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D1.1 FUTURE ENERGY ECOSYSTEM

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DELIVERABLE INFORMATION	
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1 INTRODUCTION

1.1 OBJECTIVES OF THE DELIVERABLE

This deliverable captures the work performed by T1.1, on Future Energy Ecosystems. The goal of the task, and consequently of the deliverable, is to describe the ecosystem in which the use cases will be introduced, and the effect that these will create on a working environment. This means, listing and describing the stakeholders, the role they play in this ecosystem, the interplay of energy dependencies and business relations between them, as well as presenting the value that these use cases will bring to each stakeholder, as well as the larger ecosystem.

The analysis was performed by framing a general energy ecosystem framework related to a generic ICT service delivery domain to a set of suitably selected use cases from the Exigence project. This approach enabled the identification of concrete information exchanges which lead to a reduction in the overall energy consumption. Particular attention is given to the information related to energy measurements and provisioning of incentives, as these are the main focus of the project.

1.2 STRUCTURE OF THE DELIVERABLE

This deliverable is structured as follows. It starts in Section 1.3 with a definition of key terms and concepts. Section 1.4 describes the role model the deliverable is based on. It is a generic value network of a future energy ecosystem. The value network includes roles from the domain of 6G and the broader ICT sector, as well as roles from the domain of Smart Grids which we found to be relevant and important for the future ecosystem. Section 1.5 discusses the service and money flows among the different roles, keeping in mind that the identified stakeholders may interact indirectly with each other by means of the energy dependencies. Section 1.6 describes the methodology used to identify the value created by each of the use cases presented in D1.2. It is an application of the Cambridge Value Mapping Tool [1] on a set use cases, whereby six value types (e.g. "captured", "missed", etc.) are identified for each.

Section 2 of the deliverable is devoted to the analysis of use cases. Fourteen use cases in total are discussed. In the course of work, however, a high degree of similarity within a group of use cases is observed and these use cases are therefore presented as a single group. The analysis of this group is in Section 2.1. Sections 2.2, 2.3, 2.4, 2.5, 2.6 analyse the remaining use cases, one by one.

Section 3 concludes with a summary of the main findings.

1.3 KEY TERMS AND CONCEPTS

Energy ecosystem: A set of entities, along with their interactions, that deliver and consume services to one another, and as an unavoidable consequence of that also consume energy for which other parties are made responsible, and billed.

Stakeholder: An individual entity within the energy ecosystem.

Value network: A graph that encodes business exchanges within an ecosystem.

Other terms used in the document are introduced and defined as they appear in the document.

1.4 ROLE MODEL BASED ON 3GPP

1.4.1 GENERIC FUTURE ENERGY ECOSYSTEM

Based on the 3GPP actor role model [2][3] and its extensions performed in the 5GPPP working groups and projects [3]–[9], in this subsection, we present a generic value network of future energy ecosystem. Please note, this value network includes roles from the domain of 6G and the broader ICT sector, as well as roles from the domain of Smart Grids which are relevant and important for the future ecosystem.

It should also be noted that the value network of smart energy grids is rather richer than its subset considered here, since it includes several roles relating to wholesale market, energy transmission, energy distribution, achievement of balancing etc; e.g. see Deliverable 5.1 of EU-funded H2020 project iFLEX [10]. At the same time, the operation of the energy market itself is rather complex and dynamic, with e.g. time-varying prices in the wholesale market, often determined on a daily basis. In this case, we are only interested in the interplay between the 6G and the energy ecosystems. Hence, we only focus on the roles and stakeholders of the latter that interact with those of the former and thus "hide" from them the underlying details of the energy ecosystem.

The left part of the value network presented in Figure 1 depicts the main actor roles that are relevant for the delivery of 6G-enabled vertical services across multiple sectors, such as media, industry 4.0, etc. Considering different use cases, these roles may be adopted by different stakeholder for the co-creation of value. Depending on the use case, it is also possible that only a subset of these roles may be relevant. The right part of the value network presented in Figure 1 depicts the actor roles related to the smart grid energy market, to energy efficiency services and environmental policies.

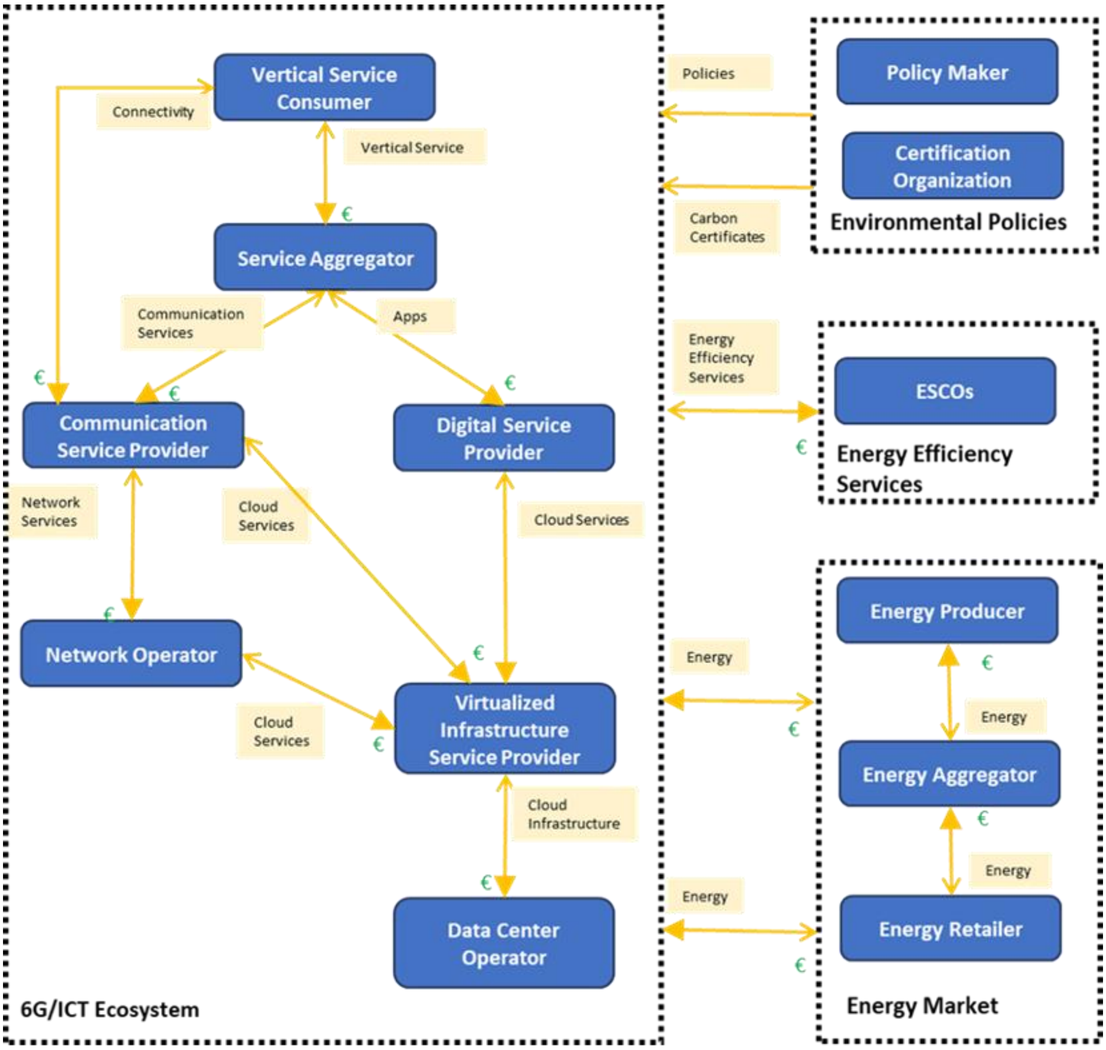

Figure 1: Generic value network

As shown in Figure 1, the actor roles are separated in parts. Each role may have business relationships with other roles within the same layer or with other layers.

The descriptions of the different roles for the 6G/ICT ecosystem part are provided below:

- **Vertical Service Consumer (VSC):** This role refers to the consumer of the end-to-end vertical service that may be a group of individual end users or an enterprise.
- **Service Aggregator:** A Service Aggregator bundles the communication services of Communication Service Providers (CSPs) with the applications of Digital Service Providers (DSPs) into one service offering towards Virtualization Infrastructure Service Provider (VISPs). This role realizes the concept of the "one-stop shop." This role can be adopted by a stakeholder that also adopts one of CSP or DSP roles or by another entity that focuses on integrating the services and delivering complete solutions to the customer.
- **Communication Service Provider (CSP):** A Communication Service Provider offers communication services (voice, messaging, multimedia, V2X, IoT, etc.) to VSC (end users and enterprises) relying and building on the network services offered by a network operator. Usually, a stakeholder that adopts the communication service provider role also adopts the network operator role (described below).

