Ref. Ares(2024)9184632 - 20/12/2024

D1.2 USE CASES AND REQUIREMENTS

DECEMBER,2024

DELIVERABLE INFORMATION	
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Document type	Deliverable
Document code	D1.2
Document name	Use Case and Requirements
Work Package / Task	WP1/T1.2
Dissemination Level	Public
Status	Draft
Delivery Date (GA)	December 2024
Actual Delivery Date	

DELIVERABLE HISTORY			
Date	**Version**	**Author**	**Summary of main changes**
23/09/2024	0.1	TID	Structure of the document
25/11/2024	0.2	TID	Version for the formal review
10/12/2024	0.3	ALL	Included comments and suggestions from reviewers and others.
15/12/2024	0.4	ALL	Version after rework
16/12/2024	1.0	ALL	Final version

Co-funded by the European Union

Funded by the European Union.

The project is supported by the Smart Networks and Services Joint Undertaking and its members.

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Smart Networks and Services Joint Undertaking (SNS JU). Neither the European Union nor the granting authority can be held responsible for them.

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List of Acronyms

3GPP	3rd Generation Partnership Project
5G	The fifth generation of wireless cellular technology
5GC	5G Core network
6G	The sixth generation of wireless cellular technology
AI	Artificial Intelligence
AnLF	Analytics Logical Function
API	Application Programming Interface
APN	Access Point Name
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CPU	Central processing unit
CDN	Content distribution network
cUPF	Core UPF
DR	Demand Response
EDGE	Enhanced Data rates for GSM Evolution
ETSI	European Telecommunications Standards Institute
eUPF	Edge User Plane Function
EC	Energy consumption
eUPF	Edge User Plane Function
FL	Federated Learning
GB	Gigabyte
GDPR	General Data Protection Regulation
gNB	Next generation Node B
GSM	Global System for Mobile Communications
GSMA	GSM Association
GPUs	Graphics Processing Unit
HW	Hardware
ICT	Information and Communication Technology
IPTV	Internet Protocol Television
ISP	Internet Service Provider
KPIs	Key Performance Indicators
MEC	Multi-Access Edge Computing
MNO	Mobile Network Operator
MIMO	Multiple-input Multiple-output
MTLF	Model Training Logical Function
MVO	Mobile Virtual Operator
NFs	Network functions
NWDAFs	Network Data Analytics Functions
NG-RAN	NG Radio Access Network
OTT	Over the Top

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OPEX	Operating Expenses
OS	Operating System
PC	Personal Computer
PDL	Permissioned Distributed Ledger
PLMN	Public Land Mobile Network
PoP	Point of Presents
PNF	Physical Network Function
QoS	Quality of Service
RAM	Random Access Memory
RAN	Radio Access Network
RF	Radio Frequency
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
VNF	Virtualized Network Function
VNFC	Virtualized Network Function Container
SDOs	Standards Development Organizations
SMF	Service Management Function
TS	Technical Specification
TR	Technical Report
TV	Television
UE	User Equipment
VMs	Virtual Machines
XR	Extended Reality

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1. INTRODUCTION

This document explores the various use cases and corresponding requirements necessary to address carbon footprint transparency in digital services across their entire end-to-end chain. It serves as a crucial step toward understanding how emerging technologies and services, such as media streaming, cloud computing, and network infrastructure, can be optimized to achieve energy efficiency goals and contribute to carbon neutrality in the Information and Communication Technology (ICT) sector.

The use cases detailed herein illustrate the challenges and opportunities associated with measuring, managing, and reducing the environmental impact of modern digital services. Each use case follows a structured approach, offering a thorough description of the scenario, service flows, and postconditions, while identifying existing technological solutions that may only partially address the issues at hand. Additionally, potential new requirements necessary to fully support these use cases are discussed.

Importantly, the information contained in this document forms the foundation of the project, as it outlines the various use cases and requirements that will enable the subsequent development of reliable methods for measuring energy consumption and collecting measurement data. This encompasses, for example, the interfaces and procedures necessary for the exchange of measurement data.

1.1. OBJECTIVES OF THE DELIVERABLE

This document (D1.2 – Use Cases and Requirements) aims to explore a range of use cases along with their associated requirements focused on enhancing exposure regarding energy consumption and carbon emissions in digital services throughout the complete end-to-end process. It represents an essential step in identifying how innovative technologies and services—including media streaming, cloud computing, and network infrastructure—can be refined to meet energy efficiency targets and promote carbon neutrality within the ICT sector.

The document is the main outcome of Task 1.2 of WP1. This task is dedicated to outlining service scenarios and aligning requirements stemming from the need to assess energy usage and carbon emissions across different stakeholders in the ICT service delivery framework.

The presented use cases reveal both the current challenges and potential future solutions related to managing and mitigating the environmental impacts associated with digital services. Each use case is organized detailing the specific scenario, service flows, and postconditions, while also highlighting existing technological approaches that may not fully resolve the identified issues. Furthermore, the document discusses additional requirements that are essential for comprehensive support of these use cases.

The EXIGENCE project aims to minimize the overall energy consumption and carbon footprint of ICT services by a) creating service user awareness of the energy consumption and of the carbon footprint pertaining to their respective usage, b) enhancing energy efficiency of the service provisioning within each involved (sub)service realization domain, c) empowering users to make informed, ecologically-aware choices with respect to their own service usage, or

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enable ecologically better service alternative/variant/configuration selection. This includes metering, analysing and exchanging the energy and carbon footprints of individual stakeholders across various heterogeneous domains within the ICT value chain and throughout the entire ecosystem. The insights presented in this document provide a foundation for the project by outlining the diverse use cases and requirements needed to develop effective methods for monitoring energy consumption and collecting measurement data.

1.2. STRUCTURE OF THE DELIVERABLE

In addition to the sections on Introduction, Conclusions and References, the document is organized into three main sections: Overview of Use Cases, Description of Use Cases and Requirements, and Consolidated Requirements.

- **Use Case Overview**: This section provides an overview of the use cases, including definitions of key terms, use case prioritization criteria, and the grouping identified for the use cases.
- **Description of use cases and requirements**: Detailed descriptions of each use case are presented here along with their specific requirements according the 3GPP SA1 template.
- **Consolidated requirements**: This section consolidates the requirements by domain, with separate considerations for environmental, social and economic factors.

1.3. KEY TERMS AND CONCEPTS

- **Use Case Description**: Description of the scenario as well as the problem and the opportunity this use case is aiming at. It must describe the new approach, and how/what is done differently. This includes details on actions, deployment aspects, end-to-end definition, and relevant KPIs.
- **Preconditions**: Description of what needs to be in place in the working ecosystem for the use case to be implementable.
- **Service flow**: Description of sequence of events/actions that explain what needs to happen.
- **Postconditions**: Description of the final result or outcome of the use case.
- **Existing feature(s) partly or fully covering the use case**: Describe/highlight technology features in existing standards that partly or fully cover this use case. Describe in which sense the existing features are not sufficient, i.e. what the gaps and limitations are.
- **Potential new requirement(s)to support the use case:** Describe novel requirements that may arise to enable the use case, including both standard-related changes and proprietary features or mechanisms specific to the devices.
- **Service:** Set of functionalities, capabilities, processes, activities, or performances designed to fulfill the specific requirements identified in the use case. This service involves interactions between various system components to deliver the desired outcome, with each step contributing to the overall functionality, and ensuring the availability of relevant data to meet the defined objectives.

2. USE CASE OVERVIEW

2.1. USE CASE CLUSTERING

The following use case clustering was made for the project in order to group similar use cases. This clustering also reflect the three pillars of the project (Measure, Optimize and Incentivise), as shown in Table 1.

Use Case Group	Relevant Use Cases
Media Streaming	1. Media streaming carbon footprint transparency 2. Digital Sobriety 3. Economic Incentives for Digital Sobriety 4. Behavioural Incentive for Digital Sobriety 5. Watch TV over 5G 6. Any Service Provider 9. Physical Security
Green batch scheduling	13. Carbon-aware pre-population of CDN nodes 15. Green social media and e-mail Content Download 10. Carbon-aware AI service provisioning and control
Green real time scheduling	11. Profiling on network nodes 14. Green Network Orchestration in the edge
Energy Efficiency Services	7. Carbon Certificates as a Service 8. Carbon emission charging

Table 1: Use case clustering.

2.2. USE CASE PRIORITIZATION

Use case prioritisation took place in two rounds in EXIGENCE. The first round gave focus to the work on the use cases, requirements, value Cases and architecture. The second round gives focus to the implementation phase of the project.

2.2.1. ROUND 1

EXIGENCE produced the following use case value effort matrix. The method is based on estimations of the value for the project and efforts for the project. The two values are plotted in the value effort matrix, resulting in an overview indicating what use cases bring the highest value for the least amount of effort. Main reason to make the first round of prioritisation is to focus the efforts of the consortium, as shown in Figure 1.

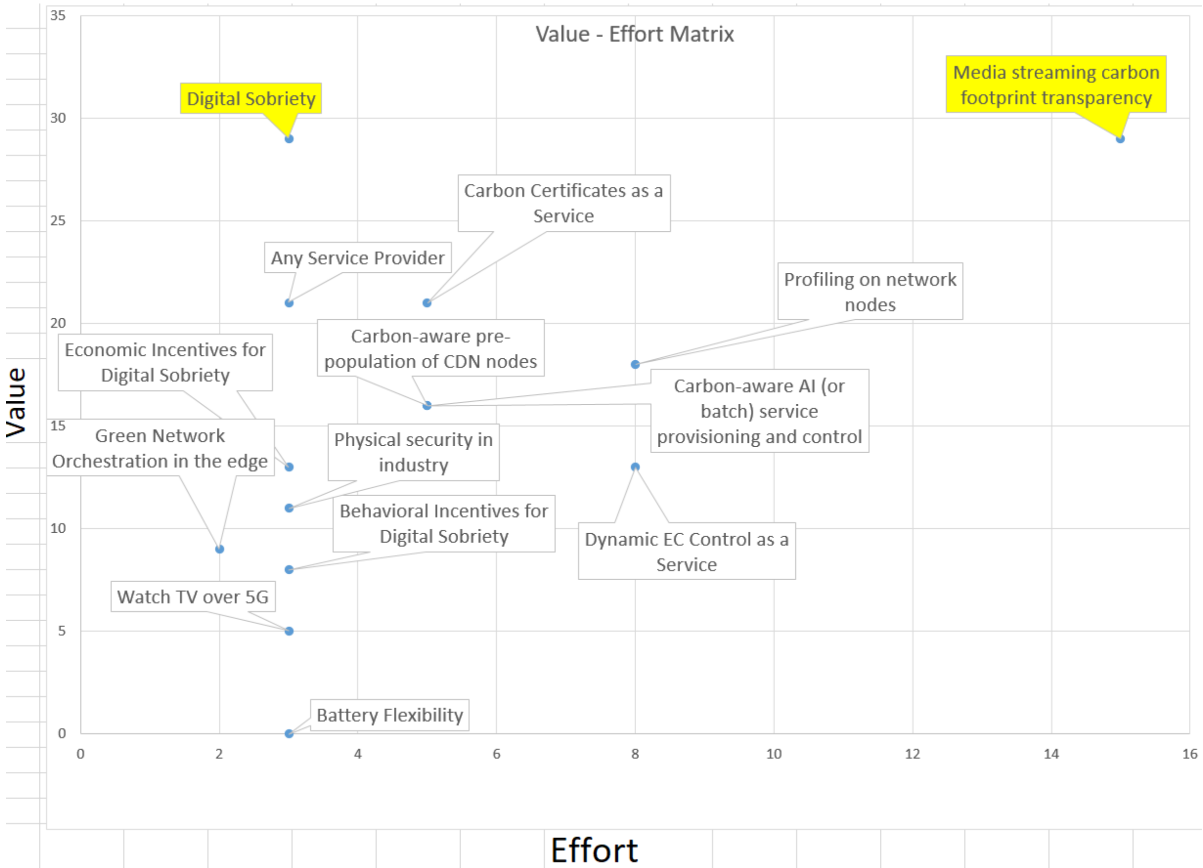

Figure 1: First use case prioritization

A first conclusion is to drop the Use Case on Battery Flexibility. A second conclusion is that two use cases are seen as important enablers for the project being: (UC1: Media streaming carbon footprint transparency, and (UC2: Digital Sobriety.

In October 2024 the Dynamic EC Control as a Service use case was deprioritised as it did not identify novel requirements for 3GPP. It was replaced by a new use case, Carbon Emission Charging. It is worth mentioning that 3GPP has different working groups related to the phase the project activities are in. So is SA1 relevant to EXIGENCE as they deal with use cases and requirements.

So, in total, 14 use cases are proposed. Initially, there were 15 of them, while further development resulted in dropping one use case due to overlapping, therefore numbering of 14 use cases goes from 1 to 11 and from 13 to 15.

2.2.2. ROUND 2

In the second prioritisation round a further down select has been made, with the purpose to agree upon the use cases to implement, having in mind the Project objectives, tasks and activities of the project. This gave is shown in Figure 2:

UC clusters vs. POs, tasks and activities

UC cluster vs. task/activity	Media streaming (1-6+9)	Batch scheduling (10, 13, 15)	Real-time scheduling (11, 14)	Energy/carbon efficiency rewards (7, 8)
PO1 Measure (T2.2)	X	–	X	X
PO1/02 Collect (T2.3) & Connect (T3.1) API	X	X	X	–
PO1 Demonstrate (T4.1)	X (D4.1, UC1)	–	–	–
"Predict" extrapolating the past (no task, PO2?)	Choose variant (UC234)	energy demand & mix (input) + available ict capacity (en tag)	UC11 prediction of user/device behaviour	–
PO2 Orchestrate (T3.2)	UC9 (network adaptation)	X	X (UC 14)	–
PO2 Optimise (T3.3)	UC9 (network adaptation)	X	X	–
PO2 Incentive based optimization (T3.4)	X	Possible	–	Mechanism for rewards

dd/MM/YYYY Event name 4

Figure 2: Second use case prioritization

And this resulted to the following conclusions for implementation, ensuring Project Objectives can be met:

- UC 1. Media streaming carbon footprint transparency.
- UC 2. Digital Sobriety.
- UC 4. Behavioural Incentive for Digital Sobriety.
- UC 9. Physical Security.
- UC 10. Carbon-aware AI service provisioning and control.
- UC 14. Green Network Orchestration in the edge.

