network

master head-end (HE): [from EN 305 200-2-4]

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NOTE: a network data centre of a cable access network may be termed a master head-end

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NOTE: where all the network telecommunications equipment (NTE) at a given location is under common governance, any supporting infrastructure for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability is included as part of the NDN

network functions virtualisation (NFV): principle of separating network functions from the hardware they run on by using virtual hardware abstraction

network functions virtualisation infrastructure (NFVI): totality of all hardware and software components which build up the environment in which VNFs are deployed

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Network Telecommunications Equipment (NTE): equipment between the boundaries of, and dedicated to providing direct connection to, core and/or access networks

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repeater: device with two RF ports, both of which are intended to be connected to antennas, which is capable of receiving, amplifying and transmitting simultaneously in one direction a signal in a BSS transmit band and in the other direction a signal in the corresponding BSS receive band
[SOURCE: ETSI EN 301 489-50]

terminal equipment (TE): [???]

user equipment (UE): [from EN 305 200-2-3]

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3.2 Symbols

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

Δt	the maximum time variation between measurement points of the different Objective KPIs within a given Global KPI
k	assessment period index
$data\_volume_{NFVI}$	volume of data transported to and from the NFVI during an assessment period
EC_{NFVI}	energy consumption of NFVI during an assessment period
$KPI_{EE\text{-}transfer}$	KPI of NFVI energy efficiency based on data volume
T_{KPI}	period of time over which $KPI_{EE\text{-}transfer}$ is assessed
T_{REPEAT}	the time between which the KPI are assessed to determine relevant trend information

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FN	Fibre Node
HE	Head-End
LOC	Last Operator Connection Point
ICT	Information and Communications Technology
ITE	Information Technology Equipment
NDC	Network Data Centre
NFV	Network Function Virtualisation
NFVI	Network Function Virtualisation Infrastructure
NFVI-Node	Network Function Virtualisation Infrastructure Node
NTE	Network Telecommunications Equipment
NUI	Network User Interface
OS	Operator Site
TE	Terminal Equipment
UE	User Equipment

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4 NFV configurations

4.1 Access networks

The ESO submission of June 2011 to the European Commission in response to Mandate M/462 (dealing with "efficient energy use in fixed and mobile information and communication networks") used Figure 1 as an overall schematic to describe with fixed and mobile networks of broadband deployment. Since that time the schematic has been subject to change and is replaced by Figure 2.

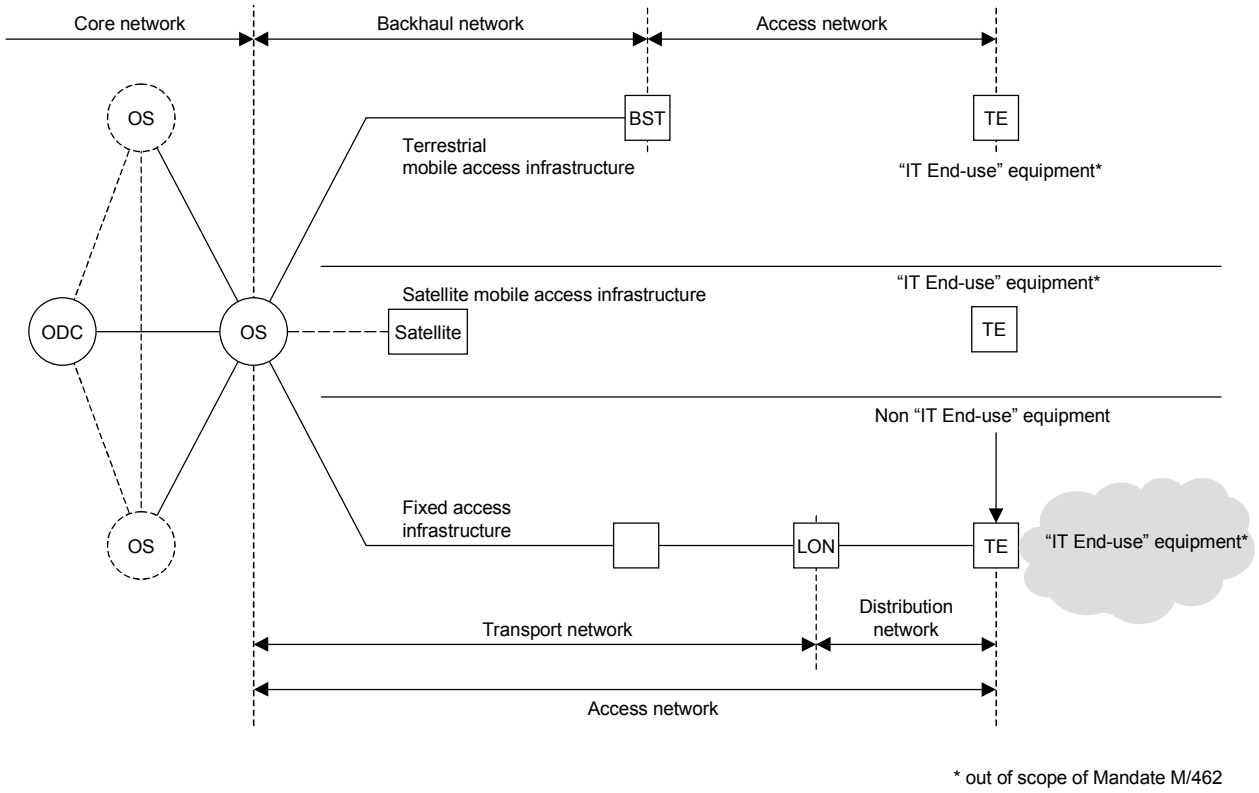


Figure 1 - Schematic of fixed and mobile communication networks (June 2011)

The principal changes for fixed access networks are that customer premises (CP) have been included, network distribution nodes (NDNs) are shown and the last operator node (LON) has been replaced by the last operator connection point (LOC), which is a specific example of an NDN.