- **Digital Service Provider (DSP):** This role focuses on the provisioning of online application and services that are consumed by VSCs. A DSP is usually specialized on applications that are specific to certain vertical sectors such as media, automotive, industry 4.0, etc., and require to be deployed on the edge of the network and consume computational or storage resources.
- **Network Operator:** The Network Operator maintains and operates its network, offering network services (e.g. connectivity, value-added services, etc.), across part or all segments of the network (i.e., access, transport, core, backbone). Such services may be offered in the form of Network Slice as a Service (NSaaS) or Network as a Service (NaaS).
- **Virtualization Infrastructure Service Provider (VISP):** Provides virtualized infrastructure services, by utilizing the physical infrastructure offered by the Data Centre Operators. A VISP may offer services ranging from multi-purpose VMs/Containers to complete virtualised infrastructure management solutions on compute, storage, network, IoT, etc. VISPs may offer their virtualized infrastructure services to Network Operators or to the roles of the service layer.
- **Data Centre Operator:** This role maintains and offers physical infrastructure that includes computational, storage, networking or IoT resources.

In certain use cases, actor roles that belong to the "Supplier" side may be relevant for consideration. For instance, if we consider a use case where "green certificates" are issued for devices, equipment, software components or services, appropriate supplier roles should be included in the value network. Examples of such a role are the End-user Equipment Supplier, Application Hardware/Software Supplier, Network Hardware/Software Supplier, etc.

Next, we elaborate on the roles of the remaining parts of the network, namely the energy market, energy efficiency services and environmental policies parts:

- **Policy Maker:** This role sets long-term goals for energy policy, including sustainability targets and carbon reduction goals. It also creates incentives for renewable energy adoption and energy efficiency improvements.
- **Certification Organization:** This role captures organizations such as regulatory bodies, carbon standards organizations, etc., who issue carbon certificates that can be traded in carbon markets. Although such certificates are important as an incentive mechanism too, there are several other mechanisms of smart energy grids that can lead to the reduction of energy consumption and CO_2 emissions. Moreover, until now renewable energy certificates have been used to offset (on a yearly basis) the use of electricity from the grid. However, this does not consider factors such as time and location, and as a result, companies are not adequately discouraged from using energy generated in part or in full, from fossil fuels, drawn from the local grid where their facilities operate. Unlike offsetting renewable energy usage on a yearly or monthly basis, the 24/7 Carbon-Free Energy (CFE) initiative [11] targets to offset green energy usage on an hourly basis, thus shifting towards time and location-based energy procurement. The 24/7 CFE [12] initiative was launched by UN-Energy and Sustainable Energy for All (SEforALL) and has received commitments from over 140 participants that includes major corporations and national governments. 24/7 CFE is considered more effective than offsetting carbon emissions based on certificates. Voluntary Carbon

Standards (VCS), Gold Standard, Climate Action Reserve (CAR), and American Carbon Registry (ACR) constitute frameworks for the certification and validation of carbon offset projects. The VCS, managed by Verra, is the most widely adopted global standard, offering robust methodologies to quantify and verify carbon reductions across various sectors [13]. The Gold Standard, established by environmental NGOs, emphasizes sustainable development by incorporating social and environmental co-benefits alongside emission reductions [14]. CAR, a North American-focused registry, supports high-quality offset projects with stringent verification processes tailored to regional policies [15]. Similarly, ACR provides a rigorous framework to quantify, monitor, and certify emission reductions, with a strong emphasis on compliance-grade projects. Together, these standards ensure the credibility, transparency, and environmental integrity of carbon offset initiatives, fostering trust among stakeholders and aligning with global climate goals [16].

- **Energy Service Companies (ESCOs):** This role offers services to improve energy efficiency for both consumers and enterprises and implements energy-saving projects, often with performance-based contracts [17]. ESCOs differ from the traditional energy consultants or equipment suppliers due to the fact that they can also finance or arrange financing for the operation, while their remuneration is directly tied to the energy savings achieved. Related activities may involve energy analysis and audits, energy management, maintenance and operation, monitoring and evaluation of savings, etc. For example, a green orchestration service provider may offer green orchestration to a network operator (e.g. energy efficient cooling systems and low-power servers and switches), or to a household (e.g. automatically switching lights at certain times).
- **Energy Producer:** This role may include traditional power plants as well as renewable energy sources such as solar panels, wind turbines, and biogas plants, possibly located close to the point of consumption. Considering the future 6G energy market, it is important to capture stakeholders that are part of the 6G and ICT ecosystem that, concurrently, may also be producers of renewable energy, thus contributing to the energy market too.
- **Energy Aggregator:** This role combines the energy production or consumption of multiple small producers or consumers to participate in the energy market as a single entity. As the Energy Producer may provide information about the energy mix, the Energy Aggregator may provide demand response services and thus enhance the flexibility of the grid to the benefit of all stakeholders. Indeed, due to the finer time granularity of 24/7 CFE mentioned above, reaching such an objective is a more difficult target compared to yearly offsetting renewable energy certificates. One approach to facilitate 24/7 CFE is to introduce feedback from the energy producers and aggregators to the 6G and ICT stakeholders that provides them with information concerning the time of day that renewable energy resources are not available, and thus to reduce or shift their energy demand by means of appropriate incentive schemes. Alternatively, the Energy Aggregator can act as a Demand Response (DR) Aggregator, receive the relevant DR signals from the Energy Producer and provide related feedback to the 6G and ICT stakeholders, on the flexibility required therefrom and the relevant incentives.
- **Energy Retailer:** This role sells electricity to consumers, providing billing, customer service, and often offering energy management services and/or retail tariffs that

encourage efficient energy use; such tariffs although affected by the highly varying wholesale prices, are usually much less dynamic or even fixed for long time-periods, thus "hiding" the volatility of the wholesale market from retail customers.

1.5 ENERGY DEPENDENCIES

A 6G-enabled ICT service may involve several stakeholders, each adopting one or multiple actor roles. According to each case, the stakeholders adopt different actor roles on the value network to contribute their part on the delivery of the end-to-end service. Indicative examples of stakeholders are YouTube and Netflix, which are Content Providers of video streaming services. They adopt the roles of Digital Service Provider and Service Aggregator for offering the video streaming service and delivering the service to end users respectively. While the value network presented in Figure 1 identifies the service and money flows among the different roles, these stakeholders interact indirectly with each other by means of the energy dependencies; that is, the effect of an energy-optimization decision of one stakeholder to the energy consumption of the other role.

It should be emphasized that the energy dependencies may not always follow the business relationships. In fact, the energy consumption depends on the flow of traffic across the different domains, but it is also affected by who is making the decisions on when and at which quality level the traffic will flow. The actor roles depicted in Figure 1, can be grouped or split based on the roles stakeholders take over. For example, a Content Provider can undertake both the role of a Service Aggregator and of a DSP. The Content Delivery Network (CDN) can share the roles of CSP and Network Operator with a Network Service Provider (NSP). The generic graphs can be transformed into scenario-specific ones, depending for example if a scenario is end-user initiated or content-provider initiated, leading to important differences in the connections between the different stakeholders.

To better highlight this, we can consider a scenario where a Content Provider decides to replicate at the edge of the network high-definition video content during peak hours. This decision increases the data traffic significantly across the network, leading to higher energy consumption in the data centres, network infrastructure, and end-user devices involved. The cost of energy during these hours may be higher and may also be less environmentally friendly because energy units may be coming from sources with high CO_2 emissions. Conversely, if the Content Provider decides (i.e. Content-Provider initiated scenario), based on appropriate incentive mechanisms, to deliver the content during off-peak hours, the patterns of energy consumption, the energy cost and CO_2 emissions of both the CDN and the NSP roles would be affected accordingly. More precisely, the decision of the Content Provider on when and where to push the videos affects the energy consumption of the CDN that will distribute the content and of the Content Hosts at the source and destination(s) of the content at the central or edge cloud.

On the other hand, the decision of content distribution may also depend on the decision of End Users (consumers) on when and at which quality level a piece of content will be streamed (i.e. End User initiated scenario). The decision of End Users on when and at which quality level to consume a video content affects the energy consumption of the NSP that will deliver the video at the end device, of the CDN that may have to fetch the video from other remote regions where the video is hosted, and of the Content Host because the content will have to be hosted close to the End User. Again, under the appropriate incentives (i.e., economic or behaviour-based), End Users can be encouraged to modify their behaviour, making more energy efficient and carbon aware choices. For example, economic End User incentives may include monetary discounts or monetary rewards through participation in lotteries. On the other hand, behavioural End User incentives can be equally important, and may include social rewards (e.g., appraisals) for contributing to the reduction of energy consumption and CO_2 emissions in a certain time interval.

Considering both scenarios, across the chain of dependencies, the amount of energy that should be provided by the Energy Supplier depends on the operation level of the NSP, the CDN and the Content Host, which depends on the decisions of End Users and of the Content Provider as elaborated above.

When considering the application of incentive mechanisms, it is imperative to consider the interplay of business relationships and energy dependencies, because they both strongly determine the types of mechanisms that can possibly be applied among different stakeholders. For example, a chain of incentives may be needed (in case there is not a direct dependency), in order to influence the energy-related decision making of a chain of stakeholders starting from content providers, network operators, and service providers and ending to end users, according to each case.

