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| 3GPP TR 26.942 V0.4.0 (2024-11) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on Media Energy Consumption Exposure and Evaluation Framework;  (Release 19) | |
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Contents

Foreword 6

Introduction 7

1 Scope 8

2 References 8

3 Definitions of terms, symbols and abbreviations 12

3.1 Terms 12

3.2 Symbols 12

3.3 Abbreviations 13

4 Introduction to energy efficiency for media 14

4.1 General 14

4.1.1 Motivation 14

4.1.2 Energy and power in mobile networks 14

4.1.3 Energy and power in mobile device 15

4.1.4 Greenhouse gas emissions reporting and energy measurement 15

4.1.5 Legislative frameworks for greenhouse gas reporting 15

4.2 Related work 15

4.2.1 Introduction 16

4.2.2 3GPP 16

4.2.2.1 Introduction 16

4.2.2.2 Collection and exposure of energy consumption information at OAM 16

4.2.2.1.1 Introduction 16

4.2.2.1.2 Collection of network energy information by OAM 16

4.2.2.1.3 Exposure of network energy information by OAM 17

4.2.2.3 Collection and exposure of energy consumption information at NF 17

4.2.2.4 UE data collection, reporting and event exposure 19

4.2.2.4.1 UE data collection, reporting and event exposure architecture 19

4.2.2.4.2 UE data collection, reporting and event exposure for 5G Media Streaming 20

4.2.2.4.3 QoE Measurement Collection (QMC) functionality 21

4.2.2.4.4 Potential use of UE data collection, reporting and event exposure architecture for collection and exposure of energy consumption information 22

4.2.3 Other Standards Development Organisations 23

4.2.3.1 ITU-T 23

4.2.3.2 ITU-R 23

4.2.3.3 MPEG 23

4.2.3.4 DVB 24

4.2.3.5 ATSC 24

4.2.3.6 ETSI 24

4.2.3.6.1 Summary of energy efficiency standards drafted by the ETSI Environmental Engineering (EE) Working Group 24

4.2.3.6.2 Definition of Mobile Network Energy Efficiency 25

4.2.4 Industry Fora 26

4.2.4.1 Greening of Streaming 26

4.2.4.2 DIMPACT 26

4.2.4.3 Ultra HD Forum 26

4.2.5 Greenhouse Gas Protocol 26

4.2.5.1 Scope 1 26

4.2.5.2 Scope 2 26

4.2.5.3 Scope 3 27

4.2.6 Study on predicted environmental impact of audiovisual media consumption in France 27

5 Use cases 29

5.1 Baseline use cases defined by SA1 29

5.2 Refinement of relevant use cases defined by 3GPP SA1 in 3GPP SA4 context 30

5.3 Additional use cases defined by 3GPP SA4 30

6 Key issues 30

6.1 Key Issue #1: Energy-related Information exposure 30

6.1.1 Description 30

6.1.2 Potential requirements 31

6.2 Key Issue #2: Energy-related monitoring and measurement 32

6.2.1 Description 32

6.2.2 Potential requirements 33

6.3 Key Issue #3: Evaluation framework 34

6.3.1 Description 34

6.3.2 Potential requirements 34

7 Potential Solutions 34

7.1 Mapping of Solutions to Key issues 34

7.2 Solution #1: Evaluation framework based on French regulators work 35

7.2.1 Key issue mapping 35

7.2.2 Functional description 35

7.2.3 Procedures 35

7.2.4 Summary 36

7.3 Solution #2: Evaluation Framework to measure energy efficiency of a UE 36

7.3.1 Key Issue mapping 36

7.3.2 Functional description 36

7.3.2.1 UE Energy Efficiency metric 36

7.3.3 Procedures 37

7.3.4 Summary 38

7.4 Solution #3: Existing UE energy-related information measurement 38

7.4.1 Key issue mapping 38

7.4.2 Functional description 38

7.4.3 Summary 38

8 Conclusions and proposed next steps 39

Annex <A>: <Informative annex title for a Technical Report> 40

Annex <B> (informative): Change history 41

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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x the first digit:

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# Introduction

This clause is optional. If it exists, it shall be the second unnumbered clause.

# 1 Scope

This clause shall start on a new page.

The present document …

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] ETSI TS 28.310: "Management and orchestration; Energy efficiency of 5G".

[3] ETSI EN 303 472: "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for RAN equipment".

[4] ETSI ES 202 706-1 V1.7.1 (2022-08): "Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power consumption - static measurement method".

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[20] 3GPP TR 23.700-66: "Study on Energy Efficiency and Energy Saving".

[21] 3GPP TS 26.531: "Data collection and reporting; General description and architecture".

[22] 3GPP TS 26.532: "Data Collection and Reporting; Protocols and Formats".

[23] 3GPP TS 26.501: "5G Media Streaming (5GMS); General description and architecture".

[24] 3GPP TS 26.247: "Transparent end-to-end Packet-switched Streaming Service (PSS); Progressive Download and Dynamic Adaptive Streaming over HTTP (3GP-DASH)".

[25] 3GPP TS 38.300: "NR; NR and NG-RAN Overall description; Stage-2”.

[26] 3GPP TS 26.114: “IP Multimedia Subsystem (IMS); Multimedia telephony; Media handling and interaction”

[27] 3GPP TS 26.118: “Virtual Reality (VR) profiles for streaming applications”

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# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**energy efficiency (EE):** ratio between performance and energy consumption.

NOTE: The performance may be measured based on, e.g., data volume, latency, number of active users, etc. as defined in TS 28.310 [2].

**energy consumption:** integral of power consumption over time, as defined in TS 28.310 [2].

**maximum energy consumption:** a policy establishing an upper bound on the quantity of energy consumption [2] by the 5G system in a specific period of time, or space, e.g. energy consumption inside a given service area as defined in ETSI ES 202 706-1 [4].

**energy credit:** a quantity associated with the subscriber that can be used for credit control by the 5G System per TS 22.261 [5].

**maximum energy credit limit:** a policy establishing an upper bound on the aggregate quantity of energy consumption by the 5G System to provide services to a specific subscriber, e.g. in kilowatt hours [56].

**renewable energy:** energy from renewable sources, defined as energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases [3].

**carbon intensity:** Global greenhouse gases emitted per unit of generated electricity, measured in grams of CO₂ equivalent per watt–hour intended for conversion to carbon emissions as defined in TS 22.261 [5] and TS 23.700-66 [20].

## 3.2 Symbols

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

Symbol format (EW)

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

5GC 5G Core

5GMS 5G Media Streaming

AC Alternating Current

AF Application Function

AMF Access and Mobility Management Function

ANBR Access Network Bitrate Recommendation

AS Application Server

ATSC Advanced Television Systems Committee

CPE Customer Premises Equipment

DSLAM DSL Access Multiplexer

DSL Digital Subscriber Line

DTT Digital Terrestrial Television

DVB Digital Video Broadcasting

DWDM Dense Wavelength-Division Multiplexing

EEER Equipment Energy Efficiency Ratio

GPON Gigabit-capable Passive Optical Network

HD High Definition

IBC International Broadcasting Convention

ICT Information and Communications Technology

ISP Internet Service Provider

ITU-T The Telecommunication Sector of the ITU

MnS Management Service

MPLS Multi-Protocol Label Switching

MSAN Multi-Service Access Node

NAB National Association of Broadcasters

NEF Network Exposure Function

NFV Network Functions Virtualisation

NFVI Network Functions Virtualisation Infrastructure

NG-RAN Next Generation RAN

NSACF Network Slice Admission Control Function

NWDAF Network Data Analytics Function

OAM Operations, Administration and Maintenance

OLT Optical Line Termination

OTN Optical Transport Network

PCF Policy Control Function

PEE Power, Energy, Environmental

PNF Physical Network Function

QMC QoE Measurement Collection

QoE Quality of Experience

RAN Radio Access Network

SBMA Service-Based Management Architecture

SDH Synchronous Digital Hierarchy

SMF Session Management Function

SoC System-on-Chip

SVoD Subscription Video-on-Demand

TV Television

UDM Unified Data Management

UE User Equipment

UPF User Plane Function

VNF Virtualized Network Function

# 4 Introduction to energy efficiency for media

## 4.1 General

[Editor’s note: Introduction to the concepts of energy efficiency for media]

### 4.1.1 Motivation

The reason for studying energy consumption in media delivery stems from a concern for the current state of the climate, and the need to mitigate the effects of human-induced climate change. These effects are due to greenhouse gas emissions associated with human activity, including the production of energy. In this regard, mitigation strategies revolve around 1) producing cleaner energy, and 2) using less energy. The latter is relevant for any sector, system or device not directly involved in producing energy, including those defined by 3GPP. However, with 70–80% of network traffic being media, media data centres, the transmission of media data and media consumption on UEs contribute significantly to the total energy consumed by mobile networks.

Considering the 5G System, energy efficiency of each of its components as well as the system as a whole is required. In order to achieve increased energy efficiency – both at the component level and at the system level – the system needs first to be characterised. Such characterisation additionally enables reporting, thereby informing the various stakeholders of the system's energy performance. High-level measurements illustrated in clauses 4.1.2 and 4.1.3 are too coarse to allow system performance improvements, nor does it allow individual stakeholders, including Application Service Providers, network operators, and end users to know their own instantaneous energy use. Having access to fine-grained information on energy use, for instance on streaming an individual content asset, would allow the identification of potential energy hot spots, and it would facilitate government-mandated reporting which is increasingly prevalent in certain markets.