Within the fixed access networks in Figure 2, the term NDN is employed to describe a variety of aggregations of NTE at locations between the OS and the CP.

The principal changes for mobile access networks are that network distribution nodes (NDNs) are shown and the base station (BS) and repeater (R) are shown as specific examples of NDNs. Also user equipment (UE) has replaced terminal equipment (TE).

Within the mobile access network in Figure 2, the term NDN is employed to describe a variety of aggregations of NTE at locations between the operator site (OS) and the UE.

The principal changes for cable access networks are that customer premises (CP) and network distribution nodes (NDNs) are shown and the network interface unit (NIU) replaces the terminal equipment (TE).

Within the cable access network in Figure 2, the term NDN is employed to describe a variety of aggregations of NTE at locations between the local head-end (HE) and the NUI.

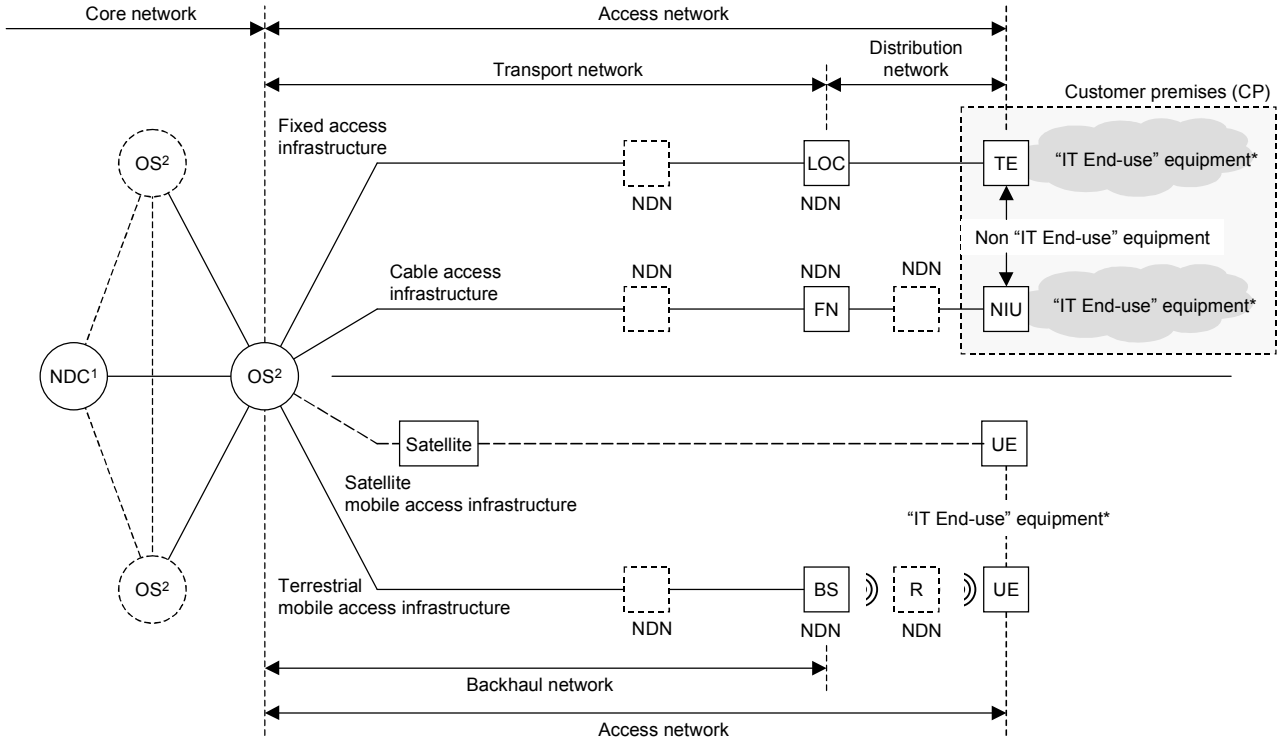


Figure 2 - Updated schematic of fixed and mobile communication networks

For all access networks, the operator data centres (ODC) have been replaced by a network data centre (NDC) and certain NDNs are shown within dashed boxes to indicate that they are:

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

4.2 Network Functional Virtualisation (NFV)

The virtualisation of network functions of fixed, mobile and cable access networks provides an opportunity for improved energy management of those networks.

The network functions that may be virtualised include:

- xxx;
- yyy.

The centralisation of network functions within the hardware resources of a NFVI, comprising information technology equipment (ITE) that is either general purpose or application-specific to those functions, results in potential reduction of energy consumption (as one of many possible operational advantages). The NFV infrastructure (NVFI) may be accommodated within the OS or NDC under the common governance with the access network to which the functions apply or in 3rd party ICT sites or CP.

The NFV process removes energy consumption of NTE equipment at the OS and NDNs of the fixed, mobile and cable access networks and relocates consumption to the NFVI. This would initially appear to result in improvement in the KPIs for energy management defined in EN 305 200-2-2, EN 305 0200-2-3 and EN 305 200-2-4. However, those standards requires the hardware resources of the NFVI to be accommodated in such a manner to allow its energy consumption to be measured (as is required by this standard also) and included in any assessment of the KPI of the access network.

This document does not address the operational energy efficiency of specific ITE such as servers which may provide NFV facilities. Other ETSI EN documents (e.g. EN 303 470) have been prepared to address such factors.

5 NFV KPIs for energy efficiency

5.1 Energy efficiency based on data transfer ($KPI_{EE\text{-}transfer}$)

$KPI_{EE\text{-}transfer}$ is a measure of the data volume transferred to and from the NFVI per unit of energy consumed by the NFVI.

The determination of the effectiveness of such NVFI in effecting a reduction of energy consumption depend upon knowledge of the energy consumption of the NFVI and data volume transmitted and received by the network telecommunications equipment associated (NTE) with the NFVI.