2.3. USE CASES ACCEPTED BY 3GPP

For EXIGENCE to have true impact on the ICT ecosystem, it needs to influence Standards Development Organizations (SDOs) to ensure that the standards for their respective domains are prepared for the solutions that EXIGENCE is working on. Obviously, 3GPP is the key player for the Mobile Network Operator (MNO) domain.

At the moment, the work in 3GPP SA1 for Release 20 has just starting and a study item is proposed by China Mobile to continue the work on "Energy Efficiency as Service Criteria" which was initiated in Release 19. The idea is that customers (end users and verticals) can include energy efficiency as criteria for consuming services, next to other, more traditional, network performance parameters. Having this ability may also enable the mobile network to play a role in the end-to-end energy optimisation scenarios that are targeted by EXIGENCE. Therefore, in February 2024 (SA1 #105, Athens), this study item proposal was supported and adjusted by TNO and Telefonica on behalf of EXIGENCE to create sufficient manoeuvring room for submitting use cases and requirements derived from EXIGENCE work.

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Subsequently, in May 2024 (SA1 #106, Jeju) and August 2024 (SA1 #107, Maastricht) adapted versions of EXIGENCE use cases #1, #6, #7, and #15 were submitted, along with three discussion documents. The use cases were further adapted and subsequently approved by SA1. They can be found in Sections 5.3 (UC #7), 5.5 (UC #1+6), and 5.8 (UC #15) of the corresponding study document TR 22.883 [1]. This document contains eight use cases in total of which three have been submitted on behalf of EXIGENCE. Also, Annex A was derived from one of the discussion documents. It is effectively a very short abstract of the EXIGENCE Green ICT DIGEST [2].

3. USE CASES & REQUIREMENTS

3.1. GROUP MEDIA STREAMING

3.1.1. UC1: MEDIA STREAMING CARBON FOOTPRINT TRANSPARENCY

3.1.1.1. DESCRIPTION

The challenge of becoming carbon neutral within the ICT sector requires concrete actions. To devise solutions in this direction, full transparency of the impacts on the carbon footprint throughout the entire end-to-end chain is required, which translates to a need for measuring and attributing energy usage and carbon footprint at a fine level of granularity (e.g., per user session).

Additionally, most energy efficiency efforts have been encompassed within the network infrastructure, leaving the end-user outside of the loop. Including the end user and providing them with the appropriate information can not only help create awareness of the impacts of different user behaviours and steer them in the right direction but also could help contain rebound effects commonly associated with the pursuit of energy efficiency.

The 'Carbon footprint transparency' use case proposes the inclusion of metrics such as "Instant Carbon Footprint" or "Total Daily CO2" explicitly during video streaming services (incl. live events), on Over the Top (OTT) platforms, or video conferencing. It is envisioned that this information would be displayed at the top of the screen of the end-user device (next to other indicators such as current time, battery status, or connectivity strength). Building on the availability of this information to create awareness of the environmental impacts each user is responsible for; the end user will have the ability and freedom to adjust the trade-off between the quality of service and the environmental footprint as provided by the ICT system.

Therefore, this use case relies on a series of energy measurements, interoperability between different network domains, AI capabilities and a deeper understanding of the impact of different network nodes/functions on the carbon emission/energy usage throughout the end-to-end chain to unravel the end to end energy consumption (including networks, applications, and devices), as well as the effects particular settings have on energy consumption (e.g., data route chosen, the energy mix where the service is running, as well as the engaged network domains). We conjecture that this necessitates flexible, novel architectural patterns, new modules and interfaces with additional procedures for the overall ICT service measurement, and per-domain energy usage and/or carbon footprint reduction mechanisms.

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Example:

User A is waiting for public transportation outdoors and watching a video from OTT B's platform using a smartphone C that is connected to the wireless cellular network of MNO D.

Alternative use case: User A is at home/work and watching a video from OTT B's platform, using a laptop C that is connected via home's/company's Wi-Fi and fixed internet access provider D.

As the video plays, the total end-to-end energy consumption/CO2 footprint for that particular video session accrues, and it is displayed on the top of the screen, as this was the selected configuration for user A. This can be displayed also in a relative manner e.g. assuming a maximum energy /CO2 credit in User A's subscription to MNO D or fixed internet access provider D.

The total end-to-end energy consumption measurements span from User A's terminal to OTT B's platform, including all networks in between.

3.1.1.2. PRE-CONDITIONS

The availability of the end-to-end energy consumption for the video stream demands changes throughout the entire video communication chain. Therefore, stakeholders will need to comply with the requirements to produce and exchange energy consumption-related data and implement them in their respective platforms. These comprise handset manufacturers to include the aforementioned CO2 indicators in their OS; OTT video streaming providers to deliver the information related to their service provision (footprint); MNOs to provide information on their energy consumption and current network architecture; etc.

Interoperability between different devices and network equipment within and among stakeholders is a must.

3.1.1.3. SERVICE FLOWS

1) User A selects a video to watch from OTT B's platform, indicating that the energy consumption needs to be displayed (accessible) while watching the video, triggering a series of processes as described below.
2) The device requests a particular set of information elements, connecting through the RAN, accessing the Core, and reaching the OTT's data through the Internet for that particular video. All of these interactions have reported their respective energy consumption to deliver the task. This information is then coupled with other contextual data, such as the current energy mix for each of the steps/actors, to later deliver a unified CO2 footprint for that particular service.
3) This information is then shown to the user and keeps accruing as the video has been played. Examples of alternatives for displaying the information are (i) showing on the top of the user's screen (Mobile) or internet tab (PC), (ii) information shown when touching the screen (Mobile) or hovering over the video (PC), (iii) sending notifications as the video plays, or (iv) dedicated app that accrues and displays the information. These are just a

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few ideas that highlight the need to have the required information related to carbon/energy measurements.

3.1.1.4. POST-CONDITIONS

In addition to the impact on their own equipment (smartphone C, laptop C), User A becomes aware of the impact of their service execution remotely, i.e. within the OTTs platform and over the networks. This more global view allows User A to make better, more informed decisions as to:

- local or remote
- immediate or postponed
- high or low resolution
- selection of various competing platforms supporting
- streaming of the same content.

Then, these configurations can be stored and applied in future service requests, but also some summaries can be presented to User A regarding associated CO_2 emissions per service type or platform basis, for example. These are only a few examples of ways to use this information to promote user awareness. These alternatives are further explored in UC2.

Additionally, the introduction of additional external mechanisms, such as subscriptions with a maximum energy consumption budget and/or CO_2 credit configured, can further benefit the application and incentivisation described by this UC.

Finally, it is essential that all energy required to provide this information is significantly less than the overall reduction achieved, and that this is monitored and adjusted throughout time to comply with this condition.

3.1.1.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

TS 28.554 (R18) [3] describes energy consumption for individual Network Functions (NFs), slices, Next Generation Radio Access Network (NG-RAN), Next-generation Node B (gNB), 5G Core network (5GC) but does not break this down to individual user flows. Ongoing work on "energy efficiency as a service criterion" within R19 is considering that level of granularity. For example, the use case on supporting carbon-aware communication service (Section 5.10 of TR 22.882 [4]) proposes that a mobile user of an XR service gets an estimation of carbon intensity information related to this flow. However, a holistic view of all the crossed domains (not just the B5G/6G network) is beyond the scope of this work, and as a matter of fact beyond the scope of 3GPP per se. Addressing user flows across Public Land Mobile Networks (PLMNs) may be within the scope of a continuation of this work within R20.

Internet Drafts, draft-cx-opsawg-green-metrics [5] and draft-irtf-nmrg-green-ps [6] are exploring similar topics with regards to the Internet, including breakdown to individual user flows. However, again, a holistic view is lacking.

Most of the requirements for implementation are currently non-existent. Fetching real numbers from all the crossed domains cannot be implemented, because of lacking interfaces to access such data and lacking mechanisms for energy – or CO2e – specific accounting on a per-user flow basis, not supported by any of the involved resources or domains, let alone in any agreed form (syntax, data structure, semantics).

3.1.1.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.1.1.6-1] The 5G/6G network shall be able to provide exchange of Energy usage and CO2e data for each traffic flow to the end user equipment.

Note: The exchange of Energy usage and CO2e data should be operator configurable, e.g. frequency or updates of thresholds for reporting.

[PR.3.1.1.6-2] The display device shall be able to present the total Energy usage and CO2e data including its own to the end user.

3.1.2. UC2: DIGITAL SOBRIETY

3.1.2.1. DESCRIPTION

The challenge of becoming carbon neutral within the ICT sector requires concrete actions, together with widening the scope of the involved stakeholders. Most energy efficiency efforts have been encompassed within the network infrastructure, leaving the end-user outside of the loop. Including the end user and providing them with the appropriate information can not only help create awareness of the impacts of different user behaviours and steer them in the right direction but also could help contain rebound effects commonly associated with the pursuit of energy efficiency.

'Digital Sobriety' use case builds on the information provided by (UC1: Media streaming carbon footprint transparency, to devise and apply effective ways in which the user can make use of the carbon footprint measurements, and act to effectively decrease the carbon footprint which they are accountable for.

Combining data on the CO2 footprint from different sub-paths across the end-to-end chain with behavioural data from the user can grant alternatives which satisfy the particular user experience while using the path with the lowest overall footprint.

Example:

User A is waiting for public transportation outdoors and watching a video from OTT B's platform using a smartphone C which is connected to the wireless cellular network of MNO D. As the video plays, the total end-to-end energy consumption/CO2 footprint for that particular video session accrues, and it is displayed on the top of the screen, as this was the selected configuration for user A in UC1.

Once the video has played for enough time to offer alternatives, the CO2 indicator lights up and suggests some actions. By clicking on the selector, a variety of actions is shown (e.g., accepting lower video resolution, or higher latency), coupled with the expected environmental benefits and consequences for the overall user experience these actions will have.

Over time, the algorithm will learn based on the user's behaviour (e.g., number of videos watched, average time spent on each before switching to another one) and can suggest automated pre-configurations for a smooth and seamless experience based on the user's preferences. It can also suggest less dynamic alternatives such as switching from MNO D to MNO E (based on their overall footprint).

Finally, this information can be transferred to a dashboard accessible by users, to further understand their behaviours, not only from the carbon measures displayed on top of the screen.

3.1.2.2. PRE-CONDITIONS

As this use case builds on UC1, a successful application of the latter is a prerequisite. Other helpful measures are the inclusion of energy/carbon budgets in MNO's data plans.

3.1.2.3. SERVICE FLOWS

Service flow A:

1) User A selects a video to watch from OTT B's platform, indicating that the energy consumption needs to be displayed (accessible) while watching the video.
2) As the device requests a particular set of data packages; energy consumption and carbon footprint information is being measured in the end-to-end chain, stored, analyzed, and displayed on the user screen as described in UC1: Media streaming carbon footprint transparency.
3) After some time, and based on statistical data and current situations, the software suggests specific actions. For example, it suggests that by switching from 4k to 1080p resolution, the carbon footprint and energy consumption will decrease by x% and z%.
4) Seconds later, a button appears next to the EC and CO2 footprint, that allows the user to revert its changes. If it is not pressed, then the system learns that the user is happy with the current service standards.
5) Over time, the algorithm learns based on the user's behavior and suggests automated pre-configurations bespoke for each user.

Service flow B:

1) User A selects a video to watch from OTT B's platform and is configured at the lowest EC and CO2e possible, indicating that the energy consumption and CO2e need to be displayed (accessible) while watching the video.
2) The user wants to get premium quality for this content and hits the gold button.
3) The system switches to a higher quality profile and shows the end user the additional EC and CO2e.

3.1.2.4. POST-CONDITIONS

It is essential that all energy required to process, analyse, and provide these suggestions and subsequent actions, is significantly less than the overall reduction achieved, and that the latter is assessed and managed throughout time.

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Finally, statistical data about the consumer behaviour and their desires has to be shared with all entities across the end to end chain, providing therefore useful information for them to take action and decrease their overall footprint, ensuring its competitive advantage.

3.1.2.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

It is assumed that all requirements of UC1: Media streaming carbon footprint transparency are fulfilled.

3.1.2.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

Interoperability along the end-to-end chain to successfully change the current settings/paths to abide by the new conditions agreed upon. Integration with AI algorithms might be needed.

[PR.3.1.2.6-1] The OTT platform shall be able to provide an eco-mode and a gold quality mode of content. Where the eco mode is providing good enough quality to the end user and the gold quality mode is providing the better-quality mode to the end user, which can be a higher resolution at a higher bitrate or lower latency.

3.1.3. UC3: ECONOMIC INCENTIVES FOR DIGITAL SOBRIETY

3.1.3.1. DESCRIPTION

The challenge of becoming carbon neutral within the ICT sector requires concrete actions, together with widening the scope of the involved stakeholders. Most energy efficiency efforts have been encompassed within the network infrastructure, leaving the end-user outside of the loop. Including end users and providing them with the appropriate information and incentives steer them in the right direction.