1.6 VALUE METHODOLOGY

The successful application of a use case in a working ecosystem is expected to benefit the stakeholders significantly. However, Exigence has pushed further to expand the understanding of the effects these use cases will have - both positive and negative - in the ecosystem, per stakeholder. Failing to consider the impact per stakeholder can result in a very uneven distribution of effects, which may lead to great resistance to further development and implementation of the use cases. Having those insights beforehand can allow the use cases to be modified in ways that the value brought by them will spread along the value chain, making implementation easier and much more favourable.

The Cambridge Value Mapping Tool [1] is a tool originally designed as a structured approach for developing sustainable business models. This method describes 6 types of values, which are then sought per stakeholder within a given activity. These are **value** (1) **captured** (i.e., value that the use case is already bringing), (2) **missed** (i.e., value given for which there is no return), (3) **destroyed** (i.e., undesired value, externalities), (4) **surplus** (i.e., excess value over what is desired), (5) **absence** (i.e., desired value which is not delivered), and (6) **opportunity**, which relates to the new value discovered after the application of this methodology. This methodology aims to maximise the desired/minimise the undesired values, think of underlying opportunities within the ecosystem, and look to create Win-Win scenarios.

This methodology was applied to Exigence's UCs, benefiting from the structured approach to identify the opportunities and benefits per stakeholder, but also the risks and challenges which were used as input for iteration in the use cases. This way, the detrimental effects can be minimised, while maximising the overall benefits and opportunities brought by these throughout the stakeholders.

2 USE CASES

2.1 GROUP1: ENERGY & CARBON MEASUREMENTS AND INCENTIVISATION

2.1.1 OVERVIEW OF THE USE CASE GROUP

As explained above, the approach taken in this deliverable is to perform ecosystem analysis, i.e. identify stakeholders in the energy ecosystem and evaluate interdependencies among them, on a number of selected use cases. In the course of work, a total of fourteen use cases have been created. As some use cases coexist in the same ecosystem and the identified stakeholders and their roles are the same, the following ecosystem analysis was conducted as a group (named simply "Group 1"). Yet, minor differences among the individual use cases in this group from the general group descriptions are reported in the subsections below, where these deviations are spotted.

In what follows, before starting reporting on the general findings about the energy ecosystem that pertain to Group 1, brief descriptions of the individual use cases in this group are in order. The detailed descriptions of the use cases (e.g. the exact service flows, etc.) can be found in the accompanying deliverable D1.2.

UC1: Media streaming carbon footprint transparency. This use case proposes the inclusion of metrics such as "Instant Carbon Footprint" or "Total Daily CO_2" 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.

UC2: Digital Sobriety. This use case builds on the information provided by 'Media Streaming Carbon Footprint Transparency' (UC1), 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. More concretely, as the media is delivered to the user, alternative modalities of that delivery (e.g. lower video resolution, lower data rate) are displayed to the user, along with their potential impact on carbon footprint. The user can select one of those alternatives and thus change the carbon profile of the respective service.

UC3: Economic Incentives for Digital Sobriety. Building further on UC2 (and thus also on UC1), this use case aims at devising and applying effective ways in which the user can be properly motivated by means of economic incentives to actually select one of the offered alternatives and thus reduce the carbon footprint of the ongoing service session. For example, the selection of alternatives can be bound to the collection of "environmental points", which are accumulated on a monthly basis and at the end of the month the user participates in a lottery where the expected benefit of the user is proportional to their points.

UC4: Behavioural Incentives for Digital Sobriety. Similar to UC3, this use case also devises and applies effective ways to motivate users to decrease the carbon footprint for which they are responsible. The incentives used in this use case are just in nature a bit different than those in UC3, as, for example, 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 users the relative "performance" percentile they are in, according to their achieved CO_2 footprint improvements e.g. in the present week.

UC5: Watch TV over 5G. This use case postulates the inclusion of metrics to indicate the carbon footprint of a service session, similar to UC1. The differences between the two use cases are in the details about the connectivity types available to the user.

UC6: Any Service Provider. Whereas UC1 visualises the energy consumption and carbon footprint data to the user, this use case postulates that such an action can be useful if the information is delivered and presented to all service providers included in the service delivery chain.

UC7: Carbon certificates as a service. This use case assumes the existence of a carbon trading market, in which carbon emissions can be traded. Users of telco services receive at the end of billing periods their carbon usage report, which indicates their total carbon footprint over a period of time. With that carbon certificate, they access the carbon market and get compensated for their unused carbon or purchase back the carbon emitted in excess of their allowance.

UC8: Carbon emission charging. This use case postulates that the carbon emission collection and, potentially, charging will be of critical importance in the future networks. Precise energy measurements, availability of the used energy mix in the network (and accurate attribution of the used types of energy to the services delivered in network), interoperability between different network domains, etc. are the key constituents of this use case.

UC11: Energy profiling on network nodes. In this use case, energy-related data of each node in the infrastructure is being monitored and aggregated dynamically. The data is then analysed in order to create an energy profile for each node. Each node is assigned an efficiency index to represent the performance in executing tasks based on its energy profile. This index is updated dynamically. Taken together, all these details set up the stage for optimized distribution of load in the network.

In summary, the use cases that form group 1 are either (1) building and expanding on certain capabilities described by other UCs within the group, or (2) providing essential information that can be used by other UCs in this group.

Thus, UC1 enables the measurement and data collection of the energy consumption and CO_2 footprint associated with a particular service along the chain. Then, UC2 uses this information and presents it to the user, together with the ability to act upon it. UC3 and UC4 describe the economic and behavioural incentives that can support these changes in the ecosystem, while UC7 supports these incentives by means of a carbon trading market. UC5 expands UC1 towards a different set of scenarios and devices, while UC6 also expands on the capabilities introduced by UC1, but from the perspective of service providers. Lastly, UC11 provides information on how green different network nodes are, which is highly beneficial information for the delivery of the use cases described above.

It is clear that these use cases are deployed within a similar ecosystem, containing similar stakeholders playing similar roles. Therefore, the analyses were performed for the entire ecosystem instead of on a per-use case basis.

2.1.2 ECOSYSTEM – STAKEHOLDER IDENTIFICATION AND ROLES

The ecosystem which encompasses the use cases from this group, depicts a standard flow of information within the communications industry aimed at delivering a particular service to a user.

As the use cases that comprise this group share a common ecosystem, the following analysis of the stakeholders and their roles applies to all. Additionally, the following section covers all other stakeholders or considerations for those use cases that involve aspects beyond the previously described ecosystem.

Stakeholders

- **End Users**: Individuals using a device for consuming video streaming or conferencing services.
- **Content Providers**: Providers of video streaming, "over-the-top" platforms, and/or videoconferencing services.
- **(CDN) Content Distribution Network:** Distributes the videos of the Content Provider "closer" to End Users at the edge of the network (e.g., Amazon CloudFront).
- **Content Host**: Provides services for the storage of videos at the cloud and edge, and other services such as video transcoding, etc (e.g., AWS).
- **(NSP) Network Service Provider**: An entity providing wireless and fixed internet access to the End Users for consuming the content. An NSP may also host content in their network in a partnership with the content provider (e.g., Telefonica).
- **Energy Supplier:** The energy supplier (typically, more than one) sells electricity to all stakeholders maintaining network or cloud infrastructure, as well as the end-user devices. Provides demand response services and enhances the flexibility of the grid, and tariffs that promote energy efficiency in the ecosystem (e.g., Engie).

Roles

Figure 2 demonstrates the future ecosystem value network instance for the "Media streaming carbon footprint transparency" use case. The stakeholders adopt different actor roles on the value network to contribute their part in the delivery of the end-to-end service of this use case.

- The **End User** adopts the role of **Vertical Service Consumer**. For use cases 1-5, the end user is the consumer and plays a key role in triggering and driving the energy consumption reductions throughout the chain, either through transparency and visualisation of the associated impacts (UC 1 & 5), enabling the user to act upon this information (UC 2), or through responding to the incentives described by UC 3, 4, 7 and 8.
  In UCs 6 and 11 the consumer does not play an important role, as these use cases target the interplay of the stakeholders upstream in the service chain. Thus, the stakeholder within this already working chain who requests the necessary information, becomes the end-user.
- The **Content Provide**r adopts the roles of **Digital Service Provide**r for offering video streaming service, but also the role of **Service Aggregator** for delivering these services to the End Users combining the content delivery service offered by the CDN.
- The CDN adopts the **Communication Service Provider** for the content distribution service which may rely on the network of NSP. In some cases, the CDN may also own its network in some areas, thus also adopting the role of **Network Operator** as well.
- The **Content Host** adopts the roles of **Virtualized Infrastructure Service Provider** and **Data Centre Operator** for hosting the videos of the Content Provider in multiple central or edge regions offering the necessary cloud services and necessary underlay physical infrastructure.
- The **NSP** adopts both the roles of **Network Operator** and **Communication Service Provider** for connecting cloud and edge locations from the source of video towards multiple destinations. NSP also provides connectivity services to end users for consuming the content. The NSP may also offer hosting of video content in its own infrastructure, thus it may also adopt the roles of Virtualized Infrastructure Service Provider and Data Centre Operator. In addition, it is assumed that the NSP adopts the **ESCOs** role, being the responsible entity for aggregating end-to-end energy consumption information, and for making it available to the Content Provider for display on the application.
- **Policymakers** play a crucial role in enabling and supporting the conditions of the ecosystem for these use cases to thrive. Despite not being explored in further detail in Exigence, it is important to highlight the key role they can play in the realisation of these use cases.
- For simplicity, we assume the existence of a single **Energy Supplier**, that adopts the roles of **Energy Aggregator** and **Energy Retailer** to sell electricity to all the other stakeholders.