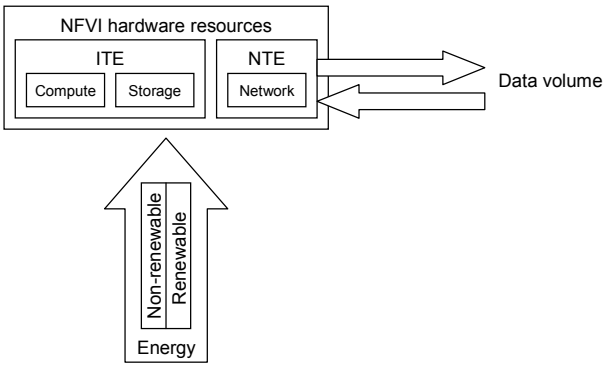


Figure 3 - Schematic of $KPI_{EE\text{-}transfer}$

6 Measurement conditions

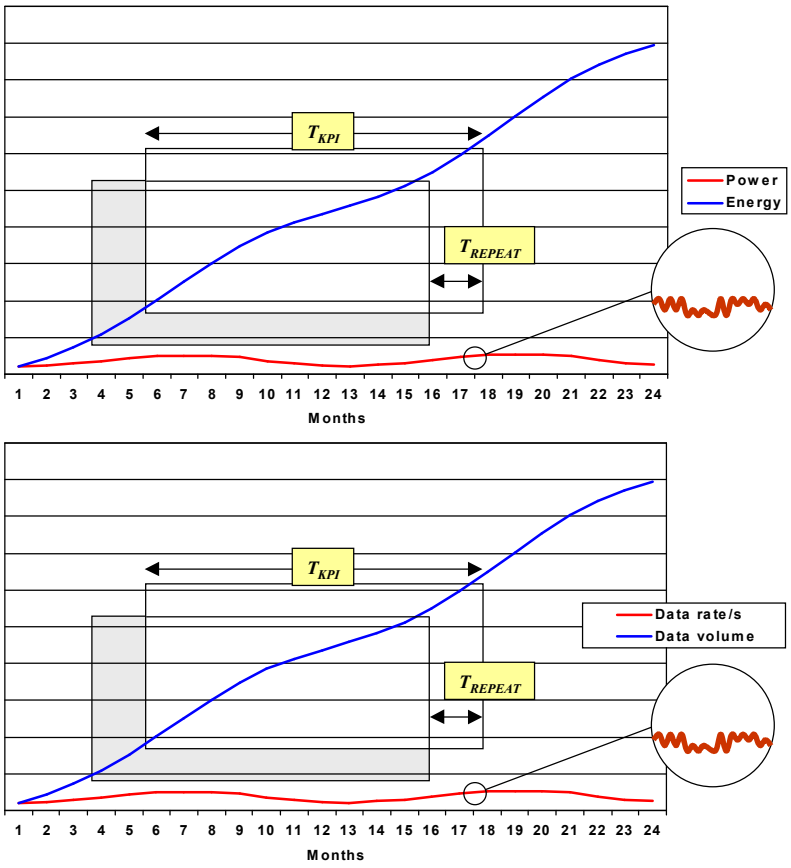
6.1 General requirements

6.1.1 Measurement period

The energy consumption and data volume used to produce a value for a $KPI_{KE\_transfer}$ shall be measured as consumption or transfer of energy and data during a defined and common time period T_{KPI}.

The measurement techniques or processes used for each parameter may not allow simultaneous commencement or completion of an assessment period. A time-spread parameter Δt is provided to allow such conditions. This is shown schematically in Figure 4.

In order to obtain useful trend information the assessment periods should overlap. This is shown schematically in Figure 4. The time interval between which the parameters shall be re-assessed is defined as T_{REPEAT}. which is bounded by a minimum (typically equal to Δt) and a maximum value. To provide the required trend profile and assessment period overlap, the maximum value of T_{REPEAT} shall be lower than T_{KPI}.



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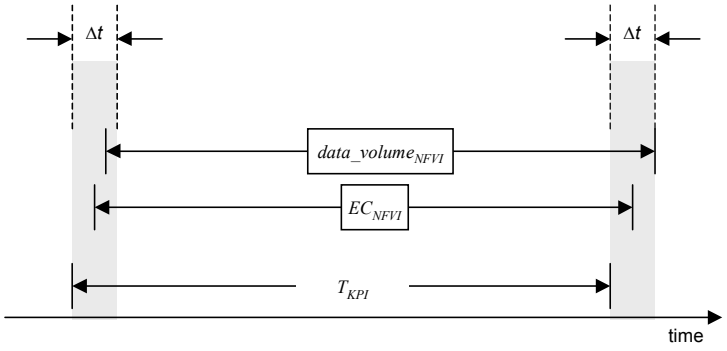

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248 **Figure 4 - Schematic showing application of T_{KPI} , T_{REPEAT} and Δt**

249 6.1.2 Detailed treatment

250 Figure 5 and the following text provides a detailed mathematical treatment of the content of clause ???.

251 The beginning of overall assessment period k is described as t_k^{begin}. The end of an overall assessment period k is described as t_k^{end} =
252 $t_k^{begin} + T_{KPI}$.

253 Any subsequent assessment period, $k+1$, shall begin after a period T_{REPEAT} following t_k^{begin}.

254 The above concepts may be applied to a mean of the relevant time periods applied to EC_{NFVI} and $data\_volume_{NFVI}$. As
255 shown in Figure 5, each measurement may start and finish at a slightly different time.