'Economic Incentives for Digital Sobriety' use case builds on the information provided by the (UC2: Digital Sobriety and to a certain extent to (UC4: Behavioural Incentives for Digital Sobriety, to devise and apply effective ways in which users can be properly motivated by means economic incentives in order to decrease the carbon footprint which they are accountable for.

A variety of economic incentives for energy efficient 'Digital Sobriety' can apply to this use case:

- The award of environmental points to the user, in accordance with the CO2 footprint improvements, can be converted at once to monetary incentives; to this end, the energy-efficient behaviour of the user should be translated to economic benefit for each of the providers in the value chain; furthermore, the providers should agree to share part of their benefit with the user, in order to thus incite such behaviour, yet in a way that each of them still benefits (although to lower extent) by this behaviour of the user.
- Environmental points of the user are accumulated on a monthly basis and at the end of the month the user participates in a lottery wherefrom the expected benefit of the user is proportional to her points; the costs of the prizes put in lottery are shared by

the providers in accordance to their economic benefit from the energy-efficient behaviour of all users.

Example of economic benefit related to environmental points

When decisions of the user lead to a reduction of CO2 emissions, the user can gain environmental points that are proportional to the amount of this reduction in the entire value chain. We can assess the corresponding economic benefit and then convert the points to the value of a gift for the user that corresponds for example to 10% of this benefit.

The basic term of economic benefit relates to the savings in the energy bill. If this proves to be a longer-term effect, other costs can be possibly reduced too, for example, by employing less VMs due to less demanding versions of s/w ran by the user.

3.1.3.2. PRE-CONDITIONS

This use case builds on UC2: Digital Sobriety". Thus, a successful application of this is a prerequisite.

3.1.3.3. SERVICE FLOWS

1) User A selects a video to watch from OTT B's platform, indicating that the energy consumption needs to be displayed (accessible) while watching the video.
2) As the device of User A requests a particular set of data packages, carbon footprint information is being measured, stored, analysed, and displayed on the user screen as described in UC 1.
3) The video streaming software of OTT B suggests specific actions, as described in UC2: Digital Sobriety, alongside with environmental points that will be awarded if an action is taken.
4) As soon as an action is taken environmental points are awarded to User A.
5) The environmental points collected from user A over the span of a month are used as "participation tokens" in a monthly lottery run by OTT platform B. In this lottery, multiple end-users participate contributing their tokens. Users with more tokens stand a higher chance of winning, with the expected benefit being proportional to the number of tokens they hold. The monetary rewards distributed to end-users are determined by calculating the economic benefit of the various providers involved in the value chain, which arises from energy savings achieved during the month (considering also their potential benefits from the carbon market).

3.1.3.4. POST-CONDITIONS

OTT video streaming platforms can apply economic incentive mechanisms to reduce unnecessary energy consumption stemming from the reckless consumption of end users. End users earn monetary benefits by adoption a green behaviour.

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3.1.3.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

Here we assume all requirements of UC1: Media streaming carbon footprint transparency and UC2: Digital Sobrietyare fulfilled.

3.1.3.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.1.3.6-1] Carbon footprint improvements caused by a user's behavioral adaptation shall be converted into environmental points.

[PR.3.1.3.6-2] The environmental points and history of monetary gains shall be stored and accumulated in the user's profile.

[PR.3.1.3.6-3] The associated economic benefit for the providers involved and the mechanism for mutually agreed distribution of the economic benefit to the providers and the user shall be provided.

This can be initiated by the primary stakeholder (i.e. Content Provider/OTT platform), with take-it-or-leave-it offers for energy benefits propagating together with the other information, while the followers (other upper stakeholders) can propose a counteroffer. Also, the OTT entity can alternatively run a centralized mechanism, such as Shapley-value or auction. The relevant stakeholders' information, such for which should also be propagated, either as explained below, or through additional direct bilateral information streams. (For the users, the economic benefit can take the form of immediate monetary discounts or periodic/monthly monetary rewards through lotteries.)

The service domains along the path from the client to the base service provider shall support the exchange of information on the energy consumption and carbon footprint measurements for on-going services, along with information on predicted energy consumption and carbon footprint estimates for alternative services that a domain can provide to the upstream domain and the incentives that the former can provide to the latter for adopting each of these alternative services. The granularity of the measurements and information exchanged by interconnected providers along the end-to-end path can be per flow or aggregated (bulk). If a domain receives aggregated measurements and/or energy/economic information from a downstream domain, it shall provide a way to apportion them to its upstream domains that use the service from the downstream domain.

[PR.3.1.3.6-4] The user interface (e.g., through a dashboard or mobile app/wallet) of the user's device shall be able to present the environmental points collected in time, the history of monetary gains (e.g., discounts or rewards), and the user actions (e.g., change of service parameters, such as modification of video resolution / video quality).

3.1.4. UC4: BEHAVIOURAL INCENTIVES FOR DIGITAL SOBRIETY

3.1.4.1. DESCRIPTION

The challenge of becoming carbon neutral within the ICT sector requires concrete actions, together with widening the scope of the involved stakeholders. Most energy efficiency efforts

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have been encompassed within the network infrastructure, leaving the end-user outside of the loop. Including end users and providing them with the appropriate information and incentives steer them in the right direction.

'Behavioural Incentives for Digital Sobriety' use case builds on the information provided by the 'Digital Sobriety' use case (UC2: Digital Sobriety), to devise and apply effective ways in which users can be properly motivated by means of non-economic incentives in order to decrease the carbon footprint which they are accountable for.

A wide variety of behavioural incentives for energy efficient 'Digital Sobriety' can apply to this use case:

- The award of environmental points to the user, in accordance with the CO2 footprint improvements, and the pictorial representation of the points accumulated, e.g. in the form of a growing tree, similarly to the approach of project Charged [29].
- The usage of peer pressure through social comparison; in this case, peer pressure can be exercised for environmentally friendly 'Digital Sobriety' simply by privately announcing to the user the relative "performance" percentile to which he falls according to his achieved CO2 footprint improvements e.g. in the present week.
- The combination of the two motives above, by estimating the relative "performance" percentile according to environmental points.
- A serious game to which users within some specific group participate, e.g. students in a school, employees in an organization etc.; competition is performed on the basis of environmental points, either among individual users, or among groups (for example, among the classes of a school).

3.1.4.2. PRE-CONDITIONS

This use case builds on UC2: Digital Sobriety"Digital Sobriety". Thus, a successful application of this is a prerequisite.

3.1.4.3. SERVICE FLOWS

1) User A selects a video to watch from OTT B's platform, indicating that the energy consumption needs to be displayed (accessible) while watching the video.
2) As the device of User A requests a particular set of information elements data packages, carbon footprint information is being measured, stored, analysed, and displayed on the user screen as described in UC1: Media streaming carbon footprint transparency.
3) The video streaming software of OTT B suggests specific actions, as described in UC2: Digital Sobriety, alongside with environmental points that will be awarded if such an action is taken.
4) As soon as an action is taken, environmental points are awarded to User A
5) A pictorial representation of the total environmental points accumulated, (e.g., a growing tree) appears on the screen of User A's device aggregating points earned in a specific time period.
6) The video streaming software of OTT platform B displays the percentile of top performers that user A is positioned (e.g., top 10%) compared to all other users of the platform from

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the same network or specific subsets such as social groups. Based on the tier that is achieved by user A, she is awarded a badge that is sharable to social media.

3.1.4.4. POST-CONDITIONS

OTT video streaming platforms can apply behavioural incentive mechanisms to reduce unnecessary energy consumption stemming from the reckless consumption of end users. End users earn green behaviour badges that can be shared with peers.

3.1.4.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

Here we assume all requirements of UC1: Media streaming carbon footprint transparency and UC2: Digital Sobriety are fulfilled.

3.1.4.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.1.4.6-1] Carbon footprint improvements caused by a user's behavioral adaptation shall be converted into environmental points.

[PR.3.1.4.6-2] The environmental points and social rewards (e.g., in the form of badges or achievements) shall be stored and accumulated in the user's profile.

[PR.3.1.4.6-3] The user interface (e.g., through a dashboard or mobile app/wallet) of the user's device shall be able to present the environmental points collected in time, comparative statistics of the collected points, the user's social rewards (e.g., graphics and awarded badges), and the user actions (e.g., change of service parameters, such as modification of video resolution / video quality).

3.1.5. UC5: WATCH TV OVER 5G/6G

3.1.5.1. DESCRIPTION

An end user wants to see content on TV. The TV is connected via Wi-Fi with the 5G/6G phone's hotspot that connects the TV to the TV service. In addition, the end user will get the energy usage and CO2e data.

Example:

The end user is fond of football and wants to watch it on the big screen on his boat. The boat doesn't have fixed internet access, and the harbour Wi-Fi isn't strong enough to stream this important football match. There's no DVB-T (2) coverage in the area, but there is good 5G/6G coverage, so the user can the phone's hotspot to connect the TV to the Internet. As an environmentally conscious consumer, the user also wants to know the energy consumption and CO_2 equivalent emissions for this setup.

3.1.5.2. PRE-CONDITIONS

The end user has an IPTV subscription that allows for mobile access to the big screen. The Smart TV can run the application from the TV service provider and can connect to the Internet via Wi-Fi. The smart phone connects to 5G/6G and a personal hotspot can be setup at it. The

Mobile Virtual Operator (MVO) provides a good enough signal to watch TV without disturbances for two hours.

Therefore, stakeholders will need to comply with the requirements to produce and exchange energy consumption-related data and implement them in their respective platforms.

Interoperability between different devices and network equipment within and among stakeholders is a must.

It is essential that all energy required to provide this information is significantly less than the overall reduction achieved.

3.1.5.3. SERVICE FLOWS

1) User A selects a video to watch from OTT B's platform, indicating that the energy consumption needs to be displayed (accessible) while watching the video, triggering a series of processes as described below.
2) The device requests a particular set of data packages, through the mobile network and reaching the OTT's data through the internet for that particular video. All of these interactions have reported their respective energy consumption to deliver the task. This information is then coupled with other contextual data, such as the current energy mix for each of the steps/actors, to later deliver a unified CO2 footprint for that particular service.
3) The EC and CO2e information is then shown to the user and keeps accruing as the video is being played. Examples of alternatives for displaying the information are (i) showing on the top of the user's screen (Mobile) or internet tab (PC), (ii) information shown when touching the screen (Mobile) or hovering over the video (PC), (iii) sending notifications as the video plays, or (iv) dedicated app that accrues and displays the information. These are just a few ideas that highlight the need to have the required information related to carbon/energy measurements.

3.1.5.4. POST-CONDITIONS

The availability of the end-to-end energy consumption for the video stream demands changes throughout the entire video communication chain. The handsets shall include the aforementioned CO2e indicators in their OS; OTT video streaming services to deliver the information related to their service provision (footprint); the network to provide information on their energy consumption and current network architecture; etc. End users will be able to see the CO2 emission generated from their activity and will be able to make informed decisions.

3.1.5.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

The existing feature partly or full covering use case functionality is the same as in section 3.1.1.5

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3.1.5.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.1.5.6-1] The 5G/6G network shall be able to provide exchange of energy usage and CO2e data for each traffic flow.

Note: The exchange of Energy usage and CO2e data should be operator configurable, e.g. frequency or updates of thresholds for reporting.

[PR.3.1.5.6-2] The 5G/6G phone hotspot shall be able to provide exchange of energy usage and CO2e data for each traffic flow.

[PR.3.1.5.6-3] All service providers shall be able to provide exchange of energy usage and CO2e data for each traffic flow to the next service provider in the end-to-end chain.

[PR.3.1.5.6-4] The display device shall be able to present the total energy usage and CO2e data including its own to the end user.

3.1.6. UC6: ANY SERVICE PROVIDER GETS EC AND CO2E DATA FOR END2END CHAIN

3.1.6.1. DESCRIPTION

A Service Provider may want to reduce EC and CO2e to reduce Operational Expenses (OPEX). Additionally, it may want to foster a green image towards customers and investors, as this may be an argument to purchase a service, respectively to invest in its company. In any case, the Service Provider may want to take part in green end-to-end services, that is in services with low EC and CO2e.

In order to achieve this, Service Providers would like to visualize EC and CO2e data for all their users, and from all elements in the service chain that they take part in, in as much detail as possible. The Service Provider role is a very generic one; it could be any party that delivers a service in the end-to-end chain. In the examples below several instantiations of this role are shown.

A Service Provider faces the challenge that it delivers its services in several end-to-end chains, which it is not really aware of. For example, other parties use its network connectivity or its ICT platform, but it does not know a lot about the services and their end-to-end EC and CO2e in detail. By gaining insights into this, the Service Provider can, for example, discuss EC and CO2e with its suppliers or customers and possibly adapt contracts accordingly.

Also, a Service Provider would like to be able to spot anomalies in energy or power consumption for particular equipment or its components, in order to detect, diagnose, and subsequently fix or prevent malfunctioning and/or unnecessary energy consumption. To accomplish this, a Service Provider would actively scan for EC and CO2e anomalies (together with the other parties in the end-to-end chain), to better understand these, identify the root causes, and solve the issues. Observe that anomalies elsewhere in the service chain can have a negative impact on the EC and CO2e emissions in the Service Provider's part of the end-to-end chain.