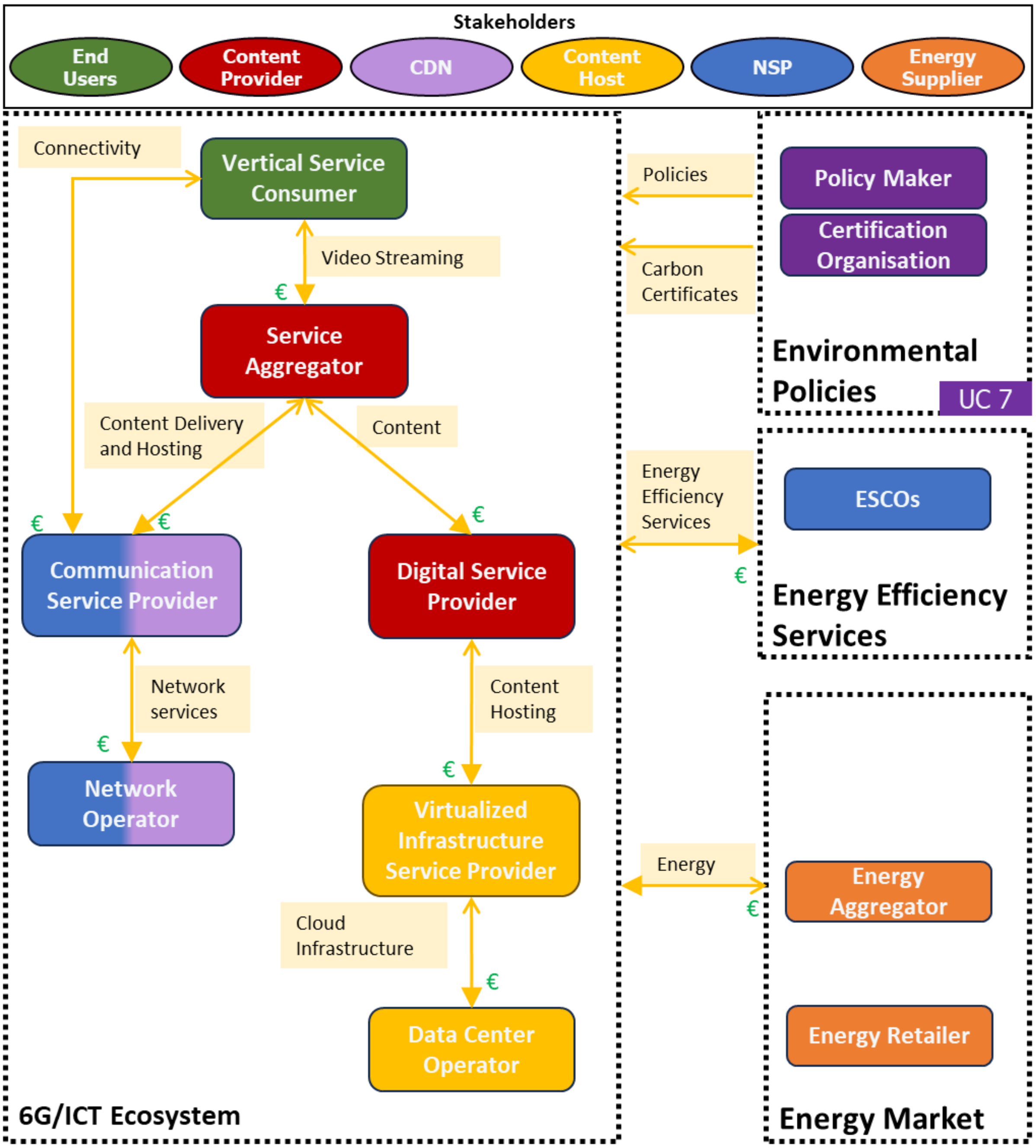

Figure 2: Media streaming carbon footprint transparency value network instance

2.1.2.1 ADDITIONAL SPECIFIC STAKEHOLDERS & ROLES

UC 7: Carbon Certificates as a Service

In addition to the stakeholders identified for Group 1, this use case relies on Certification Organisations, as shown in Figure 2.

The details of the service(s) delivered to the Virtual Service Consumer are irrelevant, as well as details on how those services are delivered. It is, however, critical that, preferably per service, the information on total consumed energy as well as the CO_2 emissions are delivered to the Consumer by the Communication Service Provider or the Service Aggregator. That information must be in a way that enables direct usage as a certificate in the carbon market.

For this reason, the link between the Certification Organization and the Communication Service Provider (or the Service Aggregator) is emphasised, i.e. through a process of certification, the Communication Service Provider must be in a position to deliver the energy consumption and CO_2 emission info that can be legally used as a certificate of consumption/emission in the energy market.

Once the information on the EC/CO_2 emission is collected by the Communication Service Provider (or the Service Aggregator) and delivered to the Service Consumer, it should be delivered to the external party that has access to the Carbon Market. For example, ESCO can take the role of mediator.

2.1.3 ENERGY DEPENDENCIES

2.1.3.1 GENERIC DEPENDENCIES

This subsection identifies the actions/decisions of different stakeholders involved in the use case, and how these actions/decisions affect the energy consumption of other stakeholders across the value chain.

Figure 3 demonstrates the **energy dependencies among the stakeholders,** along with a high-level diagram of business relationships, this time at the (higher) stakeholder level.

The decision of **End Users** on when and at which quality level to consume video content affects the energy consumption of the **NSP** that will deliver the video at the end device, over the 5G infrastructure, the **CDN** who may have to fetch the video from other remote regions where the video is hosted (if it is not cached close to the user, leading to higher power consumption), and the **Content Host** because the content will need to be hosted close to the End User. Precisely, considering the Content Host, higher-quality video streams often require additional processing, such as transcoding, and storage optimization, which increases power consumption on servers in the cloud or at the edge.

As mentioned earlier, when considering the application of incentive mechanisms, the energy dependencies should be considered in parallel with business relationships. For instance, in this use case, we can see that the decisions of **End Users** may impact the energy consumption of **CDN** but there is no direct business relationship among them. In order to capture such dependencies, the construction of a "chain" of incentive mechanisms needs to be applied.

Across the chain of dependencies, the amount of energy that should be provided by the **Energy Supplier** depends on the operation level **NSP, CDN and Content Host**, which depends on the decisions of **End Users**.

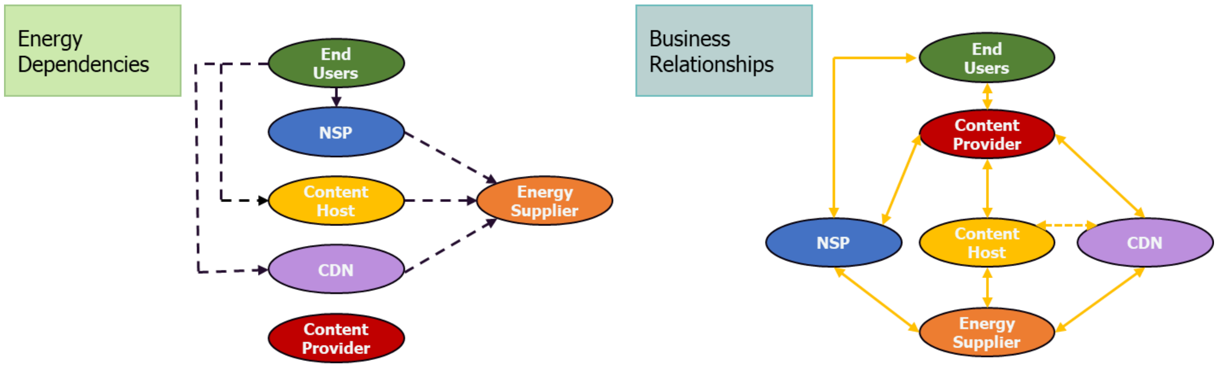

Figure 3: Energy dependencies and business relationships for UCs 1 - 6

2.1.3.2 SPECIFIC DEPENDENCIES

UC7 and UC8

Figure 4 (left part) exemplifies energy dependencies in case of carbon certificates availability and usage for UC7, and carbon emission charging for UC8. Whereas the set of actors and the black arrows connecting them pertain to a typical use case scenario (for example, "Watch TV over 5G"), the red arrow is specific to the Carbon Certificate or carbon emission charging scenarios. The assumption made in the figure is that the Network Operator provides a carbon certificate / carbon emission measurement to the user (i.e., aggregates carbon related information from other actors and delivers to the user). The certificate / carbon emission measurement provides the necessary feedback to the user, with which they can adjust their energy consumption. This dependence is novel and unique to these use cases.