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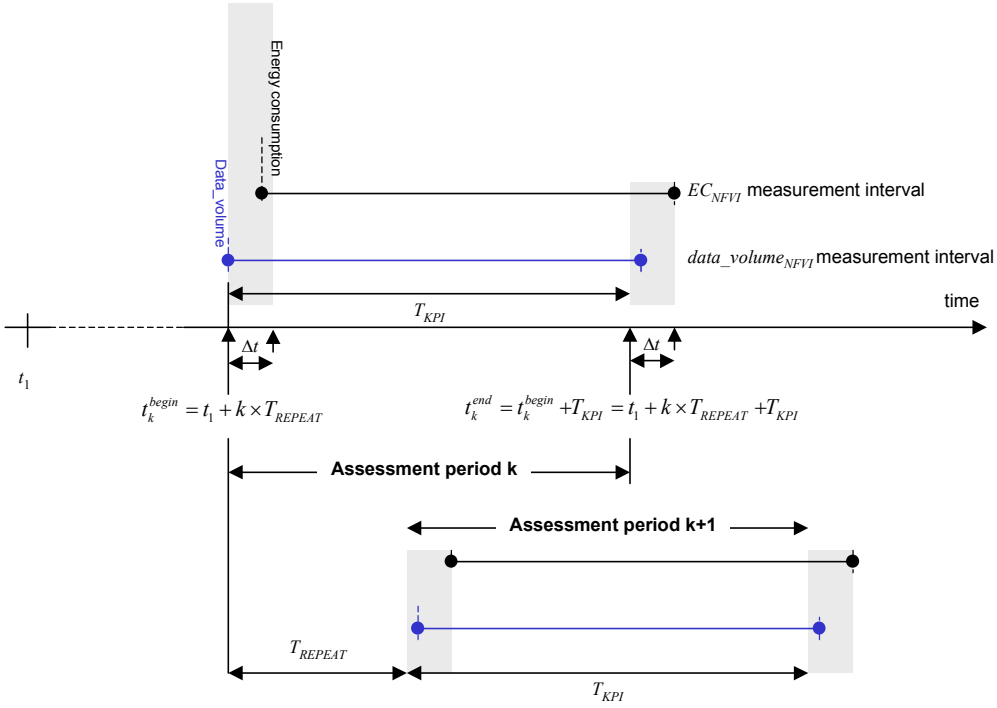

Figure 5 - Mathematical treatment of assessment timing

The default measurement period for T_{KPI} shall be 365 days. This is because:

- each NVFI be subject to different environmental conditions which will affect the energy consumption required to maintain the desired conditions for effective and long-term operation of the ICT equipment accommodated at those locations;
- those environmental conditions may vary over time in a random manner due to their location and the construction of the structure housing the NFVI.

Shorter measurement periods may be applied where seasonal climate variations are sufficiently small to enable the measurement period to exhibit the equivalence to the default measurement period. In such cases, the period shall be based upon the minimum period required to reflect annualised data throughput based on historical traffic patterns for the access network for which the functions are being virtualised.

The NFVI and the network functions being virtualised shall not change during the measurement period. In case of change a new measurement period shall be initiated. The period shall exclude any time during which engineering trails of energy efficiency measures are employed on a temporary basis.

In addition:

- T_{REPEAT} shall be between one week and one calendar month;
- Δt shall be 7 days - by ensuring that the maximum variation is maintained with the required value of 7 days whereas T_{KPI} is one year, the impact on the accuracy of the resulting KPI will be minimal. If improved accuracy is required, or if T_{KPI} is reduced substantially from the default value, the value of Δt may be reduced.

6.2 Renewable energy

The use of renewable energy is embedded within EC_{NFVI}. The energy supplied to the NFVI may meet all its energy needs from local, renewable (like solar or wind energy) sources on a continuous basis.

EC_{NFVI} takes account of renewable energy that is produced by:

a) sources dedicated to and directly serving the NFVI;
b) sources from which it is conveyed by the utility (grid) serving the NFVI;

NOTE 1: these sources may be an OS, NDC , NDN or a generator and shall be under common governance with the access network served by the NFVI.

NOTE 2: This does not, as yet, take into consideration any proportion of renewable electricity in the mix of production of utility supplies certified as "green" (e.g. based on the carbon footprint of the energy source) by electricity suppliers or in accordance with nationally recognised schemes.

In the case of (b), the renewable energy in EC_{NFVI} is counted as renewable energy at the recipient site provided that the energy produced is not considered in the public mix and there is no feed-in contract. The portion of such energy allocated to the (which) ICT site added to other ICT site consumptions shall not exceed the overall energy consumption by the ICT site.

The loss produced by the utility (grid) shall be included at the recipient ICT site(s). If losses are not otherwise specified, a default loss of 10 % shall be used.

NOTE: a power source producing 100 kW is assumed to deliver 90 kW to recipient ICT sites.

6.3 Measurement and test equipment

The measurement of the energy consumption shall be performed by either measuring the power supply voltage and true effective current in parallel and calculate the resulting energy 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 measurement equipment shall be calibrated and shall have data output interface in order to allow long term data recording and calculation of the complete energy consumption over a dedicated time.

The measurement equipment shall comply with following attributes:

- Input power:
  - Resolution: ≤ 10 mA; ≤ 100 mV; ≤ 100 mW;
  - DC current: ± 1%;
  - DC voltage: ± 1%;
  - AC power: ± 1%:
    - an available current crest factor of 5 or more;
    - the test instrument shall have a bandwidth of at least 1 kHz;

  NOTE: Additional information on accuracy can be found in EN 62018 [**Error! Reference source not found.**].
- RF output power: ± 0,4dB.

If the power consumption measurements are done remotely via built-in measurement equipment they shall fulfil the requirements specified in ES 202 336-12 [1].

7 Measurement methods

7.1 Measurement method for $KPI_{EE\text{-}transfer}$

7.1.1 Definition of data volume

The actual throughput (total data volume) shall be measured based on the number of downlink (DL) data volume sent to the user equipments (UEs). Peak and average throughput shall be measured and reported as well as BS utilisation data.

7.1.2 Formulae

An assessment of KPI_{EM} requires that the energy supplied to the FAN provides all the primary functions of the network (i.e. NTE load, environmental control etc). If the supply of energy of any of the non-NTE loads is provided by other supplies not included in KPI_{EC} then KPI_{EM} cannot be assessed.

KPI_{EM} is defined mathematically as:

$$KPI_{EE\_transfer} = \frac{data\_volume_{NFVI}}{EC_{NFVI}}, \text{ subject to a minimum value of 0.}$$

This is shown schematically in Figure 6.