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Examples:

- **A Telco Operator delivering an IPTV service.** The service is delivered on big screens, TVs, PCs, tablets and smartphones. The Telco Operator owns the complete chain from encoding to decoding and wants to reduce EC and CO2e use as much as possible without reducing QoS in a significant way. To accomplish this it needs be able to (1) see energy being used in the full chain and be able to optimise power usage (e.g., by AB testing), (2) validate supplier claims on energy usage, (3) find energy usage anomalies in equipment (e.g., end user devices, network components and Content Distribution Network (CDN) streamers), (4) switch off power hungry redundancy mechanisms, when 99.999% uptime requirements are less relevant, (5) discuss the energy usage of third party content streams in its network (e.g., OTT players going straight to its CDN or to the customer).
- **A Video Service Provider** that wants to reduce end-to-end EC while maintaining QoS, needs to be able to: (1) see energy being used in the full chain and be able to optimise on the power usage (e.g., by AB testing of CDNs, Cloud Providers or network providers), (2) find energy usage anomalies in, for example, end-user equipment, (3) discuss energy usage in its network relating to third party content streams (e.g., OTT players going straight to its CDN or to the customer).
- **A Cloud Provider** that wants to reduce the end-to-end EC while maintaining a good enough quality needs to be able to see the EC and CO2e of its data centres and different types of hardware in them, in order to advise and to provide EC and CO2e service information to its customers.

3.1.6.2. PRE-CONDITIONS

Energy data and CO2e data needs to be exchanged in a trusted and secure way, so all parties can rely on it. This information exchange needs to be compliant to certain specifications, so there is no need to implement a different protocol for each party in the chain.

3.1.6.3. SERVICE FLOWS

1) Many users select videos to watch from Video Service Provider A's video service platform. EC and CO2e information are updated during service consumption for all sessions to all parties in the chain who requesting it.
2) Each service provider in the chain has the possibility to put this data in an analytical tool, that can display, select and correlate data. The tool should also be able to provide historical data of all parties in the end-to-end chain, as far as being received.

Examples:

1. Video Service Provider A can see the energy usage of device C or user D for video E.
2. Video Service Provider A can see the top energy consuming movies on all end user devices.
3. Video Service Provider A can see the end user devices, that use the most energy of all end user devices of the same type that watch or have watched video E.

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4. Public Land Mobile Network (PLMN) F, with CDN streamers in its network (on the local edge and at a higher aggregation level) wants to introduce energy aware caching in the future. As a first step it needs measurements, totalising the EC from the CDN streamer up to the end-users.
5. PLMN F wants to be able to discuss whether Internet caching or caching on the mobile network edge is more energy efficient with Video Service Provider A.
6. PLMN F with green proposition G wants to advise or actively steer the end-user to low energy usage of the end-to-end service.

3.1.6.4. POST-CONDITIONS

Service providers can take action on unwanted energy usage in their chain. For example (relating to example 3 above), the service provider can force a reboot of the device using the most power and see if that solves the issue.

3.1.6.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

3GPP TS 28.554 [3] (R18) describes energy consumption for individual NFs, slices, NG-RAN, gNB, 5GC but does not break this down to individual user flows. Ongoing work on "energy efficiency as a service criterion" within R19 is considering that level of granularity. For example, the use case on supporting carbon-aware communication service (Section 5.10 of TR 22.882 [4]) proposes that a mobile user of an XR service gets an estimation of carbon intensity information related to this flow. However, a holistic view of all the crossed domains (not just the mobile network) is missing.

Internet Drafts, draft-cx-opsawg-green-metrics [5] and draft-irtf-nmrg-green-ps [6] exploring similar topics with regards to the Internet, including breakdown to individual user flows. However, again, a holistic view is missing.

3.1.6.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

Most of the requirements for implementation are currently non-existent. Fetching real numbers from all the crossed domains cannot be implemented, because of lacking interfaces to access such data and lacking mechanisms for energy – or CO2e – specific accounting on a per-user flow basis, not supported by any of the involved resources or domains, let alone in any agreed form (syntax, data structure, semantics).

a) Subscriber and end user device granularity.
b) Dynamic identification of routing and dynamic update according to new user settings.
c) Mechanisms for fair energy consumption/CO2e footprint attribution

[PR.3.1.6.6-1] The 5G/6G network shall be able to provide exchange of energy usage and CO2e data for each traffic flow to the next service and previous domain in the end-to-end chain.

[PR.3.1.6.6-2] All domains shall be able to provide exchange of energy usage and CO2e data for each traffic flow to the next service and previous domain in the end-to-end chain.

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Note: The exchange of energy usage and CO2e data should be operator configurable, e.g. frequency or updates of thresholds for reporting. This needs to be negotiated to other entities that depend on that information (e.g., overlays over the video in the UE indicating the current CO2)

3.1.7. UC9: PHYSICAL SECURITY IN INDUSTRY

3.1.7.1. DESCRIPTION

Physical security is one of the most important supporting processes in the industry, contributing to sustainable development of the business by providing secure workplace for the employees and, e.g., preventing damages potentially caused by third parties. Contemporary physical security methods heavily rely on IT systems, including components such as surveillance cameras (e.g., stationary, wearable) backed by AI algorithms responsible for detecting emergency situations. As with any other (IT) service, the business owner, who owns private 5G/6G and private cloud infrastructure, UEs, and operates and consumes physical security service (private 5G/6G and private cloud are operated by 3rd party contractors) is willing to know what its energy footprint is, and how it can be optimized – being it for the sake of energy costs or costs related to carbon footprint and reputation against green transition agenda. The use case assumes cameras are connected to private 5G/6G network and AI video analytics takes place in the cloud (to that extent, customer may be owner of the complete infrastructure). The goal of the use case is to evaluate end-to-end energy consumption of the service contributed by every part/domain contributing in service delivery, and, based on the service specifics and energy consumption measurements, optimize the private 5G/6G network parameters and other resources required for service delivery (e.g., AI processes, virtual computing capabilities), all aimed at optimizing/reducing overall energy consumption while not degrading quality of the service, i.e., customer's experience. However, at the time being, dynamic orchestration of the resources/components involved, and detailed energy consumption reporting are a significant challenge.

Note: in practice, a scenario where industry business owner is owner of private 5G/6G network (and private cloud) is one out of many possible models for private 5G/6G network business models.

3.1.7.2. PRE-CONDITIONS

The use case depends on the following (infrastructure) pre-conditions:

- Control over (private) 5G/6G network.
- Control over (private) network infrastructure.
- Control over (private) cloud infrastructure.
- Existing and controllable video surveillance service and known video-analytics applications.

3.1.7.3. SERVICE FLOWS

The following service flows are considered main aspects of the use case:

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1) Surveillance/security video-camera streams video over 5G/6G network to the cloud, where video-analytics application runs.
2) Video-analytics algorithm continuously checks for anything unusual detected in the video stream, i.e., a potential (physical) security issue that requires further attention, such as on-site intervention.
3) Video-analytics also continuously assesses video-stream quality (e.g., video resolution) and may signal back to the video-camera to modify video capturing and streaming parameters (e.g., video resolution used) in order to satisfy minimum requirements needed for successful image detection, which may also include activation of sleep-mode, especially in the case there are more video-cameras involved in the video surveillance process.
4) Current requirements for video streaming may also allow for 5G/6G network configuration modifications (to be required via the orchestrator), directly affecting its energy/power consumption, e.g., downgrading radio from 4x4 MIMO to 2x2 MIMO, etc.
5) The cloud, where video-analytics application runs, may also include various processing capabilities, e.g., GPUs, multiple processors of various performance. The orchestrator is therefore expected to consider this while reserving resources for the video-analytics application (e.g., offloading video stream processing to GPUs).
6) Energy consumption measurement devices/applications continuously report measurement results to the database. The consumption should be continuously measured for every process and every HW component involved in the (end-to-end) service, i.e., camera, UE, RAN, core network, cloud.

3.1.7.4. POST-CONDITION

The owner of a private 5G/6G network and private cloud infrastructure has better (or more detailed) insight into energy consumption of its specific IT service(s) comparing to public network where much more services and users would be normally served, with the operator having limited possibilities of affecting users' behaviour. Better insights into energy consumption of specific parts/components is consequently available also to the other stakeholders, i.e., operator(s) of the private network 5G/6G and cloud. Thus, in private networks it would be more means available for steering the energy consumption which may depend on the expected quality of service. Knowing energy consumption facts further helps in designing infrastructure that could be utilized for (local) renewable energy generation, thus additionally reducing carbon emissions caused by IT services, which, additionally to other services, contribute to customer's overall carbon footprint resulting in certain costs (e.g., carbon emission allowances) and/or its reputation against green transition perspective.

3.1.7.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

Within the existing infrastructure, it is possible to manually modify 5G/6G network parameters, as well as modify execution properties of video-analytics applications. Energy and power measurement tools and methodology defined by standardization bodies are at the time being mainly limited to overall energy consumption measurements per Virtualized Network Function ((V)NF), Virtualized Network Function Container ((V)NFC) and Physical Network Function (PNF) components (e.g., 3GPP Rel. 18 TS 28.554 [3] V18.5.0). For the use case goals, every single user session and/or every single service energy consumption should be measured end-to-end which requires measurements in virtualized and multi-domain environments.

3.1.7.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.1.7.6-1] Technological domains involved in providing the service (e.g., 5G/6G radio and core network, UEs, cloud environment) shall be able to provide time-continuous energy consumption measurement of a specific software process running in the virtualized environment (i.e., the use case owner/customer specifies which are these processes).

[PR.3.1.7.6-2] Technological domains involved in providing the service (e.g., 5G/6G radio and core network, UEs, cloud environment) shall be able to provide time-continuous energy consumption measurement for a specific HW component (PNF).

[PR.3.1.7.6-3] Technological domains involved in providing the service (e.g., 5G/6G radio and core network, UEs, cloud environment) shall be able to provide time-continuous energy consumption measurement of the locally produced carbon-free energy.

Requirements [PR.3.1.7.6-1], [PR.3.1.7.6-2], [PR.3.1.7.6-3] Shall all meet the following objectives:

- to provide current value of the parameter observed, i.e., averaged over the time-period between two adjacent samples,
- to provide accuracy and time resolution as requested by the particular service specifics,
- measurements shall be provided for both applications and system software processes.
- all measurement results shall be synchronized on a common timescale.

[PR.3.1.7.6-4] Technological domains involved in providing the service (e.g.5G/6G radio and core network, UEs, cloud environment) shall be able to provide measurements of user traffic volume:

- measurement results shall be synchronized with other measurements (energy/power consumption, computing resources utilization) on the common timescale.

[PR.3.1.7.6-5] Technological domains involved in providing the service (e.g.5G/6G radio and core network, UEs, cloud environment) shall be able to measure:

- CPU and GPU utilization,
- memory (RAM) utilization,
- measurement results shall be synchronized with other measurements (energy consumption, computing resources utilization) on the common timescale.

[PR.3.1.7.6-6] Technological domains involved in providing the service (e.g.5G/6G radio and core network, UEs, cloud environment) shall provide means for accesing ecodata:

- access ecodata in (near) real time,
- download ecodata for larger time-period,
- user shall be able to select ecodata of interest.

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[PR.3.1.7.6-7] Private 5G/6G network operator shall introduce an orchestrator (or similar functionality) which shall be able to provide, during the service execution, information regarding the optimal (pre-defined) network slice available in an energy and/or CO2 efficient manner, based on the (vertical) application requirements.

[PR.3.1.7.6-8] Private 5G/6G network operator shall introduce an orchestrator (or similar functionality) which shall be able to provide information regarding the optimal (5G/6G) radio access settings in an energy and/or CO2 efficient manner (MIMO settings, throughput requirements, latency requirements), based on the current (vertical) application requirements. Applies to environments where network settings can be updated during the operation (i.e., Day-2).

[PR.3.1.7.6-9] Private 5G/6G network and private cloud owner and operator(s) shall provide such capabilities (i.e., resources and functionalities) that the user (i.e., business owner) shall be able to schedule service related AI tasks on available resources (including resources available at core and base station, as well as at private cloud facilities and UEs) in an energy and/or CO2 efficient manner.

3.2. GROUP GREEN BATCH SCHEDULING

3.2.1. UC10: CARBON-AWARE AI (OR BATCH) SERVICE PROVISIONING AND CONTROL

3.2.1.1. DESCRIPTION

AI is recognized as one of the major services to be provided by 6G systems, and to be used by any entity authorized, e.g. by the customers (verticals), the operator, and by the system itself. Data privacy, resource (computation, communication, storage, and energy) efficiency, scalability, fast convergence, fairness, and reliability are among KPIs required by such a service. AI is very energy and resource-hungry, especially in terms of energy consumption during training. Sustainability considerations (e.g. as by GSMA [20] require the energy consumption and carbon footprint of the provided AI and other services to be regulated and minimized.

In this use case, an AI model is distributed and constructed (training) or used (inference) over various available computational and energy resources, specifically crafting the partial tasks in a way suitable for these constrained nodes and mapping tasks to nodes with respect to the available compute and memory resources, (excess) renewable energy, etc., hence provisioning the service in a greener manner overall.

This use case is expected to include architectural entities, interfaces, and a set of new technologies and service scheduling mechanisms to enable the execution of AI-services over renewable energy resources, as much as possible, reducing their corresponding carbon footprint. Thereby creating sustainable AI services in the 6G system.

3.2.1.2. PRE-CONDITIONS

Firstly, monitoring tools must be installed on each network node, in order to monitor its energy consumption related (directly or indirectly) data accurately. Indicative examples could include

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computation/communication resources, access to renewable sources and available energy storage, service/network traffic load. An AI-enabled central entity must be established to aggregate the aforementioned data from all nodes. The data will be analysed to extract context from the raw information exploiting an AI-driven approach, towards creating dynamically adjusted energy profiles for all nodes. The central entity itself should also measure its own energy consumption, extract its own profile and energy efficiency index. Therefore, it is essential to establish new protocols that will enable the communication between these nodes and the central entity. This central entity will reside either at the core or at the edge of the network.

3.2.1.3. SERVICE FLOWS

1) The (6G) system is requested to execute an AI service (the service request could also include a limit for the total carbon footprint generated during the execution of the task).
2) It gathers resource availability information from the nodes involved in the training.
3) It uses the resource and energy information availability to assign training tasks to these nodes in a carbon efficient manner.
4) The task nature and its assignment to the nodes can change over time to account for the changes in the resource availability at these nodes.