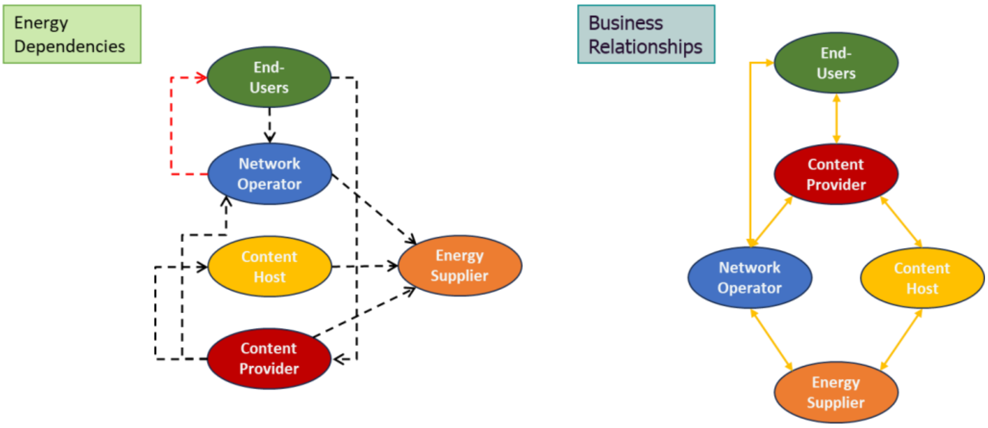

Figure 4: Energy dependencies and business relationships for UC7

UC 11

The decision of End Users on when and which AI Tasks should be executed, affects the energy consumption of the NSP that will deliver the AI model at the end device, the CDN who may have to fetch the AI model from other remote regions where the model is hosted. As mentioned earlier, when considering the application of incentive mechanisms, the energy dependencies should be considered in parallel with business relationships. For instance, in this use case, we can see that the decisions of End Users may impact the energy consumption of CDN but there is no direct business relationship among them. To capture such dependencies, the construction of a "chain" of incentive mechanisms needs to be applied.

The decision of the Service Provider on when and where to push the AI tasks affects the energy consumption of the CDN that will distribute the service and of the Service Hosts at the source and destination(s) of the task at the central or edge cloud. Across the chain of dependencies, the amount of energy that should be provided by the Energy Supplier depends on the operation level NSP, CDN and Service Host, which depends on the decisions of End Users and Service Provider as elaborated above.

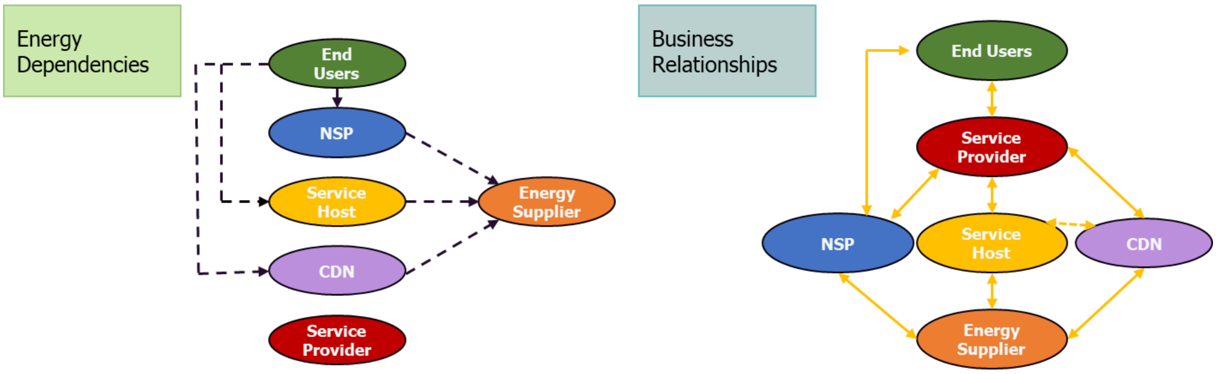

Figure 5: Energy dependencies and business relationships for UC11

2.1.4 VALUE PROPOSITION

The use cases belonging to this group enable a series of opportunities throughout the ICT ecosystem, which can result in a myriad of changes. Consequently, there is significant value brought by these UCs, but also challenges and opportunities.

Value captured

Group 1 use cases primarily aim at providing transparency in the energy consumption and respective carbon footprint throughout the chain (UCs 1, 5, 6, 11) but also providing incentives for parties to act upon this information (UCs 2, 3, 4, 7).

First, this newly introduced transparency delivers significant value for all stakeholders. Examples of such are end users, by granting them the ability to acknowledge the impact their actions are having, and the ability to modify their behaviours in favour of less energy-intensive actions. This additional transparency also applies at a 'company level', where content providers, CDNs, content hosts, and mobile network operators can benefit from the information delivered. This information can be used to understand the main sources of energy consumption within their realms, which can lead to cost reductions, process optimisations, and further greening of the chain. Furthermore, this can become a collaborative effort, creating incentives between partners to reduce their overall energy expenses.

Additionally, currently, both MNOs and Content providers seek to provide the user with the best possible service experience. However, providing end users with the possibility to manage the trade-off between service experience and carbon footprint, can significantly reduce the pressure on QoE/QoS. The latter, apart from having a big influence on network management and infrastructure investments, can even lead to a better customer experience fuelled by empowerment.

Moreover, from an energy supplier perspective, tracking the availability of green energy and consequently stimulating consumption based on any surplus of renewable sources, can help the demand to better adapt to the supply.

Lastly, this transparency and actionable insights do as well have a significant impact on the environment, society, and economy, as greater stakeholders. The latter by greening services, empowering society, and creating new business opportunities, increasing flexibility, and reducing cost/dependencies.

Challenges and risks

Despite the many benefits brought by this group, there are also some issues/characteristics that will need to be assessed and adapted over time to ensure the value is maximised.

First, a crucial point is to be able to ensure the accountability and reliability of the data. If this ecosystem proves to be transparent, accurate, and reliable, then it will add significant value to the industry. Therefore, it is mandatory. However, the exact mechanisms will need to be further defined (e.g., a third party to audit the information).

Second, the deployment of such UCs also comes with a cost. The immediate one relates to the energy consumption required to perform these measurements. It is therefore mandatory that all processes involved in calculating the energy consumption/footprint, also come with an *'energy consumption label'.* This way, it can be determined whether performing a given action will result in a net positive impact. If this is not the case, then the action should not be triggered.

Then, these use cases can bring too much value to the ecosystem, which can be too complex for it to be actionable. Therefore, the overall capabilities should be monitored, assessed, and adapted to maximise the value delivered. An example of such is the frequency of measurements will also need to be assessed over time, according to the trade-off between the actual value created, and the cost of getting this done. An example of such relates to the frequency of accumulating data (e.g., real-time, every 5 minutes, every hour, etc..). This frequency would need to be adapted depending on how fast it can trigger behaviour change, and what level of detail consumers can understand/manage.

Moreover, from a business perspective, providing transparency throughout the chain will highlight 'winners' and 'losers': those who will be able to become greener and those companies who won't. This exposure could result in negative effects for the latter, which can result in loss of competitiveness or even customers.

Finally, end users can be split into two groups: those engaged and interested in reducing the overall footprint, and those who are not. The latter group presents a riddle: performing these measurements results in additional energy consumed with no likely energy reduction. However, the larger parts of the measurements performed will be done irrespective of the type of consumer, making it possible to differentiate between consumers, only in the 'last mile'. The challenge here lies in how to minimise the energy consumption for these users (cost>benefit), but as well as how to provide an attractive value proposition for these users, to get them engaged in these mechanisms (e.g., carbon budgets in commercial plans).

The latter, together with other implementation aspects (e.g., display dashboard) falls out of the scope of the functionalities defined. However, these aspects are crucial to be taken into consideration.

Opportunities

Lastly, there are a few opportunities identified and granted by the implementation of these UCs.

First, being able to deliver transparency on the impacts together with mechanisms for action can help greatly the ICT industry as a whole to improve its social image.

Consequently, this can enable new business opportunities. A few examples of such are (1) related to the issuance of green certificates/eco-labels. This can enhance competition on green services and devices; also, (2) new business models or partnerships with energy suppliers can be sought, leading to innovative revenue streams; it can also (3) help push towards greener infrastructure, and break down current barriers to do so, and finally (4) it can create new opportunities for certification organisations, data aggregators, and device manufacturers.

Moreover, the better understanding of consumer behaviour and their needs, can enable the creation of bespoke services subject to the environmental-proneness of the stakeholders. Examples of such are (1) to attract consumers into companies based on their environmental performance (e.g., greenest MNO to increase their market share), it can also (2) allow OTTs and MNOs to adapt their content and network respectively to the real needs of consumers, or even (3) the possibility to create new commercial plans/bundles targeted towards the environmentally prone customer.