Figure 6 - Schematic of KPI_{EM} calculation and drivers

7.1.2.1 Definition of terms

$data\_volume_{NFVI}$ = ??during the KPI assessment period k (in the interval t_k^{begin} to t_k^{end}) as described in detail in Annex A

EC_{NFVI} = ?? during the KPI assessment period k (in the interval t_k^{begin} to t_k^{end}) as described in detail in Annex A

7.1.2.2 Clarity

7.1.2.3 Criteria

8 Measurement report

Annex A: Items for consideration

A.1 Real-time measurements

Measurements and methodology Indicating load on NFVI

A.2.1 ??????

Other annexes (as required)

History

Document history		
<Version>	<Date>	<Milestone>
V0.0.1	22/09/2016	Skeleton
V0.0.2	01/01/2017	Skeleton draft 2

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[i.3] ETSI EN 305 200-2-4: Energy management: Operational infrastructures: Global KPIs - Part 2: Specific requirements - Sub-part 4: Cable access networks

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NUI	Network User Interface
OS	Operator Site
TE	Terminal Equipment
UE	User Equipment

EDITORS NOTE: during the development of the document see xxxxxx

4 NFV configurations

4.1 Access networks

The ESO submission of June 2011 to the European Commission in response to Mandate M/462 (dealing with "efficient energy use in fixed and mobile information and communication networks") used Figure 1 as an overall schematic to describe with fixed and mobile networks of broadband deployment. Since that time the schematic has been subject to change and is replaced by Figure 2.

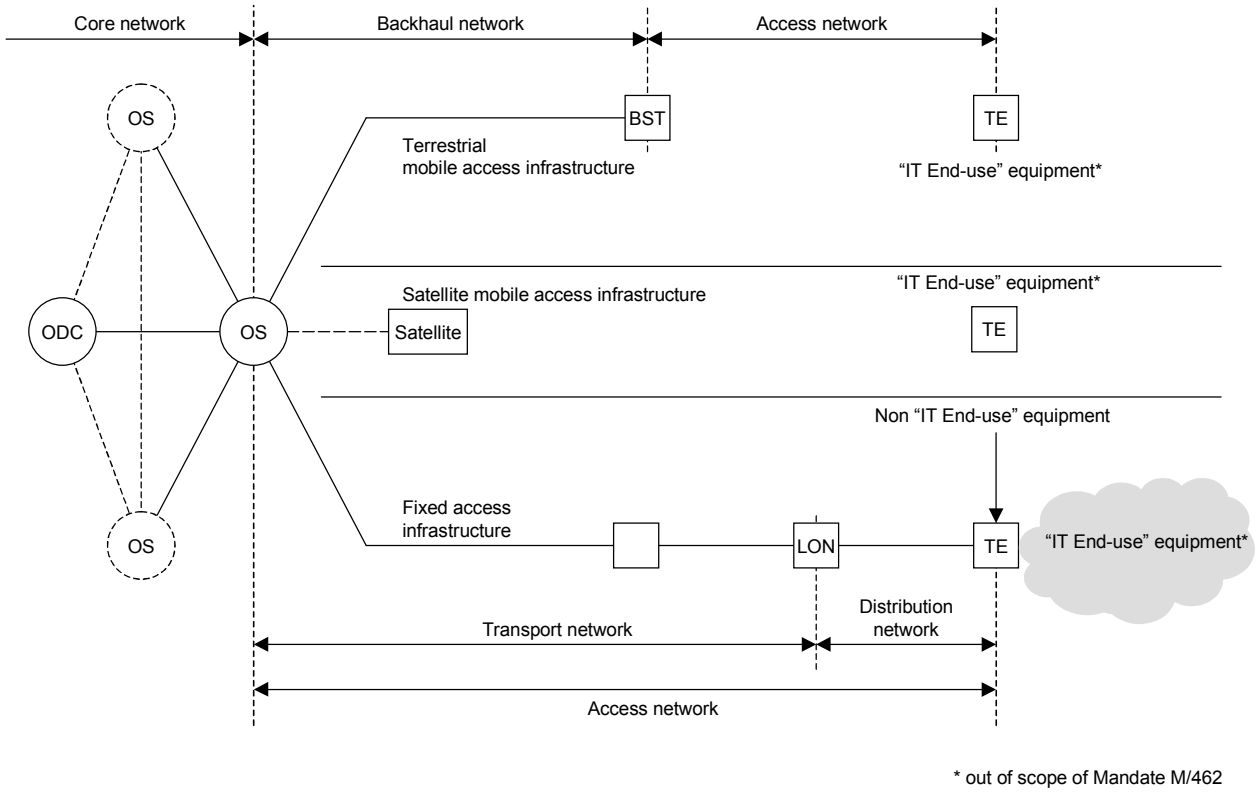


Figure 1 - Schematic of fixed and mobile communication networks (June 2011)

The principal changes for fixed access networks are that customer premises (CP) have been included, network distribution nodes (NDNs) are shown and the last operator node (LON) has been replaced by the last operator connection point (LOC), which is a specific example of an NDN.

Within the fixed access networks in Figure 2, the term NDN is employed to describe a variety of aggregations of NTE at locations between the OS and the CP.

The principal changes for mobile access networks are that network distribution nodes (NDNs) are shown and the base station (BS) and repeater (R) are shown as specific examples of NDNs. Also user equipment (UE) has replaced terminal equipment (TE).

Within the mobile access network in Figure 2, the term NDN is employed to describe a variety of aggregations of NTE at locations between the operator site (OS) and the UE.

The principal changes for cable access networks are that customer premises (CP) and network distribution nodes (NDNs) are shown and the network interface unit (NIU) replaces the terminal equipment (TE).

Within the cable access network in Figure 2, the term NDN is employed to describe a variety of aggregations of NTE at locations between the local head-end (HE) and the NUI.