This feasibility study therefore focuses on the possibility of putting infrastructure in place that would enable the measurement and reporting of energy consumption across the media delivery eco-system of 5G networks.

### 4.1.2 Energy and power in mobile networks

The terms power and energy are closely related, with power being the rate at which work is done. It is measured in Watts or equivalently Joules per second (symbol ), or in derived quantities such as , or . Energy is power integrated over time, measured in Joules (), or equivalently Watt-seconds (). Larger quantities are often measured in kilo-Watt-hours , mega-Watt-hours or tera-Watt-hours (TWh). One represents 3.6.

For the year 2020, the global annual electricity consumption (AEC) of mobile networks (including 2G up to 5G, as well as satellite communication) is estimated to have been 161 , of which 146  is spent by access networks, 6  by the core network, and 9  by support activities [8]. This represents 20  per subscription per year [8]. In the period 2015–2018 this figure was estimated at 17  per subscription per year [6].

To characterize the energy used to transmit data in a more fine-grained manner, energy-per-data figures are often reported, for example in /. This suggests that a given network expends energy directly proportional to the amount of data communicated. This, however, has been shown to be an inaccurate measure due to the presence of significant fixed overheads. As an example, the servers in a data centre need to be cooled, irrespective of whether data passes through them or not.

For this, and other reasons, the transmission of data incurs a base load which is related to the presence and maintenance of the infrastructure itself, plus a mark-up that depends on the amount of data being transmitted.

Examples of power usage for 4G systems and use cases, taking into account such base load, are given in table 4.1.2‑1 [7].

Table 4.1.2-1. example of power usage in 4G mobile transmission systems (after [7])

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System / Use case | Bit rate (/) | ( | (//) | ( |
| 4G RAN |  | 0.5 – 2 | 1 – 2 |  |
| 4G data transmission and IP core network |  | 0.05 – 0.5 | 0.03 |  |
| No data (inactive) | 0 | 1.2 | 1.53 | 1.2 |
| "YouTube" application service | 1.5 | 1.2 | 1.53 | 3.4 |
| "Netflix" application service | 4 | 1.2 | 1.53 | 7.3 |
| File download | 40 | 1.2 | 1.53 | 62 |

Where for a bit rate (in megabits per second, ), is the base load (in ), b is the data-dependent term (in //), and is the power consumped (in ).

As can be seen in table 4.1.2-1, the fixed overhead is relatively important at low bit rates. For larger bit rates (e.g. the file download example) the transmission rate dominates the power consumption.

### 4.1.3 Energy and power in mobile device

According to [8] the global annual electricity consumption of smartphones and feature phones in 2020 is estimated to have been around 17 and 2 respectively.

### 4.1.4 Greenhouse gas emissions reporting and energy measurement

A study from Ember Climate [13] emphasises that electricity use may be mapped onto greenhouse gas via a conversion factor known as the *carbon intensity* measured in grams of Cos equivalent per kilowatt hour (-e/). The carbon intensity depends strongly on the method used to produce electricity, and therefore on the natural resources available in a given geographic location. Currently, the carbon intensity ranges from under 100 -e/ to over 700 -e/, with a global average of 436 -e/ (data from [13]).

The measurement of greenhouse gas emissions is difficult if not impossible to perform directly, but through the locally and globally known carbon intensities, energy consumption measurements may be converted to estimates of greenhouse gas emissions. The energy consumption of a 5G network and its components could therefore be used as a proxy for greenhouse gas emissions.

### 4.1.5 Legislative frameworks for greenhouse gas reporting

Larger companies in European member states are subject to corporate sustainability reporting under the Corporate Sustainability Reporting Directive (CSRD), and following European Sustainability Reporting Standards which are available under [12] supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards. This reporting law follows the Scopes defined by the Greenhouse Gas Protocol [10].

Other regions in the world may be subject to other and/or additional reporting requirements.

## 4.2 Related work

### 4.2.1 Introduction

Several standards setting organisations broadly active in the areas of broadcasting and telecommunications are considering energy efficiency and the reduction of climate impact. Likewise, several industry fora are active in this area. This section documents some of the efforts underway, and references standards and reports currently available.

### 4.2.2 3GPP

#### 4.2.2.1 Introduction

#### 4.2.2.2 Collection and exposure of energy consumption information at OAM

##### 4.2.2.1.1 Introduction

This clause summarizes TS 28.554 [15] as it relates to the evaluation and collection of energy consumption information by the Operations, Administration and Maintenance (OAM) capability of the 5G System, as specified in 3GPP Release 18 by SA WG5.

##### 4.2.2.1.2 Collection of network energy information by OAM

Clause 6.7.3 of TS 28.554 [15] defines the Energy Consumption KPI of a Physical Node. The network energy information that can be collected by the OAM capability includes that listed in table 4.2.2.1.2-1.

Table 4.2.2.1.2-1: Network energy information collected by OAM

|  |  |  |  |
| --- | --- | --- | --- |
| KPI category | Description | Reference | Clause |
| Energy Consumption (EC) information | Energy Consumption of a gNodeB | TS 28.554 [15] | 6.7.3.4.2 |
| Energy Consumption of the NG-RAN | 6.7.3.4.1 |
| Energy Consumption of the 5GC | 6.7.3.2.1 |
| Energy Consumption of a 5G Network Function | 6.7.3.1.1 |
| Estimated Energy Consumption of a Virtualized Network Function | 6.7.3.1.2 |
| Energy Consumption of a network slice | 6.7.3.3 |
| Energy Consumption of a Physical Network Function (PNF) as well as other Power, Energy, Environmental (PEE) measurements | TS 28.552 [16] | 5.1.1.19.2 |
| Energy Efficiency KPIs | Energy Efficiency of the NG-RAN data | TS 28.554 [15] | 6.7.1 |
| Energy Efficiency of the 5GC | 6.7.4.1 |
| Energy Efficiency of a network slice | 6.7.2 |

In the case of a Virtualized Network Function (VNF) hosted on a physical node, the energy consumption of the VNF is estimated as a portion of the total energy consumption of the physical node on which the VNF is executing, based on its relative virtual CPU usage, virtual memory usage, virtual disk usage and I/O traffic (all metrics collected from ETSI MANO) as defined in clause 6.3.1.2 of TS 28.554 [15].

##### 4.2.2.1.3 Exposure of network energy information by OAM

Network energy information may be collected by OAM and exposed (other mechanisms may exist) as defined by the Service-Based Management Architecture (SBMA) in TS 28.533 [17]. Any authorised consumer willing to collect such measurements or KPIs is first required by [17] to create an instance of a *performance metrics production job* (i.e., an instance of the PerfMetricJob information element – see clause 4.3.31 of TS 28.622 [18]) by invoking the createMOI operation of the Provisioning Management Service (MnS) (see clause 11.1.1.1 of TS 28.532 [19]).

The consumer is required by [17] to specify:

- Which measurement(s) or KPI(s) it wishes to be collected, e.g. the energy consumption of a 5G NF, etc.

- Which network entities (represented by *managed objects*) it wishes the information to be collected from (e.g., SMF x, UPF y, etc.).

- The granularity period (expressed in seconds) it wishes the measurements or KPIs to be reported over.

- The reporting method, mainly:

- *File-based reporting:* Performance data is accumulated for a certain time before it is reported; the data is delivered as a file; the file content encoding is either XML or ASN.1.

- *Stream-based reporting:* The producer sends the performance data to the consumer as when they are ready. The volume of the performance data reported is expected to be small, and the granularity period is expected to be short. The stream content encoding technique is either GPB or ASN.1.

Depending on the selected reporting method, the consumer collects the measurements or KPIs as follows:

- In the case of file-based reporting, the producer sends the notification NotifyFileReady to subscribed consumer(s) when a new file becomes available on the producer for subsequent download by consumer(s).

- In the case of stream-based reporting, the producer sends units of streaming data to the consumer by invoking the reportStreamData operation.

#### 4.2.2.3 Collection and exposure of energy consumption information at NF

TR 23.700-66 [20] studies and identifies potential enhancements to the 5G System (e.g., including network energy-related information exposure, enhancement for subscription and policy control to enable energy efficiency as a service criterion) to improve energy efficiency and to support energy saving in the network.

Three different key issues have been identified in that study:

- KI#1: Network energy related information exposure

- KI#2: Subscription and policy control to support energy efficiency and energy saving as service criteria

- KI#3: 5GS enhancements for network energy saving and efficiency

KI#2 is not in scope of this study. The conclusions of KI#1 and KI#3 in clause 8 of TR 23.700-66 [20] and the normative work following will be used for collection and exposure of Energy Consumption information at Network Functions (NFs) and are summarised as follows:

1. A new network functionality will be defined to collect and calculate energy-related information and expose it to authorised consumers subject to operator's policy:

- If the authorised consumer is a 5GC Network Function, the information exposure granularities that can be configured in this policy will include per application, per UE, per-UE-per-QoS Flow, per PDU session.

- If the authorised consumer is an Application Function, the information exposure granularities that can be configured in this policy will include: per UE, per UE per application, per PDU session.

NOTE: Whether the new network functionality can be deployed as a standalone Network Function or co-located with other Network Functions is for further study outside the scope of the present document.

2. The energy-related information that can be exposed according to the above exposure granularities will include:

- Energy Consumption information as defined in TS 28.310 [2].

- Renewable energy information defined as energy from renewable non-fossil sources. For example (but not limited to) wind, solar, aerothermal, geothermal, hydrothermal.

3. A consumer of energy-related information (i.e., 5GC NF or AF) may request different modes of exposure (e.g. periodic reporting or threshold-based reporting) as part of its subscription request.