Finally, other stakeholders from outside the ICT industry can benefit from the capabilities introduced by these use cases. For example, policymakers, will benefit from the transparency/data to support the design of effective policies.

2.1.5 CHALLENGES AND NEXT STEPS

Building a new dimension of information into a working ecosystem has both technical challenges and those related to the implementation into the ecosystem. While Exigence will look further into the technical realisation of these use cases, it is required to look for ways to engage other stakeholders in building the conditions for these to thrive. Examples of such include policies, carbon budgets, and carbon markets.

2.2 UC 9: PHYSICAL SECURITY

2.2.1 OVERVIEW OF THE USE CASE

This use case targets the physical security in the ICT domain, one of the vital supporting processes in industry, as well as in general. The particular use case assumes a customer owning an infrastructure, including cameras connected to private 5G networks and AI video analytics embedded in the cloud. In the scope of reducing energy consumption and carbon footprint, as well as contributing to sustainable development, the goal of the use case is first to evaluate the end-to-end energy consumption of the particular service, which includes identifying related energy consumption of each part of the service chain infrastructure. Then, based on the evaluation outputs, the use case aims at optimizing energy consumption considering every part of the infrastructure included in the service delivery. The approach will consider optimizing network parameters of the (private) 5G system on one end and will aim at optimizing/orchestrating resources required for running AI video analytics processes. While the main goal is to optimize/reduce overall energy consumption, this should not come at the expense of degrading the quality of the service, i.e., customers' experience.

The detailed flow of the service involved in the use case is described as follows. To initialize, surveillance video camera streams video to the cloud over a 5G network where a video analytics application runs. The algorithm implemented in the video-analytics application continuously checks for malfunction/unusual phenomena in the video stream, which might be caused by a potential physical security issue. Besides physical security analytics, the application also continuously assesses video stream quality (e.g., video resolution), which might provide feedback to video cameras to fine-tune the video capturing and streaming parameters to satisfy the minimum requirements needed for successful image detection. This might also include the activation of sleep mode, especially in the case of multiple video cameras in the video surveillance process. Current requirements for video streaming may also allow for mobile network configuration modifications (to be required by the orchestrator), directly affecting its energy/power consumption. The cloud, where video analytics applications run, may include various processing capabilities, e.g., GPUs, multiple processors of various performances. The orchestrator is therefore expected to consider this while reserving resources for the video-analytics application (e.g., offloading processing to GPUs). 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.

2.2.2 ECOSYSTEM – STAKEHOLDER IDENTIFICATION & ROLES

Stakeholders in this use case include:

- **Industrial entity:** an entity (i.e., business) which develops some kind of industrial-based activity, that deploys its own private 5G network and private cloud (e.g., operated by third-party partners). The infrastructure is able to optimize the video surveillance operation, based on measurements obtained from energy consumption, traffic and computing resources used.
- **Private mobile network operator:** an entity that develops, customizes, deploys and manages private 5G network solutions. It deploys a private 5G network solution that offers energy consumption measurements and the possibility of realizing traffic-based optimizations based on those measurements, along with traffic-based measurements.
- **Private cloud operator:** an entity that develops, customizes, deploys and manages private cloud solutions. Deploys a private cloud solution that offers energy consumption measurements and the possibility of realizing compute resources-based optimizations based on those measurements, along with compute-based measurements.

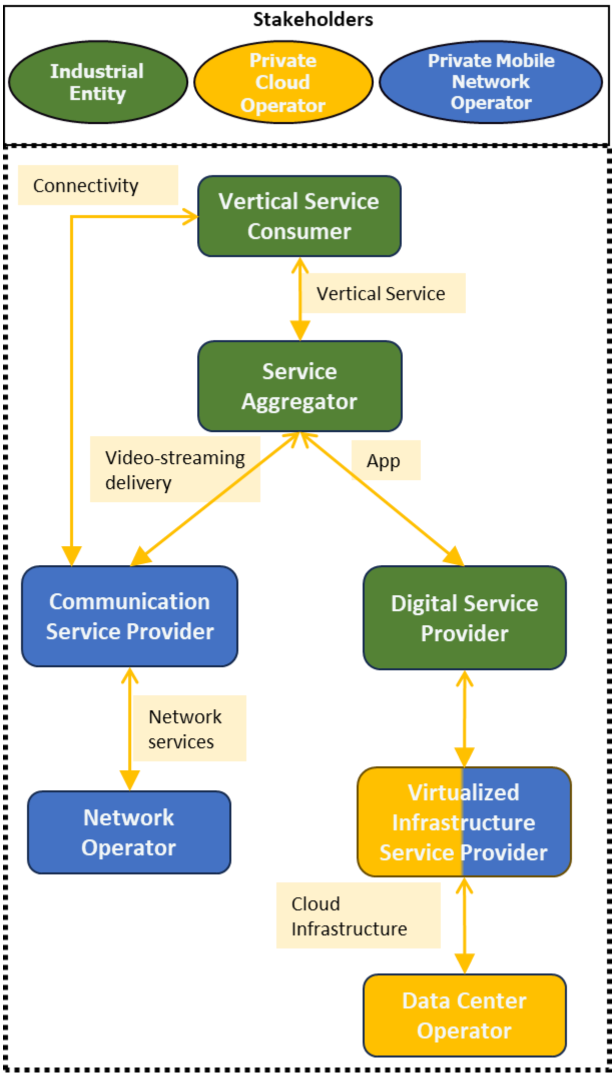

Figure 6: Stakeholder identification for UC9

2.2.3 ENERGY DEPENDENCIES

As per use case assumption, the infrastructure required for the use case is located within the premises of the industrial entity, thus making both private 5G network operator and private cloud operator dependent on the energy provided by the industrial entity. This way, the industrial entity is able to more directly control their carbon footprint.

Industrial entity: provides energy for all operations related to the use case, i.e., private 5G network, private cloud, UEs. Based on the energy mix supplied by the energy provider or available in the market, including renewable energy that might be produced by the industrial entity's own facilities, the industrial entity may, if required so, enforce the distribution of green energy to specific infrastructure parts.

Private 5G operator: depends on the energy supplied by the industrial entity, its goal is to optimize/reduce energy consumption and provide actual and forecasted data on energy consumption.

Private cloud operator: depends on the energy supplied by the industrial entity, its goal is to optimize/reduce energy consumption and provide actual and forecasted data on energy consumption.

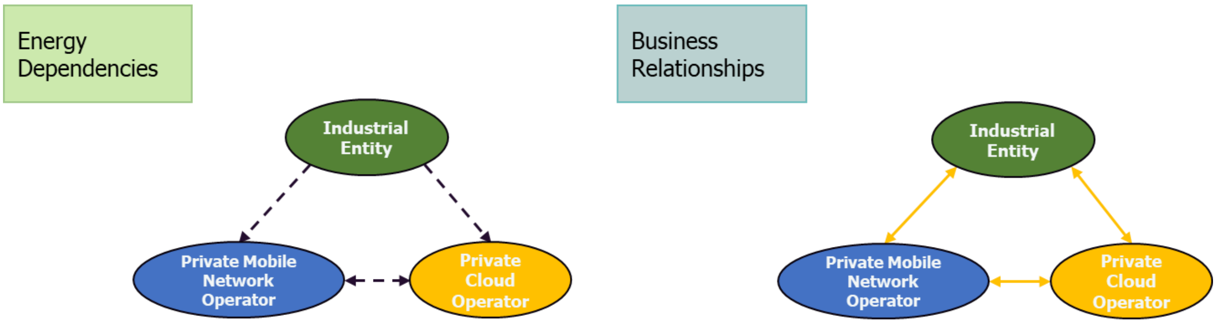

Figure 7: Energy dependencies and business relationship for UC9

2.2.4 VALUE PROPOSITION

This use case targets ICT services for physical security in the industry. ICT services supporting physical security require high availability and resilience on one hand, while on the other hand, by knowing certain energy consumption-related specifics, there is an opportunity for energy savings.

Value captured

UC9 aims at evaluating the end-to-end energy consumption of the service contributed by each part of the network, and, based on the service specifics and initial energy consumption measurements, it optimizes the private 5G network parameters as well as optimizes/orchestrates the resources required for running AI video analytics processes, all to optimize/reduce the overall energy consumption without degrading the quality of the service, i.e., customers' experience. As a consequence, the stakeholders involved, i.e., industrial entities, private 5G network vendors, and private cloud vendors, will benefit from the awareness of new possibilities to control energy consumption in the ICT sector.

Further, industrial entities will benefit from lower energy costs, thanks to the goal of energy consumption reduction during the service delivery process. Energy consumption monitoring of each single entity involved in the service chain will be enabled, based on which energy consumption could be reduced relying on the selected pre-defined alternatives (e.g., slice selection, CPU/GPU selection, etc.). Energy consumption reduction will also be achieved amongst private 5G network and private cloud operators, who are involved in the energy consumption monitoring in the service chain.