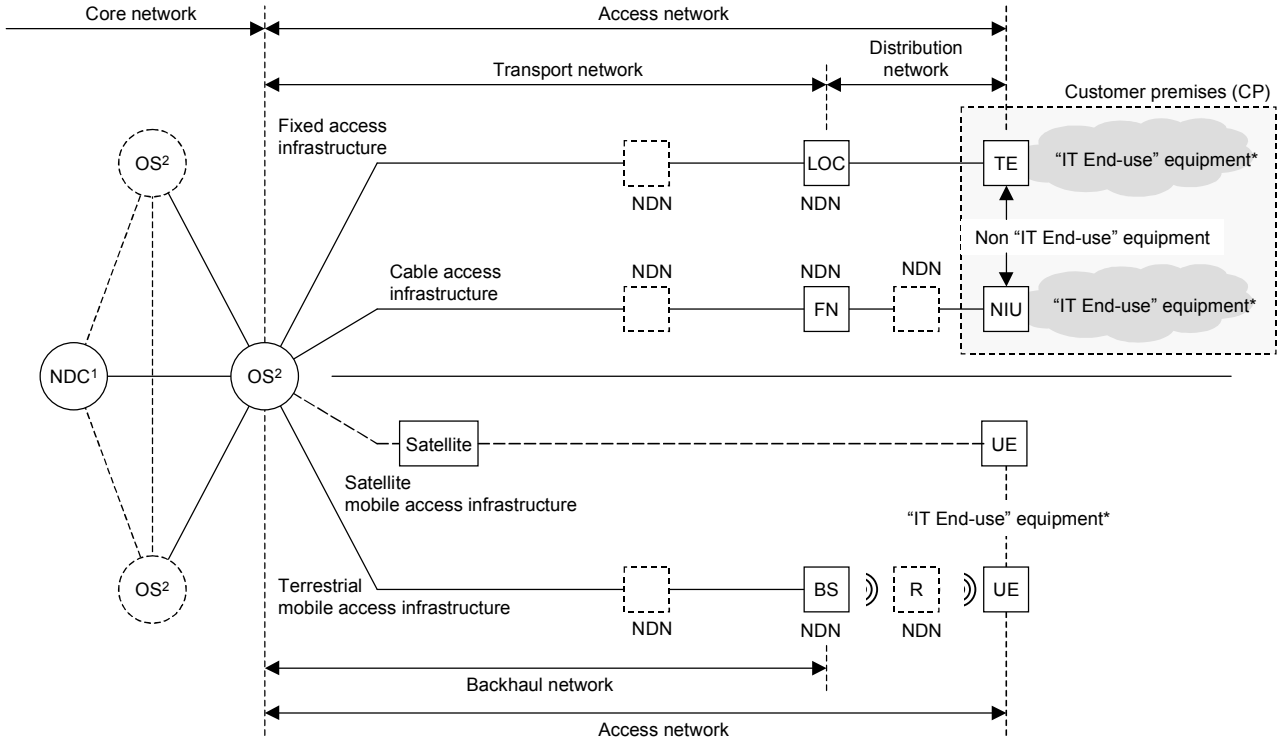


Figure 2 - Updated schematic of fixed and mobile communication networks

For all access networks, the operator data centres (ODC) have been replaced by a network data centre (NDC) and certain NDNs are shown within dashed boxes to indicate that they are:

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

4.2 Network Functional Virtualisation (NFV)

The virtualisation of network functions of fixed, mobile and cable access networks provides an opportunity for improved energy management of those networks.

The network functions that may be virtualised include:

- xxx;
- yyy.

The centralisation of network functions within the hardware resources of a NFVI, comprising information technology equipment (ITE) that is either general purpose or application-specific to those functions, results in potential reduction of energy consumption (as one of many possible operational advantages). The NFV infrastructure (NVFI) may be accommodated within the OS or NDC under the common governance with the access network to which the functions apply or in 3rd party ICT sites or CP.

The NFV process removes energy consumption of NTE equipment at the OS and NDNs of the fixed, mobile and cable access networks and relocates consumption to the NFVI. This would initially appear to result in improvement in the KPIs for energy management defined in EN 305 200-2-2, EN 305 0200-2-3 and EN 305 200-2-4. However, those standards requires the hardware resources of the NFVI to be accommodated in such a manner to allow its energy consumption to be measured (as is required by this standard also) and included in any assessment of the KPI of the access network.

This document does not address the operational energy efficiency of specific ITE such as servers which may provide NFV facilities. Other ETSI EN documents (e.g. EN 303 470) have been prepared to address such factors.

5 NFV KPIs for energy efficiency

5.1 Energy efficiency based on data transfer ($KPI_{EE\text{-}transfer}$)

$KPI_{EE\text{-}transfer}$ is a measure of the data volume transferred to and from the NFVI per unit of energy consumed by the NFVI as shown schematically in Figure 3

The determination of the effectiveness of such NVFI in effecting a reduction of energy consumption depend upon knowledge of the energy consumption of the NFVI and data volume transmitted and received by the network telecommunications equipment associated (NTE) with the NFVI.