3.2.1.4. POST-CONDITIONS

The AI service is provided to the customer with total carbon footprint minimized (or is kept below the specified limit by the customer). Other mechanisms can be used to expose the information about the carbon footprint of the service.

3.2.1.5. EXISTING FEATURES PARTLY OF FULLY COVERING THE USE CASE FUNCTIONALITY

As described in 3GPP TR 23.700-80 (R18) [7], Network Data Analytics Functions (NWDAFs) work in conjunction with the Analytics Logical Function (AnLF) and the Model Training Logical Function (MTLF) to support core operations for data collection and analysis, as presented in TS 23.288 v17.5.0 (R17) [8]. Utilizing the Edge User Plane Function (eUPF) as specified in TS 23.548 (R18)[9], which applies various policies delivered by the Service Management Function (SMF) through the Core UPF (cUPF), allows for the instantiation of different NWDAFs at associated Mobile Edge Computing (MEC) locations. Additionally, the distribution of data within the infrastructure could benefit from a Permissioned Distributed Ledger (PDL) as described in TR GR PDL 009 V1.1.1 [11], offering a potential solution to mitigate security risks associated with a Federated Learning (FL) solution. Finally, according to TS 28.554 v18.5.0 (R18) [3], various Key Performance Indicators (KPIs) can be used to estimate energy consumption (EC) (Section 6.7) per Network Function (NF), Network Slice, gNB, and other aspects from data collection to method execution as mentioned above.

3.2.1.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.2.1.6-1a] 5G/6G service providers shall provide an interface to query information regarding resource (including computation, communication, memory, memory bandwidth)

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availability and energy availability (including information regarding the amount, sources, types, and CO2 per KWH) to third party service providers.

[PR.3.2.1.6-1b] 5G/6G service providers shall provide an interface to execute AI tasks to third party service providers.

[PR.3.2.1.6-2] 5G/6G service providers and third-party service provider shall be able to schedule AI tasks on available resources in an energy and/or CO2 efficient manner.

The 5G/6G system shall support receiving the AI service execution request from the network operator and verticals. The 5G/6G system shall run execution requests in a carbon efficient manner. The 5G/6G system shall run execution request based on EC and CO2e constraints.

Existing 5G/6G core network architecture does not provide energy information of the resources available on the core and base stations. Also, it does not allow the execution of services over third party resources, and/or to acquire state information (including resource availability and energy and CO2 information) from these resources. Beside these, current 5G/6G core network does not allow scheduling and execution of services based on energy/CO2 constraints. Therefore, new interfaces are required to enable different base stations, data centres (platforms), and /or UEs to report their resource availability and energy characteristics (sources, types, etc…) to the network. Also, new entities are required to collect relevant underlying information about energy used by the resources, and to schedule AI tasks on resources in an energy/CO2 efficient manner.

3.2.2. UC13: CARBON-AWARE PRE-POPULATION OF CDN NODES

3.2.2.1. DESCRIPTION

The purpose of a content distribution network (CDN) is to bring one-to-many content geographically close to end users to improve response times and to avoid sending the same content over the same paths many times (by itself reducing network capacity usage and energy expenditure). This is typically about large data sets which are consumed by many consumers, think of OTT Video, web pages, firmware updates.

The content originates at an origin server and needs to be replicated to many so-called Points of Presence (PoPs), possibly using a hierarchy with intermediate servers (upper tier to lower tier). The replication process itself is not time-critical (low-priority, best effort) and may very well take hours or even days depending on the application (e.g., just make sure it is at the PoP before the intended ‘release date’).

Carbon-aware content replication schedules a replication step (e.g., from an upper tier server to a regional tier server or from a regional tier server to a lower tier server) when the energy / CO2e impact is minimal or even zero. Think of only using paths that are fully (or to a large extent) powered by (an overcapacity of) green energy, but also of only using excess capacity on paths that are already active (i.e., incremental energy usage will be low, as quite often networks energy usage is not proportional to their load), or a combination of both. For some scenarios (e.g., firmware updates or ordered movies for download), it is even conceivable to extend this step to the end-user device (see also Section 3.2.3, “UC15: Green social media and e-mail Content Download”).

A separate use case could be on transcoding. Transcoding operations may also be scheduled for minimal or zero CO2e impact in the transcoding farm. Note that transcoding is likely to take place at the origin server and not in the CDN itself.

Industry feedback and positioning

Representatives from several public CDN suppliers (Axello, Broadpeak, Agilecontent) have been contacted to review the current use case. Their insights are briefly summarized below.

Present-day public CDNs are based on a pull-model, rather than a push-model. This means that content ripples through the hierarchy in direct response to a (first) customer demanding the content for immediate streaming, leaving no opportunity for green scheduling (in time). Also, even if pre-positioning is done, it is done only minutes before content becomes public, not hours or days. Nevertheless, pre-positioning may be relevant in relation to downloads, (rather than streaming). Consider software downloads, game updates, and audio/video downloads. Furthermore, the lion’s share of the total traffic is from the edge to the end-user, not between origin and edge.

However, non-public CDNs, such as Netflix Open Connect and telco-based IPTV-CDNs do use the push-model, even though the growing demand for live content may lead to revisiting this.

Concluding, the current use case may best be targeted to specific target markets such as downloads, rather than streaming. Furthermore, the optional extension towards the end-user node as presented below may prove to be particularly attractive within the scope of those target markets, considering that the lion’s share of energy is expanded on this last hop.

3.2.2.2. PRE-CONDITIONS

Content Service Provider A has a green service agreement with CDN Service Provider B. CDN Service Provider B has green service agreements with Cloud and Edge Computing/Storage Service Providers C (including possible PLMNs for MEC), and with (PLMN and ISP) Communication Service providers D. Service providers C and D have green energy contracts with Energy Suppliers E. Content Service Provider A has customers, the End-Users F.

<u>Optional extension</u>: End-Users F have service contracts with further communication providers G that are enabled for carbon-aware, scheduled downloads. This extension may also include further Energy Suppliers H that are contracted by End-Users F.

3.2.2.3. SERVICE FLOWS

The services flows of Carbon-aware pre-population of CDN nodes as shown in Figure 3:

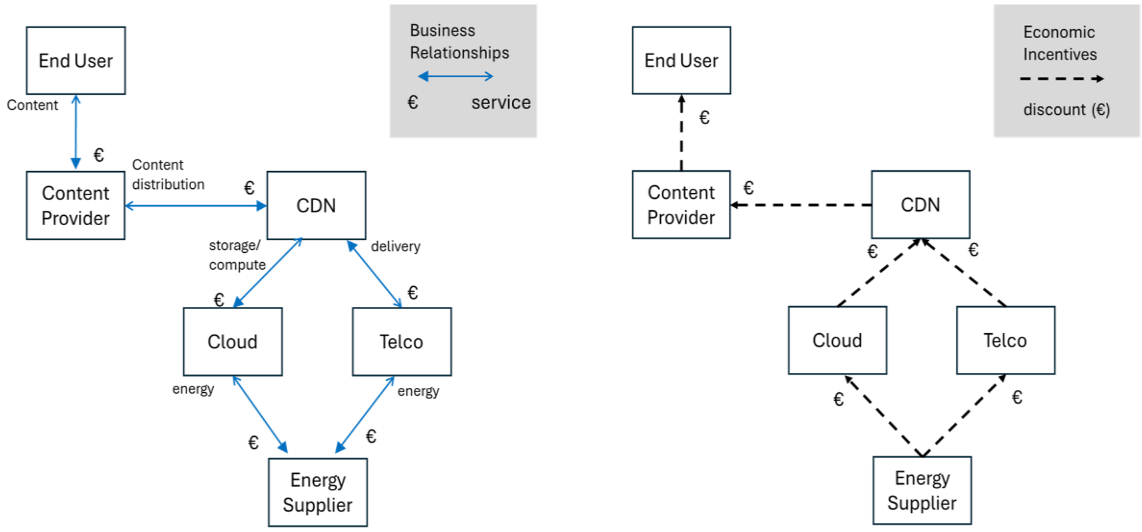

Figure 3: Diagram of services flows of carbon-aware pre-population of CDN nodes

1) Energy Suppliers E send Demand Response (DR) signals to Computing/Storage Service Providers C and to Communication Service Providers D regarding forecasts of low energy demand time-windows or time-windows of increased green energy availability. This means that Energy Suppliers E identify "green windows" where data delivery and replication can be performed in an environmentally friendly manner. These green windows may be different from location to location. For the energy consumed by Service Providers C and D within these windows, there will be a discount on their bills.
2) Computing/Storage Service Providers C and Communication Service Providers D on their end, offer a discount to CDN Service Provider B if B determines to distribute and replicate content in the green windows identified for different geographic locations.
3) Content Service Provider A enjoys a discount if it chooses to schedule a release of the content across different regions on energy efficient manner, adopting a green release plan.
4) (Optional) End-Users F gain "environmental points" (see Section 3.1.4, "UC4: Behavioural Incentives for Digital Sobriety") if (s)he chooses to access the content based on a flexible green release plan.
5) Content Service Provider A schedules for content at its origin server to be replicated over a selected set of regions (each comprising one or more PoPs) operated by CDN Service Provider B, indicating by which release date the content must be available at the respective PoPs. The Content Service Provider A follows a green release plan aiming to reduce its footprint and simultaneously achieving a discount on the CDN service, (Optional) while also rewarding the End-Users F with environmental points.
6) CDN Service Provider B requests contracted Computing/Storage Service Providers C and Communication Service Providers D information (i.e., schedules) about expected computation and communication capacity as function of time and the associated CO2e footprint thereof, pertaining to the timeframe up to abovementioned release date. A discount is earned when requesting delivery during green time windows across different regions.
7) Computing/Storage Service Providers C and Communication Service Providers D inspect their schedules and forecasts to ascertain time intervals of available capacity and, if

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needed, update the energy mix information provided by Energy Suppliers E, to associate CO2e footprint information to each time interval. The computation of CO2e footprint may also factor in the fact that excess capacity on operational servers and/or communication links may have a relatively small incremental energy (and therefore carbon footprint) impact. The collected time intervals with associated capacities, and CO2e footprint information are provided to CDN Service Provider B.

8) CDN Service Provider B computes a schedule, for replicating the content as requested by Content Service Provider A, communicates the claimed time intervals to Computing/Storage Service Providers C and Communication Service Providers D, and executes the schedule at the relevant moments in time. It may adjust these schedules, and the associated execution, at any time during execution based on possible new, updated information that deviate from the initial forecasts (e.g., other requests from Content Service Provider A, requests from other content service providers, and updates from Service Providers C and D with regards to time intervals, capacities and CO2e footprint, the latter being influenced by other users of their networks and/or the energy mix information provided by their Energy Suppliers E). Content Service provider A is notified of the replication being complete, possibly accompanied by the actual CO2e footprint realized.
9) Content Service Provider A (or CDN Service Provider B) enables the content at the release date for download and/or streaming by End-Users F.
10) End-Users F can download/stream content to their device after the release date.

Optional extension: CDN service provider B and/or End-Users F may optionally schedule abovementioned downloads to the end user's device in a carbon-aware manner. In case of e.g., firmware images or subscribed video content, the download may even occur before the release date and be enabled for installation/playout later by the Content Service Provider A (or CDN Service Provider B) at such release date, effectively extending the CDN onto the user premises. This extension would require interaction with further Communication Service providers G and Energy Suppliers H that are contracted by End-Users F, therefore requiring alternate arrangements (as those service providers will not necessarily be contracted by CDN Service Provider B).

Note that the use case "UC15: Green social media and e-mail Content Download" described in Section 3.2.3 also addresses green scheduling of transferring content to the end user's device but with a specific focus of minimizing energy usage by scheduling the transfer if the radio conditions and energy ratio are favourable. These same mechanisms may be applied for this use case. However, notice that the current use case addresses one-to-many content download, whereas "UC15: Green social media and e-mail Content Download" addresses one-to-one content download.

3.2.2.4. POST-CONDITIONS

Content from an origin server is replicated towards PoPs (optionally including end user devices) with minimal or even zero CO2e impact and ICT equipment utilization in the entire E2E chain is optimized.

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3.2.2.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

Solutions 4 and 5 of [TR 23.700-66 V19.0.0] [13] describe ways for the cellular network to provide energy usage information and (renewable) energy ratio information. These may be used by (cellular) communication providers to predict the CO2e footprint of transfers to be scheduled. Providing energy pricing forecasts to energy consumers by energy producers is also known but may not be standardized across suppliers or regions.

3.2.2.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.2.2.6-1] CDN service operator shall provide an interface for green content replication. Parameters: content to be replicated, regions/PoP to replicate over, release date by which content replication should be complete (and at which content should be enabled).

[PR.3.2.2.6-2a] Compute / communication service providers shall provide an interface to query time intervals for providing time-delayed services. Parameters: time period in which time interval should fall (e.g., up to release date), capacity available, CO2e footprint of service provision.

[PR.3.2.2.6-2b] Compute / communication service providers shall provide an interface to reserve one or more previously queried time intervals. Parameters: (identifier for) time interval and requested capacity.

[PR.3.2.2.6-2c] Compute / communication service providers shall provide an interface to consume services with reference to an earlier reserved time interval.

[PR.3.2.2.6-2d] Compute / communication service providers shall provide an interface to notify changes to an earlier agreed upon schedule and offering compute / communication service providers to adjust their reservations accordingly.

[PR.3.2.2.6-3] Energy suppliers shall provide an interface to query for time intervals with a (favourable) energy mix. Parameters: time bounds, maximum CO2e impact. Alternatively, energy suppliers send regular DR signals to subscribed users (i.e., compute / communication service providers).