4. The new network functionality supporting the calculation of the Energy Consumption information includes the following aspects:

1. OAM: provides the NF/Node-level Energy Consumption information at the gNB(s) and UPF(s) serving the UE.
2. OAM: provides the overall data volume of the gNodeB.
3. The information of a) and b) received from OAM could be used by the new network functionality for all the UEs served by the NF/Node.
4. UPF: provides the overall data volume of the UPF.
5. UPF: provides the data volume for the QoS Flow or the Service Data Flow (SDF).
6. When the gNodeB and/or the (I-)UPF(s) which are serving the UE change, the serving gNodeB ID and UPF ID will be sent to the new network functionality through AMF/SMF.

5. The new network functionality determines the end-to-end energy consumption based on energy consumption per the granularities above at the serving Network Function (i.e. NG-RAN and UPF).

6. In Release 19, only the energy-related information of user plane communication (not control plane signalling) is supported.

7. Enhancements to NF discovery and (re-)selection procedures based on energy-related information:

- The NF profile may be extended (e.g. by including the new energy-related information or by reusing existing NF profile parameters) to allow an operator to influence NF discovery and selection based on its energy strategy.

- NF discovery and (re-) selection will be enhanced to consider the energy-related information from the NF profiles and/or discovery requests from the NF consumer.

8. Enhancements to existing operations and procedures for energy saving and energy efficiency:

- The User Plane path of a PDU session may be adjusted so that it consumes less energy.

The recommendations of the present document focusing on media services will need to be aligned with the conclusions in clause 8 of TR 23.700-66 [20] impacting Application Functions used for media services.

#### 4.2.2.4 UE data collection, reporting and event exposure

##### 4.2.2.4.1 UE data collection, reporting and event exposure architecture

A generic architecture for the collection and reporting of UE data is defined in TS 26.531 [21] and the corresponding APIs are specified in TS 26.532 [22] but UE energy consumption has not been considered in these specifications up to and including in Release 18. Subject to study in the present document, a potential solution would be to expand the scope of these specifications to support the collection and exposure of energy consumption information at UE.

The main principle of the reference architecture defined in clause 4 of TS 26.531 [21] and reproduced in figure 4.2.2.4‑1 below is the addition of an intermediary Application Function named the Data Collection AF which is used collected UE data reports from data collection clients and Application Servers, and to synthesise from those reports a set of events which are exposed to event consumer subscriber, such as the Network Data Analytics Function (NWDAF) or an Event Consumer AF deployed in the Application Service Provider.



Figure 4.2.2.4.1‑1: Reference architecture for data collection and reporting

Data collection and reporting functionality in the Data Collection AF is provisioned at reference point R1 by a *Provisioning AF* of the *Application Service Provider* that may be deployed either inside or outside the trusted domain. The purpose of the Data Collection AF is to receive UE data reports from one of three possible sources:

1. Directly from the UE. In this case the *Direct Data Collection Client* is responsible for collecting relevant data in the UE (typically from a UE Application using a suitable API at reference point R7) and for sending data reports to the Data Collection AF via reference point R2.

2. Indirectly from the UE. In this case, an Application Service Provider collects data from UE Applications privately via reference point R8 and employ an Indirect Data Collection Client subfunction to then send data reports to the Data Collection AF via reference point R3.

3. From an Application Server that has been used to deliver media to/from a UE. Application Server instances (AS) inside or outside the trusted domain may also collect data and report it to the Data Collection AF via reference point R4.

The Data Collection AF aggregates and filters UE data that is reported to it. The processed UE data is exposed by the Data Collection AF to the NWDAF in the form of data reporting event notifications via reference point R5. Certain UE data may also be exposed in the form of data reporting events by the Data Collection AF to an Event Consumer AF residing in the Application Service Provider via reference point R6.

When they are deployed in different trust domains, the interactions between the system actors of the UE data collection, reporting and event exposure architecture may be mediated through the NEF, as illustrated by various collaboration scenarios defined in annex A of TS 26.531 [21].

##### 4.2.2.4.2 UE data collection, reporting and event exposure for 5G Media Streaming

The instantiation of the UE data collection, reporting and event exposure architecture in the 5GMS System is defined in clause 4.7 of TS 26.501 [23] and the reference architecture for this instantiation is reproduced in figure 4.2.2.4-2.



Figure 4.2.2.4.2‑1: Data collection and reporting architecture instantiation for 5G Media Streaming

Three existing 5GMS reference points are reused in this instantiation: M1 (for provisioning UE data collection, reporting and event exposure), M5 (for media session handling) and M6 (for interacting with the Media Session Handler).

- The *Provisioning AF* of the Application Service Provider is not instantiated in the 5GMS architecture. Data collection and reporting is instead provisioned using the procedures using M1 defined in TS 26.501 [23].

- The *Data Collection AF* for 5G Media Streaming is instantiated in the 5GMS AF.

- The *Direct Data Collection Client* for 5G Media Streaming is instantiated in the Media Session Handler. This takes logical responsibility for the UE data collection activities of the *Metrics Collection & Reporting* and *Consumption Collection & Reporting* subfunctions and the subsequent reporting of this UE data via reference point M5. It also takes logical responsibility for thelogging of ANBR-based Network Assistance invocations by the *Network Assistance* subfunction and their subsequent reporting to the Data Collection AF instantiated in the 5GMS AF via reference point R2.

NOTE: The use of M5 instead of R2 is due to the definition of some procedures before the definition of this instantiation. M5 was already used for QoE metrics and consumption reports, or invocations of the downlink dynamic policy procedures and invocations of the *AF-based downlink Network Assistance* procedures. Thus, for these procedures, M5 is used instead of R2.

- The Indirect Data Collection Client is not instantiated in the 5GMS architecture. Indirect reporting of UE data is outside the scope of 5G Media Streaming. Thus, R8 is not instantiated in the 5GMS architecture.

- The role of the AS in the abstract reference architecture is played by 5GMS AS. (This may be deployed as a trusted AS within the 5G System or deployed externally.)

- The Event Consumer AF is instantiated in the 5GMS Application Provider as a consumer of 5G Media Streaming events from the Data Collection AF.

- Reference point R7 is not instantiated in the 5GMS architecture. Configuration of 5GMS-related data reporting in the Media Session Handler by the 5GMS-Aware Application is managed through the existing media session handling client API at reference point M6.

##### 4.2.2.4.3 QoE Measurement Collection (QMC) functionality

TS 38.300 [25] defines the QoE Measurement Collection (QMC) feature which enables collection of application layer measurements from the UE. QMC is supported for the following service types in NR cells:

- QoE Measurement Collection for DASH streaming services in TS 26.247 [24];

- QoE Measurement Collection for MTSI services in TS 26.114 [26];

- QoE Measurement Collection for VR services in TS 26.118 [27].

The QMC feature also supports collection of QoE measurements for any of the supported service types carried by the MBS communication service defined in TS 23.247 [64], namely:

- MBS broadcast;

- MBS multicast.

More details of QMC control and configuration can be found in TS 28.405 [28]. A potential solution would be to reuse and expand the QMC functionality to support the reporting of energy consumption information by the UE.

##### 4.2.2.4.4 Potential use of UE data collection, reporting and event exposure architecture for collection and exposure of energy consumption information

### 4.2.3 Other Standards Development Organisations

#### 4.2.3.1 ITU-T

Within the International Telecommunication Union, the T-sector includes Study Group 5 "Environment and Circular Economy" (SG5). Part of its mandate is to define and develop "methodologies for evaluating ICT effects on climate change and publishing guidelines for using ICTs in an eco-friendly way. Under its environmental mandate SG5 is also responsible for studying design methodologies to reduce ICT’s and e-waste’s adverse environmental effects, for example, through recycling of ICT facilities and equipment."

Among its activities, ITU-T Study Group 5 is developing technical reports, supplements and recommendations for the environmental requirements of 5G.

* Recommendation ITU-T L.1310 [29] contains the definition of energy efficiency metrics, test procedures, methodologies and measurement profiles required to assess the energy efficiency of telecommunication equipment. Energy efficiency metrics and measurement methods are defined for telecommunication network equipment and small networking equipment. These metrics allow for the comparison of equipment within the same class, e.g., equipment using the same technologies.
* ITU-T L.1310 Supplement 36 [30] analyses the energy efficiency issues for 5G systems. The focus of this supplement is on methods and metrics used to measure energy efficiency in 5G systems with multi-radio equipment.

Further, the L.1400 series of reports and recommendations present methodologies and guidelines for the assessment of the greenhouse gas emissions and energy consumption of the ICT sector. For example:

- Recommendation ITU-T L.1450 [31] presents a methodology for the assessment of the impact of telecommunications systems. It was used in an assessment of the electricity usage and greenhouse gas emissions of the ICT sector [32].

#### 4.2.3.2 ITU-R

The remit of ITU-R Study Group 6 (SG6) is programme production and interchange. Its Working Party 6A (WP 6A) has published ITU-R Report BT.2385 "Reducing the environmental impact of terrestrial broadcasting systems" [33]. Working Party 6C (WP 6C) has a rapporteur group which has produced the following documents:

- ITU-R Opinion 104, "Advice for sustainability strategies incorporating carbon offsetting policies" [34]

- ITU-R Report BT.2521, "Practical examples of actions to realize energy aware broadcasting" [35]. This report is based on a webinar held in March 2022.

- ITU-R Report BT.2540, "Display energy reduction through image signal processing" [36]. This document describes techniques for producing, transmitting and using metadata which enables display devices to use less energy.