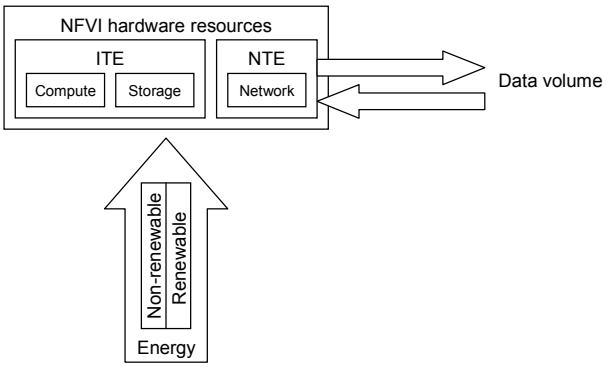


Figure 3 - Schematic of $KPI_{EE\text{-}transfer}$

6 Measurement conditions

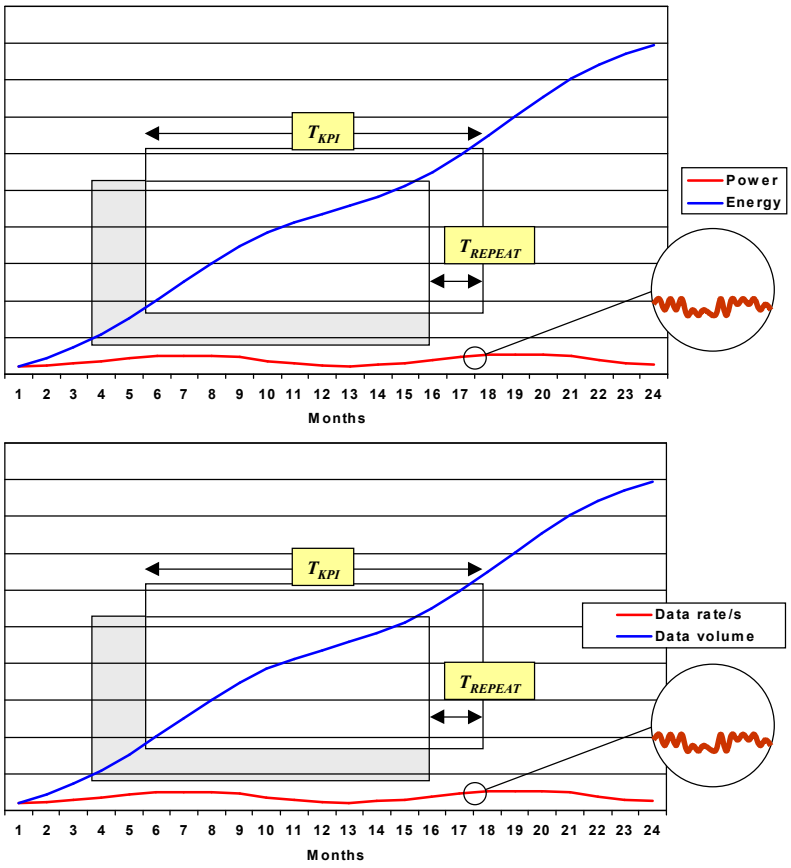
6.1 General requirements

6.1.1 Measurement period

The energy consumption and data volume used to produce a value for a $KPI_{KE\_transfer}$ shall be measured as consumption or transfer of energy and data during a defined and common time period T_{KPI}.

The measurement techniques or processes used for each parameter may not allow simultaneous commencement or completion of an assessment period. A time-spread parameter Δt is provided to allow such conditions. This is shown schematically in Figure 4.

In order to obtain useful trend information the assessment periods should overlap. This is shown schematically in Figure 4. The time interval between which the parameters shall be re-assessed is defined as T_{REPEAT}. which is bounded by a minimum (typically equal to Δt) and a maximum value. To provide the required trend profile and assessment period overlap, the maximum value of T_{REPEAT} shall be lower than T_{KPI}.



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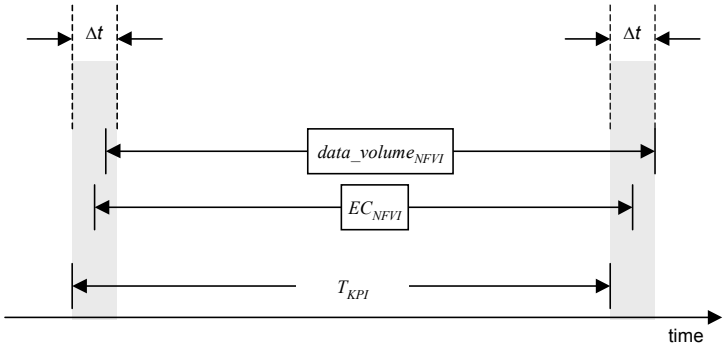

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251 **Figure 4 - Schematic showing application of T_{KPI} , T_{REPEAT} and Δt**

252 6.1.2 Detailed treatment

253 Figure 5 and the following text provides a detailed mathematical treatment of the content of sub-clause 6.1.1.

254 The beginning of overall assessment period k is described as t_k^{begin}. The end of an overall assessment period k is described as t_k^{end} =
255 $t_k^{begin} + T_{KPI}$.

256 Any subsequent assessment period, $k+1$, shall begin after a period T_{REPEAT} following t_k^{begin}.

257 The above concepts may be applied to a mean of the relevant time periods applied to EC_{NFVI} and $data\_volume_{NFVI}$. As
258 shown in Figure 5, each measurement may start and finish at a slightly different time.