3.2.3. UC15: GREEN SOCIAL MEDIA AND E-MAIL CONTENT DOWNLOAD

3.2.3.1. DESCRIPTION

With 7.9 billion users accessing instant messaging and email services worldwide [21][22][23][24] , with increasing attachment sizes (e.g., WhatsApp's expanded message size from 100MB to 2GB [25]) and volume of data consumed expected to grow exponentially, it is essential to address the challenge it imposes for achieving carbon neutrality and support global green digital future vision.

This use case aims to reduce the carbon impact of instant messaging and email services by postponing the download of attachments (i.e., the bulk of the data) to a moment in time when both the energy mix is and/or the radio signal conditions are favourable, considering that radio signal conditions have a major impact on the EC needed for RF communications.

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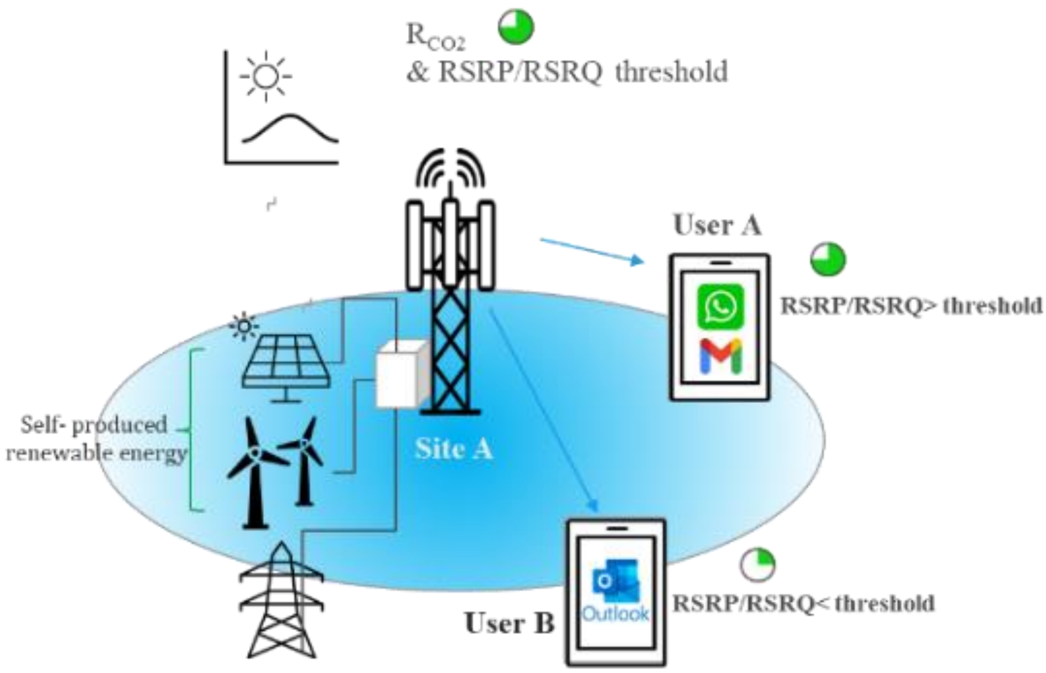

Figure 4: The 5G/6G system provides updates on the renewable energy ratio and the required RSRP/RSRQ threshold to EUs.

Figure 4Figure 4 provides an illustrative example of a 5G/6G site that transmits updates on the renewable energy ratio. When sharing media via instant messaging or email apps (such as WhatsApp, Facebook Communicator, Outlook, or Gmail), users can subscribe through their apps to only download shared music, videos, or files specifically during periods of a high renewable energy ratio and favourable radio signal conditions at the serving site. The attachment data transmission occurs only when a high renewable energy ratio is available at the cell (e.g., with an optimized threshold, determined in advanced or by AI) and is announced via for example cell broadcast channels. If the user's app determines that it has a high received signal strength and quality, it sends the download request to a Green Content Distribution server. If the renewable energy ratio falls below a certain threshold, no cell broadcast is signalled, indicating to the app that the renewable energy ratio is low, and no data transmission is requested.

In addition to the satisfaction of contributing to reducing the carbon footprint, this use case could provide dynamic CO2 credit incentives (or "environmental points") to the end-user. These credits can be applicable, for example, toward service discounts. Users can also download the content at any time, but they will not receive the incentive.

Similarly, other non-time critical data transfers, such as firmware downloads, uploads of social media or email attachments (e.g., recorded videos) and downloads from OTT video providers for offline viewing could be scheduled using the same constraints, see "Carbon-aware pre-population of CDN nodes" use case. Furthermore, this use case has been part of Exigence's contributions to 3GPP TR 22.883[1].

3.2.3.2. PRE-CONDITIONS

A Service Provider provides an option in its App for configuring green transfer of non-critical data and the End-User has selected this option in that App.

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The application must be able to send a transmission request for download to an external Green Content Delivery Server based on the receive the cell broadcast (e.g., 3GPP TS 23.041 [14]) and the received signal strength and quality (e.g., Reference Signal Received Power (RSRP) & Reference Signal Received Quality (RSRQ), 3GPP TS 38.304 [15].

A PLMN is able to compute the renewable energy ratio (R_{CO2}) at the applicable serving cell sites. The base station site is capable of measuring energy consumption supplied from both renewable and non-renewable sources (see ITU-T L.1350 [27]). Renewable sources include local self-produced energy from solar and/or wind, while non-renewable sources include on-site energy generators (e.g., diesel or other types) and utility grid power (with a portion coming from renewable sources).

The operator may have an agreement with electricity companies and get near real-time access for energy related information provided to at the sites, such as renewal energy ratio and Carbon intensity. Some sites may or may not have information about external energy suppliers, but they can rely solely on locally produced energy if necessary.

3.2.3.3. SERVICE FLOWS

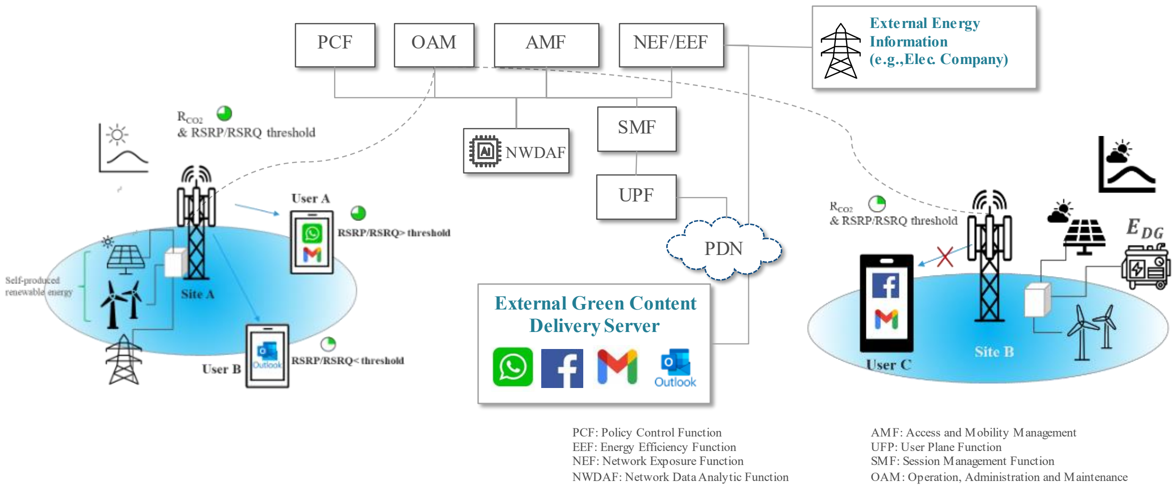

Figure 5: Green social media & email content Download, reference high-level architecture.

The following service flow includes part of the service flow as included in 3GPP TR 22.883 [1], combined with the general system architecture, as shown in Figure 5.

1) A message with attachment(s) is sent to the End-User through social media or email, represented by the External Green Content Delivery Server.
2) The message body is instantly delivered by the Mobile Network to the End-User's UE, but its attachments are scheduled for (delayed) green delivery instead.
3) The Mobile Network regularly evaluates the renewable energy ratio (R_{CO2}) at the serving cell site, as well as the energy consumption parameters relating to radio signal conditions experienced at the UE.
4) When the renewable energy ratio (R_{CO2}) is sufficiently high and/or the energy consumption parameters relating to radio signal conditions are favourable, the attachments are also delivered to the UE by the mobile network.

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5) The MNO provides incentives to the End-User that has (delayed) green download enabled. These incentives may be based on the EC and/or CO2e gains obtained through (delayed) green delivery.

3.2.3.4. POST-CONDITIONS

This use case has the potential to enhance the creation of new business opportunities by MNOs and to provide incentives for users to reduce their energy consumption and carbon footprint. Renewable energy (including energy self-produced by MNOs) is utilized more efficiently which is instrumental in achieving carbon neutrality goals and energy efficiency is improved by scheduling transmissions when signal conditions are favourable.

3.2.3.5. EXISTING FEATURE PARTLY OR FULLY COVERING USE CASE FUNCTIONALITY

The method of providing (monetary) incentives using cell broadcast channels (e.g., 3GPP TS 23.041 [14]) at cell level has been proposed by implementing dynamic tariff offers in 3G networks [26] to encourage user to increase traffic in cells with low utilization over the time (i.e. [traffic load]/capacity).

This use case extends this method for utilizing the potential of carbon credit-based customer incentives, based on the self-produced renewable energy ratio and the received signal strength and quality, enabling user engagement through their UE app. The received signal strength and quality for 5G/6G systems are defined in 3GPP TS 38.304 [15] (e.g., Reference Signal Received Power (RSRP) & Reference Signal Received Quality (RSRQ)) and for legacy standards in 3GPP TS 36.304 [16] and 3GPP TS 25.304 [17]. A similar principle is expected to be used in the future 6G standard, but with even greater energy efficiency.

Furthermore, to address the functionality for this use case, some of the procedures and network functions proposed in 3GPP TR 23.700-66 [13] to realize part of the service flow described in Section 3.2.3.3 above.

3.2.3.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.2.3.6-1] The 5G/6G system shall be able to expose information to an Application Function in the network on the (expected) energy related characteristics applicable to the serving site/network (see 3GPP TR 22.883 [1], section 5.8).

NOTE: This information can be used by applications in the Application Function to schedule non time-critical data transfer to or from the UE.

Requirements related to Economic Incentives (ITAV):

[PR.3.2.3.6-2] Carbon footprint improvements caused by a user's behavioural adaptation shall be converted into environmental points.

[PR.3.2.3.6-3] The environmental points and history of monetary gains shall be stored and accumulated in the user's profile.

[PR.3.2.3.6-4] The associated economic benefit for the providers involved and the mechanism for mutually agreed distribution of the economic benefit to the providers and the user shall be

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assessed. (For the users, the economic benefit can take the form of immediate monetary discounts or periodic/monthly monetary rewards through lotteries.)

[PR.3.2.3.6-5] The user interface (e.g., through a dashboard or mobile app/wallet) of the user's device shall be able to present the environmental points collected in time, the history of monetary gains (e.g., discounts or rewards), and the user actions (e.g., change of service parameters, such as modification of video resolution / video quality).

3.3. GROUP GREEN REAL TIME SCHEDULING

3.3.1. UC11: ENERGY PROFILING ON NETWORK DEVICE

3.3.1.1. DESCRIPTION

Progressing towards a new era of AI - enabled wireless networks, AI has been recognized as a key enabler to cope with ever-changing dynamicity of the network. This use case focuses on creating energy profiles for network nodes, in order to achieve energy efficiency, based on context awareness. More precisely, an energy profile will be comprised of a set of rules and act as a descriptive energy-related blueprint that will characterize the device. The main goal is to map an energy profile with an efficiency index, indicating the confidence level of a certain node to execute various tasks in an energy efficient manner. The energy profile and the efficiency index of each node will be tracked over time, to extrapolate underlining energy usage patterns.

3.3.1.2. PRE-CONDITIONS

Firstly, monitoring tools must be installed on each network node, in order to monitor its energy consumption related (directly or indirectly) data accurately. Indicative examples could include computation/communication resources, access to renewable sources and available energy storage, service/network traffic load. An AI-enabled central entity must be established to aggregate the aforementioned data from all nodes. The data will be analyzed to extract context from the raw information exploiting an AI-driven approach, towards creating dynamically adjusted energy profiles for all nodes. The central entity itself should also measure its own energy consumption, extract its own profile and energy efficiency index. Therefore, it is essential to establish new protocols that will enable the communication between these nodes and the central entity. This central entity will reside either at the core or at the edge of the network.

3.3.1.3. SERVICE FLOWS

1) Each node is involved in a task. The energy related data of each node, related to its task, is being monitored and aggregated dynamically.
2) All relevant data is sent to the central entity for analysis (e.g. context-aware AI solutions)
3) The central entity creates an energy profile for each node, considering the aggregated data in conjunction with energy load, historical performance, network traffic, resource consumption.

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4) Each node is assigned an efficiency index to represent the performance in executing tasks based on its energy profile. This index will be updated dynamically.

3.3.1.4. POST- CONDITIONS

1) Energy profiles for all nodes are established and regularly updated.
2) Deployment of actuation mechanisms and relevant protocols to adjust the network configuration of the respective programmable network nodes.
3) Other mechanisms could exploit the extracted energy profiles to perform further optimization leading to more sustainable and energy efficient networks.
4) The central entity sent configuration updates to all nodes enabling them to use less energy.