#### 4.2.3.3 MPEG

The ISO/IEC JTC 1/SC 29 committee *Coding of audio, picture, multimedia and hypermedia information* has published the ISO/IEC 23001-11:2023 (Green MPEG) standard [37]. The various components of the standard define methods for the reduction of the power consumption of decoders and of displays. A further component defines a method for the selection of energy-efficient media. A final method allows for quality recovery after low-power encoding. The standard is currently in revision, and it is to be extended to enable the carriage of metadata to more efficiently reduce the power requirements of display devices receiving the content with the metadata.

#### 4.2.3.4 DVB

DVB has carried out a study mission to assess the potential for developing energy-efficient video transmission systems. This work has resulted in the creation of a new CM-EE (Energy Efficiency) working group in its Commercial Module. It has also published a report on the topic available as Blue Book S100 "Study Mission report on Energy Aware service Delivery and Consumption" [38].

#### 4.2.3.5 ATSC

ATSC's "Planning Team 9 – Sustainability in Media and Data Delivery Services (PT9) will study the benefits of broadcast data delivery as relates to sustainable energy usage in a world increasingly dependent on data delivery. The team will consider linear and file-based media delivery as well as linear and file-based data delivery. PT9 will report the results of this work to the Board. If technical work in ATSC is recommended, PT9 will further document rationale for the work and ideally also document possible architectural approaches and requirements, such as interoperability with existing networks, which would accommodate the identified use cases. PT9 does not draft standards or recommended practices; it may draft New Project Proposals and/or Planning Team Reports. PT9 reports to the ATSC Board of Directors and participation is open to all ATSC members." [39].

#### 4.2.3.6 ETSI

##### 4.2.3.6.1 Summary of energy efficiency standards drafted by the ETSI Environmental Engineering (EE) Working Group

Table 4.2.3.6.1‑1 below shows a summary of energy efficiency standards developed by the ETSI Working Group on Environmental Engineering (EE). The list is non-exhaustive.

Table 4.2.3.6.1‑1: List of ETSI Environmental Engineering (EE) specifications

|  |  |
| --- | --- |
| Standard | Summary |
| ETSI ES 202 706-1  [40] | Defines the measurement method for the evaluation of base station power consumption and energy consumption with static load. The methodology described in this specification is to measure base station static power consumption and RF output power. Within the document it is referred to as "static" measurements. The results based on "static" measurements provide power and energy consumption figures for a Base Station under static load. |
| ETSI ES 203 700  [41] | Defines power feeding solutions for 5G, converged wireless and wireline access equipment and network, taking into consideration their enhanced requirements on service availability and reliability, the new deployment scenarios, together with the environmental impact of the proposed solutions. The minimum requirements of different solutions including power feeding structures, components, backup, safety requirements, environmental conditions are also defined. |
| ETSI ES 203 539  [42] | Defines energy efficiency metrics and measurement methods for NFV components including VNFs and NFVI. The energy efficiency of VNF is evaluated according to hardware energy consumption, resource consumption and utilization related with VNF. The energy efficiency of NFVI is evaluated as resource provision capability which is expressed as service capacity of reference VNFs running on it with amount of energy consumption. |
| ETSI EN 303 470  [43] | Specifies a metric for the assessment of energy efficiency of computer servers. Formalizes the tools, conditions and calculations used to generate a single figure of merit of a single computer server representing its relative efficiency and power impact. The metric is targeted for use as a tool in the selection process of servers to be provisioned. |
| ETSI EN 303 471  [44] | Specifies the method and metrics to determine the energy efficiency of operational Network Function Virtualisation (NFV) applications and their associated infrastructure. It specifies the method and metrics to determine the energy efficiency of operational Network Function Virtualisation (NFV) applications and their associated infrastructure when that infrastructure is implemented outside the boundaries of the access fixed, cable and mobile networks which they serve. |
| ETSI ES 203 475  [45] | Specifies terminology, principles and concepts for Energy efficiency and energy management. It aims to establish a common understanding of measurement methodology used to determine the energy efficiency of a good, service and network. It presents a framework for other ETSI standards and other Standard Development Organization documents about Energy Efficiency. |
| ETSI ES 203 136  [46] | Defines the energy consumption metrics and measurement methods for packet routing and Ethernet switching equipment. It defines the methodology and the test conditions to measure the power consumption of a router or switch. It is applicable to core, edge and access routers. Home gateways are out of scope. |
| ETSI EN 303 215  [47] | Defines power consumption metrics, methodology and test conditions to measure the power consumption of broadband fixed telecommunication network equipment. It does not cover all possible configuration of equipment, but only homogenous configurations. The types of broadband access technologies covered are: DSLAM DSL, MSAN, GPON OLT and point-to-point OLT equipment. |
| ETSI ES 202 706  [4] | Defines methods for evaluation of power consumption and energy efficiency of base station in static and dynamic mode. The methodology described is to measure base station static power consumption and dynamic energy efficiency, which are referred to as static and dynamic measurements respectively. The results based on "static" measurements of the Base Station power consumption provide a power consumption figure for the Base Station under static load. The results based on "dynamic" measurements of the Base Station provide energy efficincy information for a Base Station with dynamic load. |
| ETSI ES 203 184  [48] | Defines the metric, methodology and the test conditions to evaluate the Equipment Energy Efficiency Ratio (EEER) of Transport equipment, including all the transmission equipment connected to the network by means of wired medium (i.e. copper or fiber), typically running at the network OSI Layer 1. The present document also covers the equipment running at the network OSI Layer 2 (e.g. MPLS-TP) that are not included in the ETSI standard on "Measurement Methods for Energy Efficiency of Router and Switch Equipment" (the same approach is followed by ATIS standard on Transport equipment. Examples of typical wired Transport equipment covered by the present document are switches or crosses connects (SDH, OTN) and add/drop multiplexers (DWDM). The present document covers also simpler systems as multiplexers/demultiplexers (DWDM), optical amplifiers, transponders. |
| ETSI EN 301 575  [49] | Defines energy consumption measurement methods for Broadband CPE telecommunication equipment. Also defines a methodology and test conditions to measure the power consumption of end-user broadband equipment. |
| ETSI ES 203 215  [50] | Defines energy consumption limits and measurement methods for fixed broadband telecommunication network equipment. Also defines power consumption limits, a methodology and test conditions to measure the power consumption of broadband fixed telecommunication networks equipment. The types of broadband access technologies covered are: DSLAM DSL, MSAN, GPON OLT, Point to Point OLT equipment. |

##### 4.2.3.6.2 Definition of Mobile Network Energy Efficiency

ITU-T L.1310 [29] defines energy efficiency as the relationship between the specific functional unit for a piece of equipment (i.e., the useful work of telecommunications) and the energy consumption of that equipment. For example, when transmission time and frequency bandwidth are fixed, a telecommunication system that can transport more data (in bits) with less energy (in Joules) is considered to be more energy-efficient. For this reason, metrics that can evaluate the performance of a piece of equipment against its energy consumption are to be defined.

From Release 15 onwards, the definition of Energy Efficiency is clarified in 3GPP. The definition does not come directly from 3GPP itself, but rather is adopted from the ETSI Working Group on Environmental Engineering, in ETSI ES 203 228 [66] which aims to define the topology and level of analysis to assess the energy efficiency of mobile networks. In particular, [66] defines metrics for mobile network energy efficiency and methods for assessing (and measuring) energy efficiency in operational networks.

Per ETSI ES 203 228 [66], Energy Efficiency (EE) of a Mobile Network is defined as the relation between the useful output and power consumption, where power consumption is defined as the power consumed by a device to achieve an intended application performance.

Mobile Network data Energy Efficiency is the ratio between the performance indicator Data Volume () and the Energy Consumption () when assessed during the same time frame (T) as as defined in clause 7.1 of ITU-T recommendation L.1331 [67]. This is also shown by the formula:

where *DV* is the Data Volume, expressed in bits, transported across a network element. The Data Volume measurements are collected via OAM. *EC* is the Energy Consumption, expressed in Joules, of the same network element. The MN suffix stands for Mobile Network.

Clause 8.2 of ITU-T L.1331 [67] illustrates how to measure/collect the information about data volume (for capacity), coverage area (for coverage) as well as energy consumption over a measurement period called *T*, that can span one week, one month, or longer periods.

This formula is reproduced in several 3GPP TSs and TRs dealing with energy efficiency (EE).

### 4.2.4 Industry fora

#### 4.2.4.1 Greening of Streaming

Greening of Streaming is a member association investigating energy efficiency in the context of media streaming applications [51]. One of the challenges the group is aiming to address is that of accurately measuring the energy expenditure of streaming services, given that currently the available data is sparse and not very precise. It further intends to define best practices.

#### 4.2.4.2 DIMPACT

"DIMPACT is a collaborative initiative between leading media, entertainment and technology companies and world-class researchers" [52]. The group is convened by Carnstone Partners Ltd, and research and technical expertise is provided by researchers from the University of Bristol. It has currently over 20 members. The group has developed a tool to measure the emissions of serving digital media and entertainment products. This tool is available as a web application and is able to estimate emissions originating from video streaming, online banner advertising, digital publishing, and audio streaming. The DIMPACT website makes available several publications explaining their methodology [53] and defining principles for streaming and digital media carbon footprinting [54].

#### 4.2.4.3 Ultra HD Forum

The Sustainability Working Group of the Ultra HD Forum is investigating energy efficiency opportunities throughout content distribution, from content encoding through distribution and display. One result has been a regular series of public demonstrations directed to sustainability at major broadcast conferences (specifically IBC and NAB) where the Ultra HD Forum regularly has a booth [55]. Some of these demonstrate the degree of influence the consumer can have on the energy consumption by the display.