Challenges and risks

There are some challenges embraced by UC9. First of all, the additional energy consumed for the measurement and optimization processes will bring a concern to the environment, which might reduce, or even "neutralize", the efforts made in UC9 towards energy consumption reduction. This might further bring concerns to all the stakeholders, if they expect a significant cost reduction due to the energy consumption reduction. Another potential risk to realising UC9 will be considered by all the stakeholders involved, that not every piece of data provided may be directly utilized for the energy consumption optimization, causing unnecessary costs and risks of privacy.

Another challenge is the current lack of fully dynamic processes for energy consumption reduction while keeping the required QoS. Fully dynamic reconfiguration and scaling of resources while maintaining QoS will also be demanded by both private 5G network vendors and cloud vendors.

Opportunities

There are opportunities identified and granted by the implementation of UC9. Energy consumption will be optimized, with "wiser strategies" based on the measurement, i.e., less waste of energy. This UC, then, could contribute to the promotion of green technologies, especially in the ICT and industry sector; this could be further supported by potential investment in energy measurement and optimization services justified by energy consumption savings. The market niche will also be benefitted by UC9. Bottom line, all the stakeholders will benefit from energy consumption optimization, based on the collection of energy consumption monitoring data and awareness of energy mix supplied.

2.2.5 CHALLENGES AND NEXT STEPS

As required by the use case, as well as the project, energy consumption measurement on the level of processes is a must to support E2E carbon reduction. Besides, this use case also relies on measurement of traffic volume for streaming and computing resource utilization in cloud. Based on the measurement, an efficient mechanism for dynamic identification of requirements from providing the service with required level of quality, as well as the corresponding optimization for network parameters/video analytics applications is needed.

2.3 UC 10: CARBON AWARE AI

2.3.1 OVERVIEW OF THE USE CASE

AI is recognised as one of the major services of a 6G network, although it is considered to be energy-hungry, especially during training. Sustainability issues require the energy consumption and the carbon footprint of the network services to be mitigated. Therefore, the "Carbon Aware AI" use case (UC10) aims at creating sustainable AI services in a 6G system. To do so, it is necessary for architectural entities, new technologies and a series of service scheduling mechanisms to be included in the use case, in order to utilise any available renewable energy resources as much as possible.

Monitoring tools will be needed to be installed on each network node, so as to draw conclusions and take AI-driven decisions from the raw data.

The main service flow includes a requested execution of an AI service, followed by the collection of the resource availability information from the involved nodes, will be then used to assign training tasks to these nodes in a carbon efficient manner. It should be mentioned that the task nature and its assignment can change over time, based on any changes that might occur in the resource availability of these nodes.

2.3.2 ECOSYSTEM – STAKEHOLDER IDENTIFICATION & ROLES

Stakeholders in this use case involve:

- **End Users**: End Users are considered the individuals using a device or vertical companies requesting some AI services.
- **Network Service Provider (NSP)**: NSP is an entity providing wireless and fixed internet access to the end users.
- **AI Service Providers (AISPs)**: AISPs are AI-service owners who provide the services to be distributed through a Content Distribution Network (CDN).
- **Content Distribution Network (CDN)**: CDN is responsible for distributing the AI services through a geographically distributed group of servers which are located relatively close to the end users and have access to cleaner energy.
- **Service Host**: The Service Host offers computing services that could be distributed over an execution platform (e.g. a distributed cloud platform).
- **Energy Supplier**: The energy supplier (in practice more than one) sells electricity to all stakeholders maintaining network or cloud infrastructure, as well as the end-user devices. Provides energy-related information, enhances the flexibility of the grid, and tariffs that promote energy efficiency in the ecosystem and offer discounts for green energy.

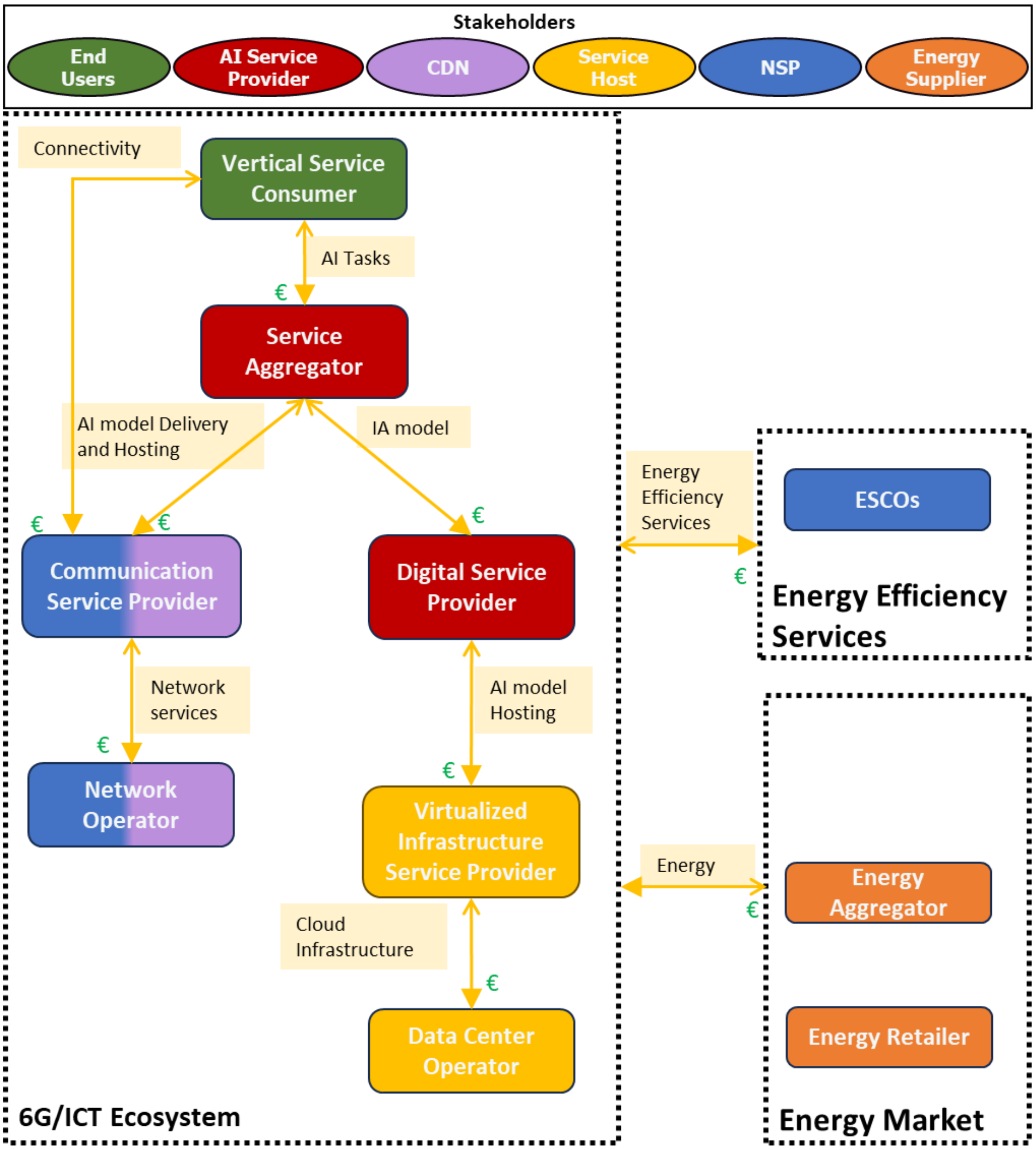

Figure 8: Stakeholder Identification for UC10

2.3.3 ENERGY DEPENDENCIES

Based on the actors and energy dependencies the section could list each actor for the energy dependency in order to provide a more detailed view. **End User Requests to Network Service Provider (NSP) influence on Network Energy Use**: the timing, volume, and nature of AI requests from **End Users** directly affect the energy consumption across multiple layers, including **Network Service Providers (NSPs)** and the **Content Distribution Network (CDN)**. For example, an increase in requests during peak hours can elevate NSP energy usage to maintain quality of service, increasing the energy demand on network infrastructure. Moreover, if End Users in one region frequently access AI services hosted remotely, the CDN may need to fetch and transfer data across longer distances, consuming additional energy in data transmission and server operations. These lead to NSPs facing variable energy demands as they adapt network infrastructure to balance load efficiently, particularly during high-traffic times. Their energy usage is interdependent with End User behaviour, CDN workload, and AI service demand. Load balancing across nodes may involve routing data via less congested or more energy-efficient paths, which requires additional computational energy for network traffic analysis and rerouting. These energy expenditures may be mitigated by using data from monitoring tools to dynamically route traffic in an energy-efficient manner.

Dynamic AI Task Assignment: **AI Service Providers (AISPs)** control when and where to assign AI tasks, significantly impacting the energy requirements of **CDN** nodes and **Service Hosts** at central or edge cloud facilities. Assigning tasks to locations with greater renewable energy availability reduces fossil-fuel dependency, though it may necessitate data transfer across regions, which incurs additional energy use. Additionally, the AI model's complexity and duration influence processing energy costs, which can vary based on available hardware efficiency and resource limitations of the chosen node. Because **Service Hosts'** energy use fluctuates based on their operational load, may often experience variable demand based on real-time AI usage, impacting both their energy and cooling requirements. Moreover, higher workloads on edge nodes may trigger data processing shifts to central clouds, increasing both computational energy and the need for robust data transfer paths within the CDN.