3.3.1.5. EXISTING FEATURE PARTLY OR FULLY COVERING THE USE CASE FUNCTIONALITY

As described in 3GPP TR 23.700-80 (R18) [7], Network Data Analytics Functions (NWDAFs) work in conjunction with the Analytics Logical Function (AnLF) and the Model Training Logical Function (MTLF) to support core operations for data collection and analysis, as presented in TS 23.288 v17.5.0 (R17) [8]. Utilizing the Edge User Plane Function (eUPF) as specified in TS 23.548 (R18) [9], which applies various policies delivered by the Service Management Function (SMF) through the Core UPF (cUPF), allows for the instantiation of different NWDAFs at associated Mobile Edge Computing (MEC) locations. Furthermore, according to TS 28.554 v18.5.0 (R18) [9], various Key Performance Indicators (KPIs) can be used to estimate energy consumption (EC) (Section 6.7) per Network Function (NF), Network Slice, gNB, and other aspects from data collection to method execution as mentioned above. Finally, considering the system architecture in GS ENI 005 V2.1.1 [19] and the energy saving use case specifications described in GS ENI 001 v3.2.1 [28] then the information of energy consumption for pattern recognition could be used to create the potential profiles for this AI framework.

3.3.1.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

The current UC necessitates the development of a robust AI framework is needed to aggregate and analyse energy-related metrics, extract context-aware energy profiles, and develop a scoring algorithm for energy efficiency indices of nodes. Accurate (near) real-time monitoring tools are essential for continuously updating these profiles and indices. The capability to provide energy information, support third-party resource execution, and schedule services based on energy constraints is needed. Therefore, new interfaces and entities must be developed for reporting resource availability and energy characteristics and scheduling tasks efficiently. The system must handle increasing node numbers and data volumes, be adaptable to various network configurations, and support native AI for seamless integration of energy profiling and management.

[PR.3.3.1.6.1] The 5G/6G Network must report resource availability.

[PR.3.3.1.6.2] The 5G/6G Network must provide energy characteristics of resources.

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3.3.2. UC14: GREEN NETWORK ORCHESTRATION IN THE EDGE

3.3.2.1. DESCRIPTION

For network operators it is imperative to handle and satisfy requests for network resources in a timely manner, which can be difficult when receiving large and partially unexpected requests for expensive and/or limited resources. In 4G and earlier generations, the main resource that was contended for is the radio, but for 5G/6G and next generations, Edge Computing resources are also expected to be scarce and/or expensive (depending on their distribution). This will lead to intensive resource sharing, so sudden request peaks already seen in current generations may have even bigger impacts on the delivery of services and in the overall functioning of the network itself. In this case, instead of having all users admitted to resources equally on a best effort basis and providing all of them equally bad service, it would be beneficial to quantify an objective service quality threshold in resources, energy and CO2e which is satisfiable and allow only enough users until that value reaches (or is predicted to reach) the threshold but no lower. The rest of the users are either prevented access or (if possible) moved to other greener resources. The reasoning comes from the fact that it is better to have some percentage of satisfied users, and the rest disconnected or re-directed to other resources rather than all of them with bad service. A similar reasoning comes from the energy usage and CO2e, it is better to shift the resources to 'greener' locations. The residual heat and energy source of batteries also need to be taken into account. The use case service used in our analysis is crowd uplink video streaming on an event (i.e. concert), as shown in Figure 6.

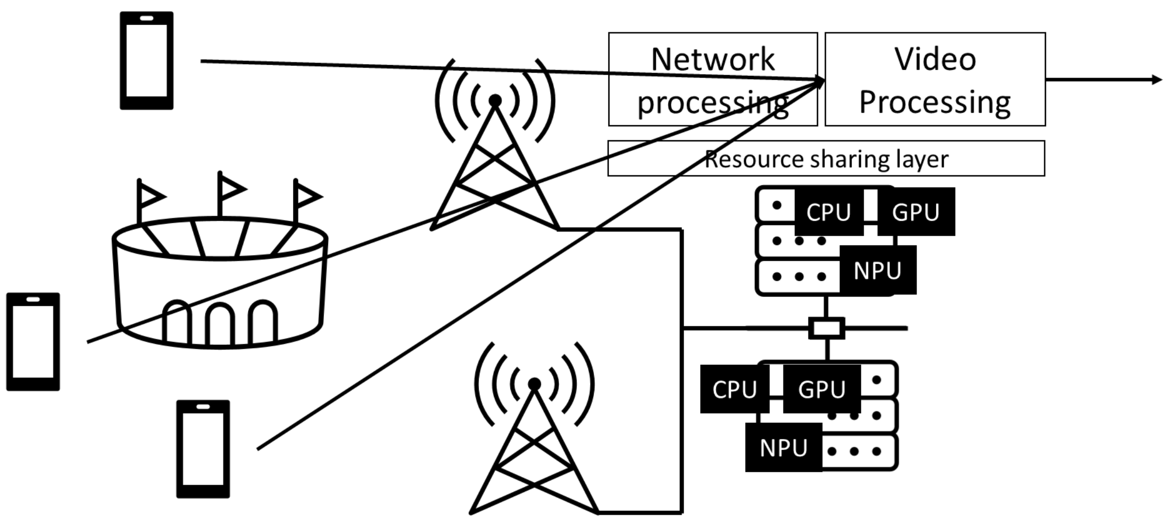

Figure 6: Crowd uplink video streaming on an event (i.e. concert).

An alternative use case is where an AI application is running in the edge to extend the mobile AI usage, where the end user device is not powerful enough. This is particularly interesting as such a function can extend the lifetime of the end-user device.

A second alternative use case can be video rendering in the cloud to facilitate XR glasses. Next to optimizing energy usage and CO2e, congestion in the radio resources is a very common problem in current networks during mass events. It happens when the base stations don't have enough resources to cope with all users, so they get very bad service due to their share being very small. Service prioritizations have been always present, but they can only solve the problem across services – when one is prioritized over the other based on static configuration. Furthermore, admission of traffic only happens on a local level at the base station and omits knowledge about service quality which may end up with positive result but actually be disastrous for a service (i.e. allowing 1kbps for a XR service requiring 150Mbps) unless the service requests guarantee via APIs (i.e. Guaranteed Bitrate). However, throughput bitrates in the network are not the best level to set guarantees at, since service quality may be differently impacted. Hence, a service requiring certain throughput guarantee may be an over dimensioning and more expensive that necessary. One other reason is that QoS characteristics are way too complex for administrators to grasp and contain too many parameters for configuration without a clear service impact. Simpler mechanisms are necessary in order to provide meaningful QoS while keeping resource usage to the maximum and maintaining efficiency.

If we extrapolate this problem to next generation networking and consider extremely distributed edges that are very expensive to deploy and operate, it would be very beneficial for an operator to use the same compute infrastructure for network functions and hosting services whenever possible. Hence, NFs would compete for resources with service processing functions. Although this provides benefits in terms of physical infrastructure costs, it presents a big challenge on the sharing of these resources and their allocation to specific functionalities, as well as the trade-offs relating to performance, energy use and CO2e. However, this issue has not been tackled since they are usually seen as a separate problem because NFs are currently envisioned to run on specific telco clouds which makes things more expensive.

The main problem with a common infrastructure for NFs and service functions is that the impact they have on each other is not clearly understood. In terms of resources, they use the same – CPU, memory, networking, but they need different portions of them at different times and when they both draw from the same resource pool, contention issues may arise and decrease performance. The energy and CO2e aspects of these resources adds another layer of complexity, i.e. CPU and networking do not use the same amount of energy so perhaps from an energy perspective one is cheaper over the other. We would like to study these aspects and develop an algorithm that will continuously monitor and optimize resource or energy use, as well as expose this information to the end-user and/or allow their input in the process.

3.3.2.2. PRE-CONDITIONS

The Edge cloud is made available to third party service providers.

3.3.2.3. SERVICE FLOWS

Standard Edge computing service flows, accompanied with CO2e and EC data

1) The third-party provider requests CO2e and EC prediction data for a certain processing load from one or more Edge Cloud providers.
2) The Edge cloud provider(s) provides the third-party service provider CO2e and EC predication data for certain time intervals.

3) The third-party provider (selects an Edge Cloud provider and) launches containers or alike on the Edge cloud provider's platform using certain time intervals with low CO2e and low EC.

3.3.2.4. POST-CONDITIONS

The third-party service provider receives insight in the energy used and the CO2e.

The third-party service provider has minimal EC usage and CO2e.

3.3.2.5. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.3.2.5.1] The Edge cloud provider shall indicate the energy usage and CO2e expectations to the third-party service providers, so the third party service provider can decide when to launch its containers on the edge cloud.

3.4. GROUP ENERGY EFFICIENCY SERVICES

3.4.1. UC7: CARBON CERTIFICATES AS A SERVICE

3.4.1.1. DESCRIPTION

TS 23.288 [8] presents an estimation of the impact of digital lifestyle on carbon emissions from OKO Institute. It has been estimated that Information and Communication Technology sector is responsible for 0.85 tonnes of CO2e/year and each person is responsible for 12 tonnes of CO2e/year in Germany alone. It is an objective of many national and international bodies such as the UN, the Green Deal in EU, LCA, ISO 14040:2006, to achieve net zero emission by 2050, and it is becoming increasingly important to reduce carbon emission not only at manufacturing, but also at consumer level. In fact, France has passed a new legislation to raise awareness of the large energy consumption and resources required for consuming digital services [9] and since 1 January 2022, French telecom operators are obliged to indicate the carbon footprint of their subscribers on the invoices [10].

Due to the recently introduced regulations that target reduction of carbon emissions, in sectors other than Information and Communication Technology, Carbon Markets have emerged to allow trading of carbon credits and carbon offsets. Carbon markets not only help in adhering to such regulations but simultaneously also provide an opportunity to capitalize on carbon emission reduction. They are also expected to grow and could be worth 90-480$bn by 2050. Currently, 1 carbon credit gives permission to generate 1 ton of Equivalent CO2e and companies can buy carbon credits from regulators. On the other hand, carbon offsets are generated when someone e.g., a company removes carbon from the atmosphere. Companies buy carbon offset from each other. Third-party auditors collect and analyse data (from non-regulated sources) to confirm the validity of carbon credits and carbon offsets [12][11]. A successful example of leveraging carbon markets by consumers is the use of electric vehicles in Germany, where at the end of a fiscal year, the total carbon allowance for a consumer is calculated through calculating the total CO2e of non-electric vehicles and providing equivalent carbon credits to the electric vehicle users as their unused carbon allowance.

Carbon Market related developments underpin this use case, enabling the participation of the telecom networks and Information and Communication Technology sector in general. The consumers of telecom services should get correct and accurate information on the usage of CO2e of their consumed services, which they can use in the Carbon Markets, expected to emerge soon in ICT sector just as in the automotive sector, since the CO2e are under regulatory thresholds. Equipped with the accurate Carbon Usage Report, a consumer can access the Carbon Market to realize benefits generated by their CO2e- service consumption. Note the simple logic that applies here: taken as a whole, all players in the Information and Communication Technology sector contribute to CO2e emission. So long as an individual player, call it P (operator, consumer, etc.), emits considerably less than the average equivalent player, they can realize high benefits. Should, however, all involved players reduce their emission, then P needs a further reduction in emission to realize the same benefits. Note also that, besides consumers, operators also see benefits from making their networks greener (e.g. powered by green energy) – it is their consumers that will generate higher benefits in the Carbon Market, which will attract more users to use their networks, etc. Thus, both Service Consumers and Service Providers have interest in enabling functional Carbon Markets in the Information and Communication Technology sector. Accurate Carbon Usage Reports are a first, but essential step toward this goal.

3.4.1.2. PRE-CONDITIONS

- There is a Carbon Market where carbon emission offsets can be traded.
- The Mobile Network Operator can measure the energy consumption and corresponding equivalent CO2e of each service of each Service Consumer.

3.4.1.3. SERVICE FLOWS

1) The mobile Service Consumer consumes its subscribed services.
2) The Mobile Network Operator accurately measures and collects energy consumption and equivalent CO2e data for the user at the service granularity.
3) The Mobile Network Operator creates the Carbon Usage Report, by aggregating CO2e data over various time intervals for each subscribed service and all services in total for the mobile consumer and appending a description of the methodology used to generate the data create the report.
4) The Mobile Network Operator delivers the aggregated data to the consumer at the end of the concerned time period (e.g., month, quarter, year).
5) The mobile Service Consumer presents their aggregated data, i.e. Carbon Usage Report, to the Carbon Market to get their carbon allowance for the concerned time period.

3.4.1.4. POST-CONDITIONS

Consumed energy and generated equivalent carbon emissions are no longer an externality. They are internalized not only through the possibility for the Service Consumer to monitor their carbon footprint and react accordingly, but the Service Consumer is given a concrete lever that they can use to realize (monetary) gains by consuming their services within the regulatory range. The Service Provider is also rewarded for lowering their carbon footprint, e.g. by attracting more Consumers.

3.4.1.5. EXISTING FEATURES PARTLY OR FULLY COVERING THE USE CASE FUNCTIONALITY

There are efforts in the 5G/6G network, Release 19 precisely – its part named Energy as a Service Criterion (3GPP TS 22.26), to deliver energy consumption data at various granularity levels. However, accuracy of the related solutions available in (3GPP TR 23.700-66 [13]) is questionable, both in the sense of how accurately the nodes attribute the consumption and which nodes can do that. Thus, the main concern here is about accuracy. The current solutions attribute energy consumption by projecting the consumed portion of indirect metrics, e.g. total data volume generated by the service, to the total energy consumed by the node involved in the service delivery. (In essence, although with quite some simplification: 1% of total consumed data volume in a node by a specific service leads to 1% of total consumed energy of the node that is attributed to the service.) Whereas the linearity, inherently present in this approach, might be accurate enough for as simple services as eMBB (although that is never shown or proven), it is certainly highly inaccurate for more complex services of 5G, let alone the envisioned services of 6G, in which energy consumption is a much more complex function of a multitude of service-related parameters. Therefore, enhancements of these solutions are necessary, in our opinion through direct measurements at the element level – as only those can bring the desired accuracy and be future-proof.