### 4.2.5 Greenhouse Gas Protocol

The Greenhouse Gas Protocol [9] is an organisation that "provides standards, guidance, tools and training for business and government to measure and manage climate-warming emissions." The first edition of their reporting standard was published in 2001, establishing a reporting framework for businesses. Relative to a given company, the concept of “scopes” is introduced, which delineate direct and indirect emission source, and are used for accounting and reporting purposes. The reporting principally involves the six greenhouse gasses that are defined in the Kyoto protocol: carbon dioxide (), methane (), nitrous oxide (), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (). Scopes 1 (sources owned or controlled by a company giving rise to direct greenhouse gas) and 2 (the electricity purchased and consumed by a company gives rise to greenhouse gas emissions) are defined in [10], and Scope 3 (All other indirect emissions) is defined in [11].

NOTE: 3GPP SA5 is also considering the Greenhouse Gas Protocol as part of TR 28.913 [14]

#### 4.2.5.1 Scope 1

Sources owned or controlled by a company give rise to direct greenhouse gas emissions. The activities undertaken by a company that give rise to scope 1 emissions include the generation of electricity, heat, or steam; physical or chemical processing; transportation of materials, products, and waste; fugitive emissions.

#### 4.2.5.2 Scope 2

The electricity purchased and consumed by a company gives rise to greenhouse gas emissions. Scope 2 emissions occur at the facility where the electricity is generated, rather than where the electricity is consumed. For the reporting company, these emissions are therefore counted as one form of indirect emissions. As purchased electricity is for many companies one of the largest sources of greenhouse gas emissions, it also offers a significant potential for reductions, either by investing in energy efficient technologies, by energy conservation, or by switching to less greenhouse gas intensive sources of electricity.

#### 4.2.5.3 Scope 3

All other indirect emissions can be reported under scope 3. The emissions reported in this category are the consequence of the activities of a company, but they come from sources not owned or controlled by this company. These indirect emissions arise elsewhere in the corporate value chain of a given company, both upstream and downstream. Upstream emissions are indirect emissions relating to purchased or acquired goods and services. Downstream emissions relate to sold goods and services. Scope 3 indirect emissions are categorised into 15 distinct categories, of which the upstream categories are:

1. **Purchased goods and services.** Extraction, production, and transportation of goods and services purchased or acquired by the reporting company in the reporting year, not otherwise included in categories 2 to 8.

2. **Capital goods.** Extraction, production, and transportation of capital goods, purchased or acquired by the reporting company in the reporting year.

3. **Fuel- and energy-related activities (not included in scope 1 or scope 2).** Extraction, production, and transportation of fuels and energy purchased or acquired by the reporting company in the reporting year.

4. **Upstream transportation and distribution.** Transportation and distribution of purchased products or services in the reporting year, including inbound and outbound logistics; transportation between a company’s own facilities.

5. **Waste generated in operations.** Disposal and treatment of waste generated by the reporting company’s operations in the reporting year.

6. **Business travel.** Transportation of employees for business-related activities in the reporting year in vehicles not owned or operated by the reporting company.

7. **Employee commuting.** Transportation of employees between their homes and their worksites during the reporting year, in vehicles not owned or operated by the reporting company.

8. **Upstream leased assets.** Operation of assets leased by the reporting company in the reporting year.

The downstream categories are:

1. **Downstream transportation and distribution.** Transportation and distribution of products sold by the reporting company in the reporting year between the reporting company’s operations and the end consumer, if not paid for by the reporting company (in vehicles and facilities not owned by the reporting company).

2. **Processing of sold products.** Processing of intermediate products sold in the reporting year by the downstream companies.

3. **Use of sold products.** End use of goods and services sold by the reporting company in the reporting year.

4. **End-of-life treatment of sold products.** Waste disposal and treatment of products sold by the reporting company (in the reporting year) at the end of their life.

5. **Downstream leased assets.** Operation of assets owned by the reporting company and leased by other companies in the reporting year.

6. **Franchises.** Operation of franchise in the reporting year.

7. **Investments.** Operation of investments (including equity and debt investments and project finance) in the reporting year.

### 4.2.6 Study on predicted environmental impact of audiovisual media consumption in France

In 2022, the audiovisual communications regulator for France, Arcom, and its communication networks regulator, Arcep, published a joint study [61] on the predicted environmental impact of audiovisual media consumption in France over the period from 2022 to 2030. The study assesses the environmental impact of consuming audiovisual mass media, taking all the component parts into account: hardware (user devices), networks (fixed broadband and superfast broadband, digital terrestrial, and satellite) and data centres. Its scope includes the main systems used to access audiovisual media: linear and time-shifted television and radio, audio and video streaming (including video-on-demand services), and video sharing platforms. Every type of impact has been assessed (carbon footprint, consumption of mineral and metal resources, final energy consumption) including energy usage, the target for the framework of the report.

In this study, energy usage (termed *final energy consumption*) is measured in kilowatt-hours (kWh) and refers to the quantity of electricity consumed during the usage phase of the three tiers of the digital value chain (user devices, networks and data centres). It concerns itself only with the usage stage of terminals, networks, and data centres; upstream electricity consumption for the manufacturing phase is not addressed by this indicator.

A comparative assessment of nine audiovisual usage scenarios (on the scale of one hour of audio or video content consumption in France in 2022) is considered in the report:

- **A1:** Listening to live FM radio on a radio set

- **A2:** Listening to live FM radio on a car radio

- **A3:** Listening to live radio via the Internet on a smartphone connected to the fixed network

- **A4:** Listening to music/podcast on a streaming platform (app) on a smartphone connected to the Internet via mobile network

- **V1:** Watching a TV channel in HD on a television via integrated Digital Terrestrial Television (DTT) access

- **V2:** Watching a TV channel in HD on a television connected to the Internet via a TV decoder linked to an ISP box (managed IPTV)

- **V3:** Watching catch-up TV in HD on a smart TV connected to the Internet via a TV decoder linked to an ISP box

- **V4:** Watching Subscription Video-on-Demand (SVoD) in HD on a smart TV connected to the Internet via fixed network

- **V5:** Watching online videos on a video sharing platform in HD on a smartphone connected to the Internet via mobile network

To estimate energy consumption of devices, four differents devices have been evaluated under laboratory test conditions (two smartphones, one PC and one smart TV set).

- For the smart TV and the PC, a measurement module (digital watt meter) is inserted between the device and the mains power outlet. This module measures energy consumption in Alternating Current (AC). The watt meter is connected to a computer to record the energy consumption measurements.

- For smartphones, measurements are taken using software probes to record energy and data consumption.

Energy is measured in units of milliwatt-hours per second (mWh/s) or milliamp-hours (mAh). The measurements are sampled for a period of one minute. Several iterations are performed (a minimum of three samples) to ensure relevance and to limit artifacts related to the measurement itself. Testing conditions are noted for traceability of the measurements.

Two measurement modes are possible:

- *Systematic content change between iterations.* This measurement mode has the advantage of eliminating the effects of content caching strategies in the terminal device or delivery network but has the disadvantage of introducing variability. However, this measurement mode is more representative of real-world user behaviour.

- *Iterations are conducted on a continuously played video.* This measurement mode has the advantage of controlling for the variability of content but has the disadvantage of potentially underestimating consumption due to caching technologies.

The systematic content change solution is favoured in the scenario V5 (video sharing platforms). On the other hand, the continuous video strategy is used when it is useful to control for the content's impact and to study certain parameters (such as video codec).

Given the diversity of hardware studied, it was decided that the user journey would not be automated.

The data measured under laboratory test conditions are very specific. They are conducted on a single device (two for smartphones), which performs a single precise usage. This allows, for example, consumption during content playback to be differentiated from browsing a content catalogue. However, these measurements are not necessarily representative of the entire equipment landscape. Thus, comprehensive and representative data from the literature on a more diverse equipment pool were preferred over certain laboratory measurements for the quantification of audio and video usage at the national level in France.

In the context of the present document:

- The method to estimate the energy consumption of the mobile network described in [61] is not reusable because it uses a theoretical calculation based on the total amount of energy consumed by the mobile network, the mobile network usage duration per subscriber and a formula allocating energy consumption per subscriber per year and per data volume.

- The method to estimate the energy consumption of data centres described in [61] is not reusable either because it is based on external estimates.

- The method to estimate the energy consumption of a UE described in [61] could be used as a basis for evaluating the energy usage/savings of multimedia standards features and proposals on UEs.

# 5 Use cases

## 5.1 Baseline use cases defined by SA1

Use cases regarding enhancements to Energy Efficiency of 5G network and application service enabler aspects are listed in TR 22.882 [56]. Five of them have been identified as media-related and therefore fall within the scope of this study:

- *Use case 5.5 on service energy monitoring by an Application Server:* The Application Service Provider cares about energy consumption in the Data Network as a result of the service provided by an Application Server to UEs. This could be for one or more of the following three reasons:

- The Application Service Provider needs to demonstrate that it is reducing energy consumption;

- The service has an associated energy cost, and the Application Service Provider wants to reduce it;

- The Application Service Provider recognises that there are policies that limit energy use and controls the overall use of the service to operate within those constraints.