259

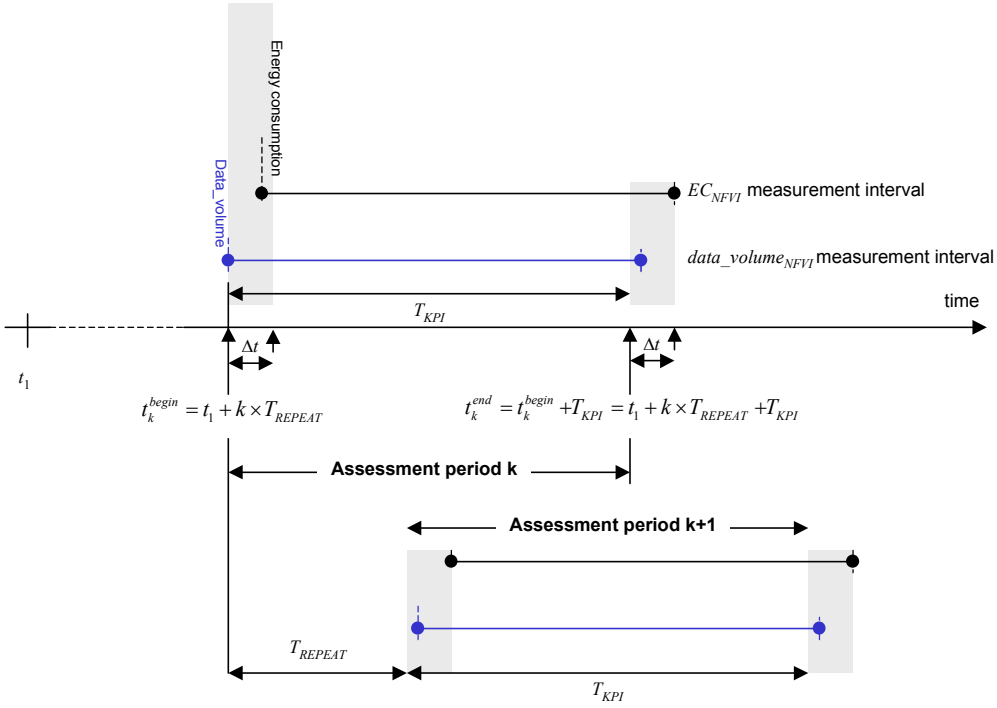

Figure 5 - Mathematical treatment of assessment timing

The default measurement period for T_{KPI} shall be 365 days. This is because:

- each NVFI be subject to different environmental conditions which will affect the energy consumption required to maintain the desired conditions for effective and long-term operation of the ICT equipment accommodated at those locations;
- those environmental conditions may vary over time in a random manner due to their location and the construction of the structure housing the NFVI.

Shorter measurement periods may be applied where seasonal climate variations are sufficiently small to enable the measurement period to exhibit the equivalence to the default measurement period. In such cases, the period shall be based upon the minimum period required to reflect annualised data throughput based on historical traffic patterns for the access network for which the functions are being virtualised.

The NFVI and the network functions being virtualised shall not change during the measurement period. In case of change a new measurement period shall be initiated. The period shall exclude any time during which engineering trails of energy efficiency measures are employed on a temporary basis.

In addition:

- T_{REPEAT} shall be between one week and one calendar month;
- Δt shall be 7 days - by ensuring that the maximum variation is maintained with the required value of 7 days whereas T_{KPI} is one year, the impact on the accuracy of the resulting KPI will be minimal. If improved accuracy is required, or if T_{KPI} is reduced substantially from the default value, the value of Δt may be reduced.

6.2 Renewable energy

The use of renewable energy is embedded within EC_{NFVI}. The energy supplied to the NFVI may meet all its energy needs from local, renewable (like solar or wind energy) sources on a continuous basis.

EC_{NFVI} takes account of renewable energy that is produced by:

a) sources dedicated to and directly serving the NFVI;
b) sources from which it is conveyed by the utility (grid) serving the NFVI;

NOTE 1: these sources may be an OS, NDC , NDN or a generator and shall be under common governance with the access network served by the NFVI.

NOTE 2: This does not, as yet, take into consideration any proportion of renewable electricity in the mix of production of utility supplies certified as "green" (e.g. based on the carbon footprint of the energy source) by electricity suppliers or in accordance with nationally recognised schemes.

In the case of (b), the renewable energy in EC_{NFVI} is counted as renewable energy at the recipient site provided that the energy produced is not considered in the public mix and there is no feed-in contract. The portion of such energy allocated to the (which) ICT site added to other ICT site consumptions shall not exceed the overall energy consumption by the ICT site.

The loss produced by the utility (grid) shall be included at the recipient ICT site(s). If losses are not otherwise specified, a default loss of 10 % shall be used.

NOTE: a power source producing 100 kW is assumed to deliver 90 kW to recipient ICT sites.

6.3 Measurement and test equipment

The measurement of the energy consumption shall be performed by either measuring the power supply voltage and true effective current in parallel and calculate the resulting energy 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 measurement equipment shall be calibrated and shall have data output interface in order to allow long term data recording and calculation of the complete energy consumption over a dedicated time.

The measurement equipment shall comply with following attributes:

- Input power:
  - Resolution: ≤ 10 mA; ≤ 100 mV; ≤ 100 mW;
  - DC current: ± 1%;
  - DC voltage: ± 1%;
  - AC power: ± 1%:
    - an available current crest factor of 5 or more;
    - the test instrument shall have a bandwidth of at least 1 kHz;

  NOTE: Additional information on accuracy can be found in EN 62018 [**Error! Reference source not found.**].
- RF output power: ± 0,4dB.

If the power consumption measurements are done remotely via built-in measurement equipment they shall fulfil the requirements specified in ES 202 336-12 [1].

7 Measurement methods

7.1 Measurement method for $KPI_{EE\text{-}transfer}$

7.1.1 Definition of data volume

The actual throughput (total data volume) shall be measured based on the number of downlink (DL) data volume sent to the user equipments (UEs). Peak and average throughput shall be measured and reported as well as BS utilisation data.

7.1.2 Formulae

An assessment of KPI_{EM} requires that the energy supplied to the FAN provides all the primary functions of the network (i.e. NTE load, environmental control etc). If the supply of energy of any of the non-NTE loads is provided by other supplies not included in KPI_{EC} then KPI_{EM} cannot be assessed.

KPI_{EM} is defined mathematically as:

$$KPI_{EE\_transfer} = \frac{data\_volume_{NFVI}}{EC_{NFVI}}, \text{ subject to a minimum value of 0.}$$

7.1.2.1 Definition of terms

$data\_volume_{NFVI}$ = volume of data transported to and from the NFVI during the KPI assessment period k (in the interval t_k^{begin} to t_k^{end}) as described in detail in sub-clause 6.1

EC_{NFVI} = energy consumption of the NFVI during the KPI assessment period k (in the interval t_k^{begin} to t_k^{end}) as described in detail in sub-clause 6.1

NOTE: this measurement excludes the allowable renewable energy content described in sub-clause 5.1

7.1.2.2 Clarity

7.1.2.3 Criteria

8 Measurement report

Annex A: Items for consideration

A.1 Real-time measurements

Measurements and methodology Indicating load on NFVI

A.2.1 ??????

Other annexes (as required)

History

Document history		
<Version>	<Date>	<Milestone>
V0.0.1	22/09/2016	Skeleton
V0.0.2	01/01/2017	Skeleton draft 2