3.4.1.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.4.1.6-1] The 6G network shall provide a Carbon Usage Report of the energy consumption and equivalent CO2e the subscriber is accountable for along with the method/formula used to calculate the Energy Consumption and equivalent CO2e.

[PR.3.4.1.6-2] The provided Carbon Usage Report and the used methodology shall stand all expected technological scrutiny (e.g. methodology is not sound for the service in question of the Service Consumer).

3.4.2. UC8: CARBON EMISSION CHARGING

3.4.2.1. DESCRIPTION

The challenge of becoming carbon neutral within the ICT sector requires concrete actions. To devise solutions in this direction, full transparency of the impacts on the carbon footprint throughout the entire end-to-end chain is required, which translates to a need for measuring and attributing energy usage and carbon footprint.

Therefore, this use case relies on a series of energy measurements, interoperability between different network domains, and a deeper understanding of the impact of different network nodes/functions on the carbon emission and energy usage throughout the end-to-end chain to unravel the E2E energy consumption (including networks, applications, and devices), as well as the effects of particular settings have on energy consumption (e.g., data route chosen, the energy mix where the service is running as well as the engaged network domains). We conjecture that this necessitates flexible, novel architectural patterns, new modules and interfaces with additional procedures for the overall ICT service measurement, and per-domain energy usage and carbon footprint exposure mechanisms.

Next to measuring and reporting of the ecodata involved, the MNO should also be able to charge for the energy consumption and CO2e.

3.4.2.2. PRE-CONDITIONS

- The MNO is able to measure the energy consumption and CO2 emission of each service execution of each service consumer

3.4.2.3. SERVICE FLOWS

1) A service consumer consumes a service delivered by an MNO.
2) The MNO collects charging information on how much energy consumption and CO2 emissions is attributed to the service provided to the service consumer from various network elements / network domains along the service chain.
3) The charging information from the various network elements / network domains is stored.

3.4.2.4. POST-CONDITIONS

The service consumer is attributed for his/her energy consumption and CO2 emission. The MNO can e.g. use this information to incentivize the service consumer (out of scope of 3GPP).

3.4.2.5. EXISTING FEATURES PARTLY OR FULLY COVERING THE USE CASE FUNCTIONALITY

In Release 19 the "5G/6G system shall provide a mechanism to include Energy related information as part of charging information”. It is not clear whether CO2 emission information can be part of charging information. Furthermore, accuracy of the related measurements is questionable, both in the sense of how accurately the nodes attribute the consumption and which nodes are capable of doing that.

3.4.2.6. POTENTIAL NEW REQUIREMENTS TO SUPPORT THE USE CASE

[PR.3.4.2.6-1] The mobile network shall be able to collect information on energy consumption and carbon emission that are attributed to the subscriber as part of charging information.

4. INITIAL CONSOLIDATED REQUIREMENTS

This section bundles and consolidates the requirements of the EXIGENCE Use Cases. The requirements are bundled by domain, with the exception for environmental and economics. A cross-reference table is included to facilitate tracing back the requirements to the Use Cases, as shown in Table 2.

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	UC1 - Media streaming carbon footprint transparency	UC2 - Digital Sobriety	UC3 - Economic Incentives for Digital Sobriety	UC4 - Behavioral Incentive for Digital Sobriety	UC5 - Watch TV over 5G	UC6 - Any Service Provider	UC9 - Physical Security	UC13 - Carbon-aware pre-population of CDN nodes	UC15 - Green social media and e-mail Content Download	UC10 - Carbon-aware AI service provisioning and control	UC11 – Energy profiling on Network Device	UC14 - Green Network Orchestration in the edge	UC7 - Carbon Certificates as a Service	UC8 - Dynamic EC Control as a Service
PR.UE.1	X				X									
PR.UE.2		X		X					X					
PR.N.1a	X													
PR.N.1b													X	
PR.N.1c														X
PR.N.1d						X								
PR.N.1e						X								
PR.N.2									X					
PR.N.6					X									
PR.N.8												X		
PR.N.9							X					X		
PR.N.10								X						
PR.N.11								X						
PR.N.12								X						
PR.N.13								X						
PR.N.14										X				
PR.N.15										X				
PR.N.16										X				
PR.N.17							X							
PR.N.18							X							
PR.N.19							X							
PR.N.20							X							
PR.N.21							X							
PR.N.22													X	
PR.N.23											X			
PR.N.24											X			
PR.SP.1						X								
PR.SP.2		X												
PR.SP.3								X						
PR.ES.1								X						

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PR.EP.1			X	X					X					
PR.EP.2			X						X					
PR.EC.1			X						X					

Table 2: Cross reference table is included to facilitate tracing back the requirements to the use cases.

The requirements described in this section are initial and focus on inter domain functions; west and east bound interfaces, and on intra domain requirements; the south bound interfaces to make a uniform abstraction level. More work is needed for the consolidated requirements, this will be included in D1.4.

4.1. USER EQUIPMENT

[PR.UE.1] The display device shall be able to present the total energy usage and CO2e data including its own to the end user. [PR.3.1.1.6-2], [PR.3.1.5.6-4]

[PR.UE.2]: The user interface (e.g., through a dashboard or mobile app/wallet) of the user's device shall be able to present the environmental points collected in time, comparative statistics of the collected points, the user’s social rewards (e.g., graphics and awarded badges), and the user actions (e.g., change of service parameters, such as modification of video resolution / video quality). [[PR.3.1.3.6-4], [PR.3.1.4.6-3], [PR.3.2.3.6-5]

4.2. NETWORK DOMAIN

4.2.1. EXCHANGE OF ENERGY USAGE

[PR.N.1a] The 5G/6G network shall be able to provide exchange of energy usage and CO2e data for each traffic flow to the end user equipment. [PR.3.1.1.6-1]

[PR.N.1b] The 5G/6G network shall provide a Carbon Usage Report of the energy consumption and equivalent CO2e the subscriber is accountable for along with the method/formula used to calculate the energy consumption and equivalent CO2e. [PR.3.4.1.6-1]

[PR.N.1c] The 5G/6G network shall be able to collect information on energy consumption and carbon emission that are attributed to the subscriber as part of charging information (see 3GPP TR 22.883 PR.5.3.6-1). [PR.3.4.2.6-1]

[PR.N.1d] The 5G/6G network shall be able to provide exchange of energy usage and CO2e data for each traffic flow to the next service and previous domain in the end-to-end chain. [PR.3.1.6.6-1]

[PR.N.1e] The 5G network shall be able to provide exposure of energy consumption data and CO2e data for a specific service data flow, to an Application Function (see 3GPP TR 22.883 PR 5.5.6-1).

[PR.N.2] The 5G/6G system shall be able to expose information to an Application Function in the network on the (expected) energy related characteristics applicable to the serving site/network (see 3GPP TR 22.883 PR 5.8.6-1). [PR.3.2.3.6-1]

[PR.N.6] The 5G/6G phone hotspot shall be able to provide exchange of Energy usage and CO2e data for each traffic flow. [PR.3.1.5.6-2]

4.2.2. RUNNING THIRD PARTY CONTAINERS

[PR.N.8] The 5G/6G system (Edge cloud part) shall indicate the energy usage and CO2e expectations to the third party service providers, so the third party service provider can decide when to launch it containers in the Edge cloud. [PR.3.3.2.5.1]

[PR.N.9] The 5G/6G network shall provide time-continuous energy consumption measurement of a specific software process or container running in the virtualized environment (i.e., the use case owner/customer specifies which are these processes). [PR.3.1.7.6-1]

4.2.3. TIME-DELAYED SERVICES NETWORK AND COMPUTE

[PR.N.10] The 5G/6G network and compute service providers shall provide an interface to query time intervals for providing time-delayed services for ecodata. Parameters: time period in which time interval should fall (e.g., up to release date), capacity available, EC and CO2e footprint of service provision. [PR.3.2.2.6-2a]

4.2.4. RESERVATION FOR TIME-DELAYED SERVICE IN NETWORK AND COMPUTE

[PR.N.11] The 5G/6G network and compute service providers shall provide an interface to reserve one or more previously queried time intervals. Parameters: (identifier for) time interval and requested capacity. [PR.3.2.2.6-2b]

[PR.N.12] The 5G/6G network and compute service providers shall provide an interface to consume services with reference to an earlier reserved time interval. [PR.3.2.2.6-2c]

[PR.N.13] The 5G/6G network and compute service providers shall provide an interface to notify changes to an earlier agreed upon schedule and offering compute / communication service providers to adjust their reservations accordingly. [PR.3.2.2.6-2~~e~~d]

4.2.5. INTEGRATION WITH THIRD-PARTY PROVIDERS

[PR.N.14] 5G/6G service providers shall provide an interface to query information regarding resource (including computation, communication, memory, memory bandwidth) availability and energy availability (including information regarding the amount, sources, types, and CO2 per KWH) to third party service providers. [PR.3.2.1.6-1a]

[PR.N.15] 5G/6G service providers shall provide an interface to execute AI tasks to third party service providers. [PR.3.2.1.6-1b]

[PR.N.16] 5G/6G service providers and third-party service provider shall be able to schedule AI tasks on available resources in an energy and/or CO2 efficient manner. [PR.3.2.1.6-2]

4.2.6. DETAILED NETWORK REQUIREMENTS

[PR.N.17] The 5G/6G network shall provide time-continuous energy consumption measurement for a specific HW component (PNF). [PR.3.1.7.6-2]

[PR.N.18] The 5G/6G Network shall be able to measure:

- CPU and GPU utilization.
- Memory (RAM) utilization.
- Measurement results shall be synchronized with other measurements (energy consumption, computing resources utilization) on the common timescale. [PR.3.1.7.6-5]

[PR.N.19] The 5G/6G network shall provide means for accessing ecodata:

- Access ecodata in (near) real time.
- Download ecodata for larger time-period.
- user shall be able to select ecodata of interest. [PR.3.1.7.6-6]

[PR.N.20] The 5G/6G Network shall provide information regarding the optimal (pre-defined) network slice available in an energy and/or CO2 efficient manner, based on the (vertical) application requirements. [PR.3.1.7.6-7]

[PR.N.21] The 5G/6G network shall provide information regarding the optimal (5G/6G) radio access settings in an energy and/or CO2 efficient manner (MIMO settings, throughput requirements, latency requirements), based on the current (vertical) application requirements. Applies to environments where network settings can be updated during the operation. [PR.3.1.7.6-8]

[PR.N.22] The 5G/6G network shall provide Carbon Usage Report and the used methodology shall stand all possible technological scrutiny (e.g. methodology is not sound for the service in question of the Service Consumer). [PR.3.4.1.6-2]

[PR.N.23] The 5G/6G Network must report resource availability. [PR.3.3.1.6.1]

[PR.N.24] The 5G/6G Network must provide energy characteristics of resources. [PR.3.3.1.6.2]

4.3. APPLICATION SERVICE PROVIDERS

[PR.SP.1] All domains shall be able to provide exchange of energy usage and CO2e data for each traffic flow to the next service and previous domain in the end-to-end chain when requested. [PR.3.1.6.6-2]

[PR.SP.2] The OTT platform shall be able to provide an eco-mode and a gold quality mode of content. Where the eco mode is provide good enough quality to the end user and the gold quality mode is providing the better-quality mode to the end user, which can be a higher resolution at a higher bitrate or lower latency. [PR.3.1.2.6-1]

[PR.SP.3] CDN service operator shall provide an interface for green content replication. Parameters: content to be replicated, regions/PoP to replicate over, release date by which content replication should be complete (and at which content should be enabled). [PR.3.2.2.6-1]

In addition. section 4.2.3 TIME-DELAYED SERVICES NETWORK AND COMPUTE cover several Service provider requirements

4.4. ENERGY SUPPLIERS

[PR.ES.1] Energy suppliers shall provide an interface to query for time intervals with a (favourable) energy mix. Parameters: time bounds, maximum CO2e impact. Alternatively, energy suppliers send regular DR signals to subscribed users (i.e., compute / communication service providers). [PR.3.2.2.6-3]

4.5. ENVIRONMENTAL POINTS

[PR.EP.1] Carbon footprint improvements caused by a user's behavioural adaptation shall be converted into environmental points. [PR.3.1.3.6-1], [PR.3.2.3.6-2]

[PR.EP.2] The environmental points and history of monetary gains shall be stored and accumulated in the user's profile. [PR.3.1.3.6-2], [PR.3.2.3.6-3]

4.6. ECONOMIC

[PR.EC.1] The associated economic benefit information for the providers involved and the mechanism for mutually agreed distribution of the economic benefit to the providers and the user shall be provided. (For the users, the economic benefit can take the form of immediate monetary discounts or periodic/monthly monetary rewards through lotteries.) [PR.3.1.3.6-3], [PR.3.2.3.6-4]

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5. CONCLUSION

This document presents the findings from a thorough analysis of various use cases, which have enabled the identification of key challenges and opportunities faced by stakeholders in managing their environmental impacts.

Through a methodological approach specific scenario, service flows, and postconditions, have been defined, providing a clear understanding of existing technological solutions and the additional requirements necessary for comprehensive support in measuring energy consumption and carbon footprint.

The insights gained from this phase will serve as a crucial foundation for developing effective methods to monitor energy consumption and gather measurement data across the ICT ecosystem. This will enable us to implement strategies that promote energy efficiency and carbon neutrality, aligning with the overarching goals of the Exigence project.

In conclusion, the work presented in this document not only addresses the immediate needs of the project but also sets the stage for future advancements in sustainable ICT practices. Continued collaboration among stakeholders will be vital to ensure the successful implementation of the identified use cases and requirements, ultimately contributing to a more energy-efficient and environmentally responsible ICT sector.

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