- *Use case 5.6 on supporting service-level energy efficiency analysis for verticals:* An Application Service Provider is running three different enterprise applications over two network slices. It proposes exposure of data volume and energy consumption of different Network Functions participating in the delivery of the service for different time periods at the request of the Application Service Provider. The Application Service Provider may use existing 3GPP procedures to infer Network Slice energy consumption and the number of PDU sessions per network slice.

*- Use case 5.8 on Application service Energy Efficiency (AEE) monitoring:* The energy consumed by an application service at the device side as well as at the network side is monitored and predicted by the 5G System and is exposed as a monitoring event to the Application Service Provider to allow an application layer action. In the context of media delivery, this action could be for example triggering multicast/broadcast delivery for a given service area and time of the day.

- *Use case 5.9 on renewable energy consumption information exposure:* Mobile Network Operators need to understand and track the proportion of energy consumed in their networks that is sourced from renewable sources, which can be made available to customers and authorized third parties.

- *Use case 5.10 on supporting carbon-aware communication service:* The Mobile Network Operator provides to end users an estimate of the carbon emissions for the services consumed, for example the equivalent carbon dioxide emissions corresponding to the data consumed by a user during a particular billing cycle.

- *Use case 5.14 on reducing GHG footprint of Application Services:* By considering the temporal and spatial information of sustainable energy source and availability, the possibility of reduction of the greenhouse gas footprint for application services is explored. Rather than optimising compute tasks for highest throughput or lowest latency, those tasks having flexibility in both when and where they are executed (e.g., some AI/ML training or video processing) are routed to a computing node using the (most) sustainable energy sources at that moment.

Media-related requirements associated with these use cases are addressed in the following Key Issues, complemented by requirements associated with the findings identified in clause 4.

## 5.2 Refinement of relevant use cases defined by 3GPP SA1 in 3GPP SA4 context

## 5.3 Additional use cases defined by 3GPP SA4

Use cases defined by SA1 on energy monitoring or energy consumption information exposure are not yet taken into consideration in 26.XXX series specifications but similar use cases have already been addressed. As explained in clause 4.2.2.4, some mechanisms like UE data collection, reporting and event exposure have already been defined. For consistency between specifications, supporting the collection and exposure of UE energy consumption information will require expansion of these existing mechanisms or else the use of mechanisms widely deployed in the market. This expansion will have to take into consideration indicators requested by regulators.

In France, the "Chaize Act" on reinforcing regulation of the digital sector by Arcep, strengthens Arcep’s powers by giving it the ability to collect environmental data not only from electronic communications operators, but also from online communication service providers, data centre operators, consumer device manufacturers, network equipment suppliers and operating system providers. Arcep (France’s Regulatory Authority for Electronic Communications, Postal Affairs and Press Distribution) has been collecting indicators since 2020 from France’s four largest telecoms operators, to be able to track the evolution of their environmental footprint, and relays this information through the publication of its annual "Achieving digital sustainability" survey [57]. The fourth edition of the survey, which Arcep will be publishing in early 2025, will incorporate data for monitoring the environmental footprint of a new category of player, namely mobile network equipment suppliers. This work has been complemented by ARCOM (the French Regulatory Authority for Audiovisual and Digital Communication) in its recommendation n° 2023-02 about consumer information on energy consumption and greenhouse gas emissions equivalents of data consumption related to the use of television services, on-demand audiovisual media services and video sharing platform services.

In addition to collecting energy consumption information from UEs and exposing it to event consumers, ARCOM encourages collection and exposure of energy consumption information *to* UEs could help to address the energy efficiency issue. This would be used to inform users about the environmental impact of consuming audiovisual content, but this information could also be used by UEs to optimise energy efficiency associated with media consumption.

ARCOM also encourages service providers to offer access to video quality parameter settings, allowing an easy way for end users to choose a simple "energy efficiency" mode. Instead of always being in a "best video performances according to network conditions regardless energy consumption" mode, having data on the QoE and energy consumption could enable a second mode to be offered to users representing reasonably good video performance with good energy efficiency. Having this information, instead of having a manual selection of video bit rates or SDR/HDR modes, the 5GMS Client could automatically select the best compromise to offer this additional mode to the users.

Regulators like ARCOM also encourage TV services, VOD services, video sharing platforms and other actors in the sector to put in place a common methodology for calculating the environmental impact of audiovisual uses. This work will have to be follow as the study item plans to study the feasibility of having implementation-independent metrics and a framework to evaluate the energy usage/savings of multimedia standards features and proposals.

# 6 Key issues

## 6.1 Key Issue #1: Energy-related Information exposure

### 6.1.1 Description

As described in the use cases summarised in clause 5.1, energy-related information needs to be collected, estimated, and exposed by the 5G System. This information is not only necessary for internal network optimisation, but it will also benefit service adaptation by third-party Application Service Providers. With the consent of Mobile Network Operators, it is relevant to expose energy-related information (e.g., energy consumption information, energy efficiency information, renewable energy and carbon emission information) to authorised consumers. TR 23.700-66 [20] study and identify potential enhancements to the 5G System (e.g. including network energy related information exposure, enhancement for subscription and policy control to enable energy efficiency as service criteria) to improve energy efficiency and to support energy saving in the network, taking the Energy requirements in TS 22.261 [5] into consideration. The purpose of this Key Issue is to extend this work, to study and identify potential enhancements to the energy-related information exposure for media architectures, applications and services (e.g., taking into consideration the 5G Media Streaming System according to TS 26.501 [23], 5G Multicast–Broadcast User Services according to TS 26.502 [58], the Real-time Media Communication according to TS 26.506 [59], Split rendering Media session Enabler according to TS 26.565 [65], etc.) including UE-related energy information exposure. As explained in clause 4.2.2, a UE data collection and reporting architecture already exist in the 5G System. But energy-related information is missing.

In this context, the subsequent analysis by this Key Issue should consider:

1. How should UE energy-related information be reported by a UE to the 5G System?

2. Which reference points should be used to report UE energy-related information to the Data Collection AF?

3. Would it be useful to expose energy-related information of the network to the Media Session Handler to help it optimize its media session in an energy-efficient way?

4. How to allow a UE to report its energy-related information without exposing its energy consumption rate?

This analysis will need to take into consideration existing work done in 3GPP but also other market trends. Application Service Providers are often reluctant to deploy solutions specific to mobile networks. Proposing technologies already supported in their services or technologies that are agnostic to the network, or which operate passively without the active involvement or knowledge of applications, are more likely adopted.

### 6.1.2 Potential requirements

Clause 6.4 in TR 22.882 [22882] contains the consolidated requirements extracted from use cases, related to information exposure related with this Key Issue:

|  |
| --- |
| [CPR 6.4-1] Subject to operator’s policy and agreement with 3rd party, the 5G system shall be able to expose information on energy consumption for serving this 3rd party.  [CPR 6.4-2] Subject to operator’s policy, the 5G system shall support a means to expose energy consumption to authorized third parties for services, including energy consumption information related to the condition of energy credit limit (e.g. when the energy consumption is reaching the energy credit limit).  [CPR 6.4-3] Subject to operator policy, the 5G system shall provide means for the trusted 3rd party, to configure which network performance statistic information (e.g. the data rate, packet delay and packet loss) for the communication service provided to the 3rd party, needs to be exposed along with the information on energy consumption for serving this 3rd party.  [CPR 6.4-4] Based on operator policy and agreement with 3rd party, the 5G system shall be able to expose energy consumption information and prediction on energy consumption of the 5G network per application service to the 3rd party.  [CPR 6.4-5] Subject to operator’s policy and agreement with 3rd party, the 5G system shall support a mechanism for the 3rd party to provide current or predicted energy consumption information over a specific period of time. |

Additional potential requirements identified from related work:

|  |
| --- |
| [PR 1-1] Where possible, it is required to reuse existing mechanisms (e.g., UE data collection and reporting architecture as in TS 26.531 [21]) and information for exposure of energy-related information.  [PR 1-2] It is required to reuse commonly supported client data reporting formats for energy-related information exposure when possible.  [PR 1-3] It is required that the 5GMS Client is able to obtain energy-related information from the UE, allowing it to optimise the media delivery sessions it is handling in an energy-efficient manner. |

## 6.2 Key Issue #2: Energy-related monitoring and measurement

### 6.2.1 Description

The measurement of energy consumption by media services is an essential pre-requisite to facilitate efficient energy use and energy saving. The environmental impact of the consumption of media services depends various system actors: equipment manufacturers, networks, datacentre operators, service providers but also users through their usage behaviour.

Requirements of monitoring and measurement relating to energy consumption and efficiency have already been defined by 3GPP in TR 22.882 [56] but those requirements are only related to energy consumption monitoring of the 5G network or 5G System. TR 23.700-66 [20] studies and identifies potential enhancements to the 5G System (e.g. including network energy related information exposure, and enhancement of subscription and policy control to enable energy efficiency as a service criterion) with the dual aims of (i) improving energy efficiency and (ii) supporting energy saving in the network, taking the EnergyServ requirements in TS 22.261 [5] into consideration.

The purpose of this Key Issue is to extend the above work, by studying and identifying potential enhancements to energy-related monitoring and measurement aspects (including UE-related energy information measurement and monitoring) in the context of the following media delivery architectures, applications and services namely the 5G Media Streaming System according to TS 26.501 [23], 5G Multicast–Broadcast User Services according to TS 26.502 [58], the Real-time Media Communication according to TS 26.506 [59], Split rendering Media session Enabler according to TS 26.565 [65], etc.

The most efficient way to address energy saving in this context is to consider the complete end-to-end media delivery chain, seeking to understand how decisions made on one end of the chain impact power consumption on other ends of the workflow. As explained in clause 4.2.2, UE data collection has been defined to monitor QoE in the 5G system. But energy-related information is missing.

NOTE 1: It is presumed that the user has granted consent for its UE data to be collected, reported and subsequently exposed by means outside the scope of the study or following normative work.

NOTE 2: The collection, reporting and exposure of location-based UE data is expected to comply with regional regulatory requirements and may be further limited by MNO policy.

In this context, the subsequent analysis by this Key Issue will consider the following questions:

1. Which UE energy-related information will be collected to measure, correlate, and optimize energy usage across the entire streaming distribution chain?
2. Can existing methods be leveraged to measure/monitor the identified UE energy-related information?
3. Which UE entity is appropriate to measure this UE energy-related information?

This issue is even more important for advanced media services such as XR services, Split Rendered media services, etc. which are expected to incur substantial energy consumption both at the device and network levels, presenting significant challenges for operators and service providers.

For instance, when a Mobile Network Operator (MNO) deploys a communication service to fulfil application service requirements, such as those of a gaming application, it is crucial for the customer – whether an Application Service Provider (ASP) or an industry vertical – to ensure that the application service reduces energy consumption for both end users and the data network. Failure to do so could necessitate short-notice application layer adaptations within the Application Service Provider's domain. This may result in adjustments being made to service levels in response to anticipated high energy consumption in specific service areas or during peak hours that adversely affect the Quality of Experience for service users.

In a practical scenario, an ASP intends to deploy a gaming service within a designated service area, served by an MNO's 5G network. Various service levels may exist, each associated with specific Key Performance Indicators (KPIs), such as automation levels or video quality targets. To ensure energy efficiency the ASP monitors the energy efficiency of its application service across specified service levels. Monitoring of application energy consumption may occur periodically or may be event-triggered, depending on the ASP's requirements, which are typically outlined in the Service Level Agreement (SLA). The MNO and ASP may agree on a certain energy efficiency target for the application service and optionally for given service levels.

This analysis will need to take into consideration existing work done in 3GPP but also other market trends. Application Service Providers are often reluctant to deploy solutions specific to mobile networks. Proposing technologies already supported in their services or technologies that are agnostic to the network, or which operate passively without the active involvement or knowledge of applications, are more likely adopted.

### 6.2.2 Potential requirements

Clause 6.3 in TS 22.882 [56] contains the consolidated requirements extracted from use cases, related to monitoring and measurement related with this Key Issue:

|  |
| --- |
| [CPR 6.3-1] Subject to operator's policy, the 5G network shall support energy consumption monitoring at per network slice and per subscriber granularity.  NOTE 1: Energy consumption monitoring as described in the preceding requirement is done by means of averaging or applying a statistical model. The requirement does not imply that some form of 'real time' monitoring is required. The granularity of the subscription policies can either apply to the subscriber (all services), or to particular services.  [CPR 6.3-2] Subject to operator’s policy and agreement with 3rd party, the 5G system shall be able to monitor energy consumption for serving this 3rd party, independently from NG-RAN deployment scenarios.  NOTE 2: The granularity of energy consumption measurement could vary according to different situations, for example, when several services share a same network slice, etc.  NOTE 3: The energy consumption information can be related to the network resources of network slice, NPNs, etc.  [CPR 6.3-3] Subject to operator policy and regulatory requirements, the 5G system shall be able to monitor the energy consumption for serving the 3rd party, together with the network performance statistic information for the services provided by that network, through same update rate e.g. hourly or daily.  NOTE 4: The network performance statistic information could be the data rate, packet delay and packet loss, etc. |

Based on TS 28.310 [2] and other related work in 3GPP, the following potential requirements need to be considered in this Key Issue:

|  |
| --- |
| [PR 2-1] Where possible, it is required to reuse existing mechanisms (e.g., UE data collection and reporting architecture as in TS 26.531 [21]) and information for measurement and monitoring of energy-related information.  [PR 2-2] It is required to reuse commonly supported client data metrics for energy-related information measurement and monitoring when possible.  [PR 2-3] Based on the collected and/or predicted energy efficiency information exposed from the 5G System, the Application Service Provider is able to adapt the application service parameters based on the 5GS feedback. Monitoring of application energy consumption may occur periodically or may be event-triggered, depending on the ASP's requirements, which are typically outlined in the Service Level Agreement (SLA). In order to perform such operations, the Application Service Provider requires relevant APIs to be exposed by participating entities related to the usage of media applications in order to expose Energy efficiency related information. For example, in the case of the 5G Media Streaming collaboration described in clause A.2 of TS 26.501 [23], this depends on the relationship between 5GMS Application Provider, 5GMSd-Aware Application, 5GMSd Client, 5GMSd AF, and 5GMSd AS. |

## 6.3 Key Issue #3: Evaluation framework

### 6.3.1 Description

The complexity of the media delivery chain raises technical challenges in terms of environmental impact measurement and accountability. There is no explicitly and uniformly defined methodology to evaluate the energy usage/savings of multimedia standards features and proposals which leads to significant variation in the results of different studies. Regulators and legislatures like the European Parliament have already provided more precise guidelines, targeting companies or services, to assess cases of unfair environmental advertising [60].

A characterisation framework to evaluate the energy usage/savings of multimedia standards features and proposals for relevant 3GPP scenarios is also needed to justify claims. The framework presented in this Key Issue is based on the normative work (e.g., granularities or energy-related information) recommended by Key Issues #1 and #2 of the present document, and includes a set of relevant scenarios and anchors. It is not dependent on a particular implementation of the feature or other parts of the system and allows an energy-efficient implementation to be compared against an implementation not relying on the proposed standards feature. The commonly supported external estimation frameworks mentioned in clauses 4.2.3 and 4.2.4 are to be reviewed and agreed by SA4 before using them to develop the evaluation framework in this Key Issue.

### 6.3.2 Potential requirements

|  |
| --- |
| [PR 3-1] Based on the APIs, metrics, and mechanisms available in the 5G System, it is required that a framework is defined to evaluate the energy usage/savings of multimedia standards features and proposals for relevant 3GPP scenarios on which anchors are defined.  [PR 3-2] It is required that standardized approaches to estimate the energy usage/savings that have been reviewed and agreed by 3GPP SA4 are used in the evaluation framework. |

# 7 Potential Solutions

## 7.1 Mapping of Solutions to Key issues

Table 7.1-1: Mapping of solutions to Key Issues

|  |  |  |  |
| --- | --- | --- | --- |
| Solutions |  |  |  |
|  | KI#1 | KI#2 | KI#3 |
| #1 |  |  | X |
| #2 |  |  | X |
| #3 |  | X |  |
| #4 |  |  |  |
| #5 |  |  |  |
| #6 |  |  |  |
| #7 |  |  |  |
| #8 |  |  |  |
| #9 |  |  |  |

## 7.2 Solution #1: Evaluation framework based on French regulators’ work

### 7.2.1 Key issue mapping

This solution partially addresses Key Issue#3 (Evaluation Framework) described in clause 6.3.

### 7.2.2 Functional description

The methodology described in the ARCOM/ARCEP [61] study (as summarised in clause 4.2.6) is used as a point of departure for designing a UE energy consumption evaluation framework in the context of the present document. However, it is observed that [61] does not include energy consumption during the usage phase of all three tiers of the digital value chain (user devices, networks and data centres). In particular, no metrics or APIs are available today for the network and data centre aspects. Their scopes would be too broad to be addressed. These parts are for further study outside the scope of the present document.

This is not the case for the user device part, because the required metrics and APIs are already available, at least on major smartphones Operating Systems, and are already used by regulators for evaluating the impact of some specific parameters. The ARCOM/ARCEP study [61] demonstrated their usefulness in evaluating the environmental impact of video codecs, video resolutions and frame rates. But this could easily be extended to other parameters such as different access network types (i.e., Wi-Fi, 5G, LTE) or content delivery modes (i.e., unicast, MBS, 5G Broadcast).

For example, the Battery Manager API is available on Android [63], allowing the status of the UE battery to be interrogated by an application without the need for any external network connection. Using this API, it is possible to query the battery status at various points/intervals and to collate results over time to be able to calculate the energy usage of a specific workload. Samples can be taken periodically (e.g. once per second) including the timestamp, instantaneous battery current in microamperes and current battery voltage. From the collection of these data points, the energy (measured in Joules) is calculated as follows:

*joules* = *currentInAmps* × *timeDifference* × *voltage*

There are a few limitations to measuring energy usage by this method:

1. Other applications or system processes running at the same time may affect the results.
2. The data collection itself service consumes some energy when collecting energy values. This artefact can be negated or controlled for by ensuring certain device conditions.

Contrary to the Test and Characterization Framework for Video Codecs described in TS 26.955 [62], reference software tools are not used in this candidate solution. Real-life implementation is used as the anchor against which specific features are evaluated. Exact results from testing a specific model of device will not be generalised for all devices, nor for all implementations on that device or others.

### 7.2.3 Procedures

The following methodology is proposed to measure energy consumption in the UE:

1. A test scenario is defined, and test conditions described in terms of:

a. Network (connection type, upload and download bandwidth, latency).

b. User device (type, model, SoC, OS version, video player).

c. Test conditions (test duration, number of iterations, factory setting applied, etc.).

d. Anchor against which the specific features will be evaluated (i.e., 5GMS service delivering a 720p video at 2 Mbps in HEVC).

e. Reference sequence(s) used.

2. The application under test which implements the reporting of energy-related information is started.

3. The test is done for the anchor and the implementation including the feature evaluated.

- The measurement period and the number of iterations performed are required to ensure relevance and to limit artefacts relating to the measurement itself.

Two measurement modes are possible, selection is made according to the influence of the caching on the test:

a. *Systematic content change between iterations.* This has the advantage of avoiding user-side CDN caching strategies but has the disadvantage of introducing variability with different content. This measurement also provides stronger representativeness of user behaviour.

b. *Iterations are conducted on a continuously played video.* This has the advantage of controlling for the content, but the disadvantage of potentially underestimating consumption due to caching technologies.

4. Store results for non-real-time analysis.

5. Characterization is documented in terms of expected energy savings, and may include additional comparison parameters such as impact on the end user’s Quality of Experience, etc.

### 7.2.4 Summary

Collection per-media-application of energy-related information, allowing energy use by certain computational workloads (e.g., battery current and battery voltage) over a cellular network to be measured and analysed offline, is needed.

## 7.3 Solution #2: Evaluation Framework to measure energy efficiency of a UE

### 7.3.1 Key Issue mapping

This solution addresses Key Issue #3 (Evaluation Framework) described in clause 6.3.

### 7.3.2 Functional description

#### 7.3.2.1 UE Energy Efficiency metric

Similar to the definition of the Mobile Network Energy Efficiency KPI (see clause 4.2.3.6.2), one possible example to represent the UE energy efficiency is *bits per Joule.* A UE is considered to be more energy-efficient when the data usage (in bits) is high with less energy consumption (in Joules), assuming that battery capacity and consumption rate are fixed when assessed during the time frame (*T*). The metric is defined as below:

* **Data Volume [bit]** represents the traffic volume for the UE for a given duration.
* **Energy Consumption [*estimated* Joule]** represents the total energy consumption of the UE for a given duration, which is the summation of power consumption.

The data volume consumed by *k* sub-applications is defined as the summation of the data volume consumed by the User Equipment under investigation during the time frame *T* of the energy consumption assessment for these sub-applications. This could be shown as:

where , measured in bits, is the data volume over the measurement period *T* of the UE for a given duration.

The overall UE Energy Efficiency, *EEUE* is then calculated as follows:

### 7.3.3 Procedures

The following methodology is proposed to measure the Energy Efficiency of a test application running on a UE:

1. A test scenario is defined, and test conditions described:

a. Network (connection type, upload and download bandwith, latency).

b. User devices (type, model, SoC, OS version, video player). At least 2 devices should be used.

c. Test environment (number of devices, number of iterations, etc.).

d. Anchor against which the specific features will be evaluated (i.e., 5GMS service delivering a 720p video at 2 Mbps in HEVC).

e. Reference sequence(s) used.

2. Launch the application under test which implements the collection of energy-related information, including either battery discharge rate or else total energy discharged and duration.

3. The test is done for the anchor and the implementation including the feature evaluated.

4. Extract data from the data collector for non-real-time analysis. Characterization is documented in terms of expected energy savings, and may include additional comparison parameters such as impact on the end user’s Quality of Experience, etc.

5. The time duration of the measurement, denoted as *T*, shall be one of the following alternatives:

- Weekly measurement: *T* = 7 days.

- Monthly measurement: *T* = 30 days.

- Yearly measurement: *T* = 365 days.

The minimum duration is therefore one week: monthly and yearly measurements are extensions of the basic week test per the guidelines in ETSI ES 203 228 [66].

6. The Energy Consumption of the mobile network is measured by means of metering information provided by utility suppliers or by measurement systems integrated into the mobile network. Moreover, sensors can be used to measure the energy consumption of individual sites or pieces of equipment, following the requirements set by ETSI ES 202 336-12 [68].

7. The data volume is measured using network counters for data volume in the UE under test.

- For *Packet-Switched traffic*, the data volume is considered as the overall amount of data transferred to and from the UE under test. Data volume is measured separately for each application present in the UE.

- For *Circuit-Switched traffic* (e.g. CS voice or VoLTE), the data volume is considered as the number of minutes of communications during the time *T* multiplied by the data rate of the corresponding service and the call success rate per ETSI ES 203 228 [66].

### 7.3.4 Summary

The solution described in clauses 7.2.2 and 7.2.3 has the following limitations:

1. The solution proposes to evaluate the energy efficiency of the entire UE as a whole device, while individual energy consuming aspects such as the media energy consumption, energy consumed during radio transmissions (4G, 5G, Wi-Fi), etc. may have additional impact on the energy efficiency of the UE.

2. The solution is UE implementation-specific, i.e. the same feature may result in different evaluations of energy efficiency on different UEs.

3. The solution may result in different evaluations of energy efficiency of the same UE depending upon the test conditions that may vary over time (e.g. environmental changes and radio conditions, etc.).

## 7.4 Solution #3: Existing UE energy-related information measurement

### 7.4.1 Key issue mapping

This solution partially addresses Key Issue#2 (Monitoring and measurement) described in clause 6.2.

### 7.4.2 Functional description

This solution addresses only energy-related information measurement from the UE; it does not address energy-related information measurement from the network. The two main questions raised in the Key Issue description are about which UE energy related information is collected, and which UE entity is collecting.

Currently, the 5G System does not have access to energy-related information on UEs. Because neither a component external to the UE nor mechanisms requiring debug mode are excluded by the use cases described in clause 5, this candidate solution proposes to use an existing entity allowing to provide energy-related information to the 5G System via existing API.

Most UE Operating Systems already provide tools to assess the energy footprint of applications using system-wide metrics. Different Operating Systems provide different data about energy consumption. However, common basic data are available on two of the three main smartphone OS: Android [63] and Harmony OS [69], enabling the requirements of the Key Issue to be fulfilled. The common basic data between those two OSs are:

- *Charging status:* Battery charging state of the current device. Indicates if the battery is being/not being/fully charged.

- *Voltage:* Instantaneous battery voltage of the device, expressed in unit of microvolts (μV).

- *Current:* Instantaneous current of the device battery, expressed in units of milliamperes (mA).

Using APIs providing this information, the 5GMS Client is able to calculate the energy consumption during media streaming in Joules using the formula:

*energyInJoules* = *currentInAmps* × *timeDifference* × voltage

However, this method as several key limitations:

- Such public API are not available on iOS.

- Energy consumption during charging phases is not included.

### 7.4.3 Summary

This solution indicates how applications currently measure energy consumption of a smartphone. This has the advantage of answering questions raised in the description of Key Issue #2:

1. Which UE entity is appropriate to measure this UE energy-related information?

Answer: This is done by the UE directly.

2. Which UE energy-related information will be collected to measure?

Answer: The parameters commonly exposed by some smartphone Operating Systems.

However, in the context of this study, this solution has major limitations:

- UE energy-related information is not publicly available on all UE Operating Systems, including some major ones (e.g., iOS)

- This energy-related information is related to the entire smartphone, and is not limited to media consumption.

- Accuracy of information provided by the APIs is uncertain and likely to vary between different devices.

# 8 Conclusions and proposed next steps

[Editor’s note: This clause will list conclusions that have been agreed in the study.]

Annex <A>:  
<Informative annex title for a Technical Report>

Informative annexes in Technical Reports do not use "(informative") in the title, since all annexes in TRs are informative. Use style "Heading 9" in TRs.

Annex <B> (informative):  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Change history | | | | | | | |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2024-03 | SA4#127-bis-e | S4-240565 |  |  |  | TR skeleton | 0.0.1 |
| 2024-04 | SA4#127-bis-e | S4-240816 |  |  |  | Addition of related work (S4-240803) | 0.1.0 |
| 2024-05 | SA4#128 | S4-240875 |  |  |  | Addition of Collection and exposure of energy consumption information by OAM (S4aI240057) | 0.1.1 |
| 2024-05 | SA4#128 | S4-241243 |  |  |  | Addition of Description of the existing collection and exposure of energy consumption information at UE (S4-241212), Context information on greenhouse gas reporting laws, protocols and framework (S4-241218), Network energy use (S4-241220), UE energy consumption information reporting (S4-241224), KI#1 (S4-241228) | 0.2.0 |
| 2024-08 | SA4#129-e | S4-241409 |  |  |  | Addition of Key Issue #2: Monitoring and measurement (S4aI240112) | 0.2.1 |
| 2024-08 | SA4#129-e | S4-241736 |  |  |  | Addition of Additional use cases defined by SA4 (S4-241718), related work in ITU-R (S4-241431), energy-related information amendment (S4-241432), Description of the existing collection and exposure of energy consumption information at NF (S4-241722) and KI#3 (S4-241732). | 0.3.0 |
| 2024-10 | SA4-e (AH) MBS SWG post 129e | S4aI240172 |  |  |  | Addition of Correction on collection and exposure at NF (S4aI240173), Complements on KI#2 (S4aI240142). | 0.3.1 |
| 2024-10 | SA4-e (AH) MBS SWG post 129e | S4aI240174 |  |  |  | Modification to description to Key Issue #1: Information exposure (S4aI240126). | 0.3.2 |
| 2024-11 | SA4#130 | S4-242087 |  |  |  | Addition of Clause 3.1. Energy-related terms and definitions (S4-242067), Update to Clause 4.2.3.1 (S4-242068), Summary of energy efficiency standards from ETSI Environmental Engineering (EE) WG (S4-242069), Modification to description to Key Issue #2: Monitoring and measurement (S4-242070), Solution for KI3 based on French regulators study (S4-242109), Potential solution to Key Issue #3: Evaluation framework (S4-242164), KI2 solution based on existing UE energy-related information measurement (S4-242165). | 0.4.0 |