Renewable Energy Availability and Allocation by Energy Suppliers: **Energy Suppliers**, providing power to **NSPs, CDNs, Service Hosts, and End User devices**, play a pivotal role in UC10's energy efficiency. The availability and type of energy (renewable vs. non-renewable) directly impact carbon emissions associated with each AI task execution. Suppliers can also adjust tariffs based on energy demand, potentially incentivizing energy use at off-peak hours or in areas with higher renewable energy availability. These adjustments help synchronize AI task scheduling with periods of low-cost, green energy, encouraging more carbon-aware AI task execution.

Dependency Chains and Indirect Energy Consumption: the **"dependencies chain"** in UC10 reflects indirect energy dependencies where stakeholders' actions impact others' energy consumption. For instance, an **AISP**'s decision to push AI tasks to specific **Service Hosts** impacts the energy consumption of not only those Hosts but also the **CDN** nodes that route data, **NSPs** maintaining connectivity, and ultimately the **Energy Supplier** that provides power across the chain. These dependencies highlight how each stakeholder's energy decisions cascade, impacting the network's total energy footprint and necessitating cooperation to optimize energy use collectively.

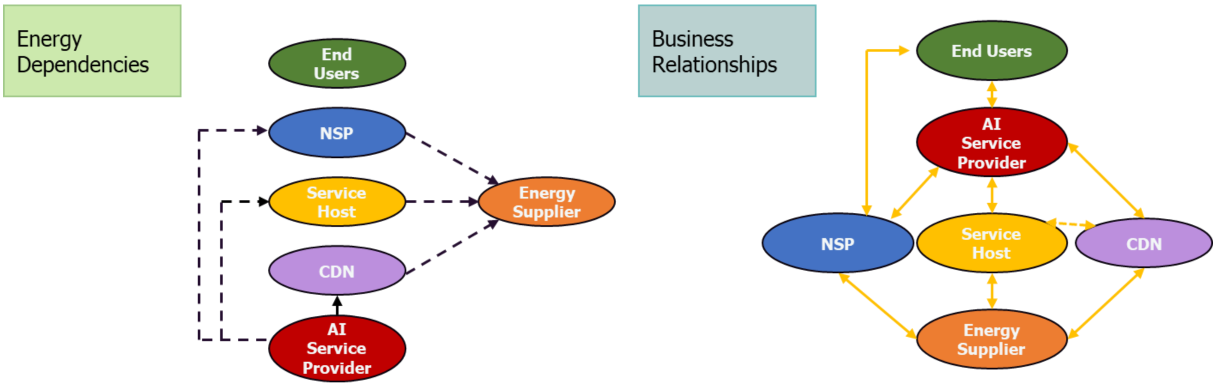

Figure 9: Energy dependencies and business relationships for UC10

2.3.4 VALUE PROPOSITION

The "carbon-aware AI" use case addresses the need for environmentally responsible AI services within the ICT and industrial sectors. By monitoring and adjusting energy usage, UC10 promises both environmental and economic benefits, though it also brings associated challenges and opportunities for improvement.

Value captured

UC10 focuses on reducing energy consumption across network and AI service providers, service hosts, and energy suppliers. The primary value captured is environmental: reducing energy consumption leads to lower emissions, contributing to a greener ecosystem. Additionally, end users benefit from lower energy costs and increased access to environmentally conscious services. By optimizing energy use in AI operations, service providers can benefit from positioning themselves as sustainable leaders, creating brand loyalty among eco-conscious customers. Economic benefits also emerge as reduced operational costs allow businesses to reinvest in new sustainable technologies. For network service providers and AI vendors, the reduction in energy consumption not only lowers costs but also enables compliance with emerging environmental standards, providing a competitive advantage in the growing green tech market.

Challenges and risks

While UC10 offers substantial benefits, several challenges and risks need to be mentioned. Firstly, the additional energy required for monitoring and optimizing AI processes could partially offset the benefits of reduced consumption, creating a risk that the net impact on emissions might be lower than anticipated. Privacy and data security present another challenge; the extensive data required to monitor and optimize energy usage may expose user information, raising concerns over compliance with data privacy laws. Furthermore, network service providers may face operational complexity in adapting to carbon-aware models, which could increase infrastructure demands and complicate service delivery. For AI service providers, the potential for degraded service quality in pursuit of energy efficiency might negatively impact user experience, particularly if AI functionalities are compromised. Finally, the competition in the specific field is constantly increasing, as more organizations adopt green solutions, requiring continuous innovation to maintain a leading position.

Opportunities

Despite these challenges, UC10 brings up numerous opportunities. The transition to carbon-aware AI allows businesses to develop new green services, tapping into the part of the market that values sustainability. This positions companies as frontrunners in the field, appealing to eco-conscious consumers and differentiating them from less sustainable competitors. Moreover, data-driven optimization based on energy usage insights creates the potential for new business models, particularly in energy consultancy and resource management. For end users, carbon-aware AI presents an opportunity for more affordable, energy-efficient services, promoting customer retention. Additionally, regulatory alignment with global carbon reduction initiatives will be an asset as businesses increasingly face mandates to reduce their carbon footprint. Through continuous innovation and commitment to green technology, stakeholders across the board—from network service providers to energy suppliers—have the opportunity to shape a future where technology and sustainability can work together.

2.3.5 CHALLENGES AND NEXT STEPS

One of the main challenges lies in the requirement for real-time data collection across various network nodes, necessitating the installation of advanced monitoring tools to accurately track energy usage, computational resources, and renewable energy availability. Balancing energy efficiency with service quality is another critical hurdle, as AI optimizations must meet stringent Key Performance Indicators (KPIs) such as latency, scalability, and reliability.

To overcome these challenges, establishing robust, real-time monitoring tools across all network nodes and developing a central AI-enabled entity to aggregate and analyse this data are fundamental to achieving carbon efficiency. New communication protocols must be created to allow seamless interaction between network nodes and the central entity, supporting dynamic task assignments based on energy and resource availability. Finally, investing in research and development for AI-driven energy optimization and renewable energy integration will also be vital in advancing the sustainability goals of UC10, creating a foundation for greener AI services in the 6G ecosystem.

2.4 UC 13: CARBON-AWARE PRE-POPULATION OF CDN NODES

2.4.1 OVERVIEW OF THE USE CASE

The "Carbon-aware pre-population of CDN nodes" use case enables stakeholders to offer green energy-efficient content delivery and carbon-awareness to end users promoting sustainability while at the same time maximising the utilization of renewable energy for the replication of content. These services encompass OTT video (e.g., Netflix, YouTube), web pages, software and firmware updates (e.g., Android, iOS).

The content is replicated from an origin server to many geographically distributed servers called Points of Presence (PoPs). The content replication process itself is not time-sensitive and operates on a low-priority, best-effort basis (e.g., the content must reach the PoP before the scheduled 'release date'). These replications prioritize utilizing paths and servers powered by green energy sources (such as solar, wind, or hydroelectric power). Additionally, energy efficiency is enhanced by utilizing paths with excess capacity that are already active, resulting in minimal incremental energy usage whenever possible. By optimizing green energy-efficient paths and servers, the environmental impact of content replication can be minimized or even reduced to zero.

2.4.2 ECOSYSTEM – STAKEHOLDER IDENTIFICATION & ROLES

The stakeholders encompassing this use case are:

- **End-users:** individuals or enterprise users who use devices to access and consume the content from a Content Provider (e.g., video streaming, web pages, software and firmware updates such as for Android, iOS).
- **Content Providers (CP):** content owners who provide the content to be distributed through a Content Distribution Network (CDN).
- **Content Distribution Network (CDN):** Distributes the content (e.g., video streaming, web pages, software and firmware updates such as for Android, iOS) through a geographically distributed group of servers which are located relatively close to the End-users.
- **Content Host:** offers cloud and edge computing services. These services are utilized to process and store the content enabling efficient delivery.
- **Network Service Provider (NSP):** entities that provides the necessary network infrastructure such as 5G/6G connectivity and fixed internet access, enabling internet connectivity for CDN providers and to End-users. An NSP may also offer Edge computing services to CDN providers.
- **Energy Supplier:** The energy supplier (in practice is more than one) sells electricity to all stakeholders maintaining network or cloud infrastructure, as well as the end-user devices. Provides energy related information (e.g., CO_2 emission), and discount offers for green energy windows (i.e., periods of forecasted high availability of renewable energy)

Figure 10 illustrates how stakeholders assume various roles within the future ecosystem value network to contribute to end-to-end service delivery of this use case.

End Users assume the role of Vertical Service Consumer (VSC), using devices to access and consume video streaming, web pages, or software and firmware updates such as for Android, iOS. End Users may have service contracts with NSPs to schedule content downloads in a carbon-aware manner.

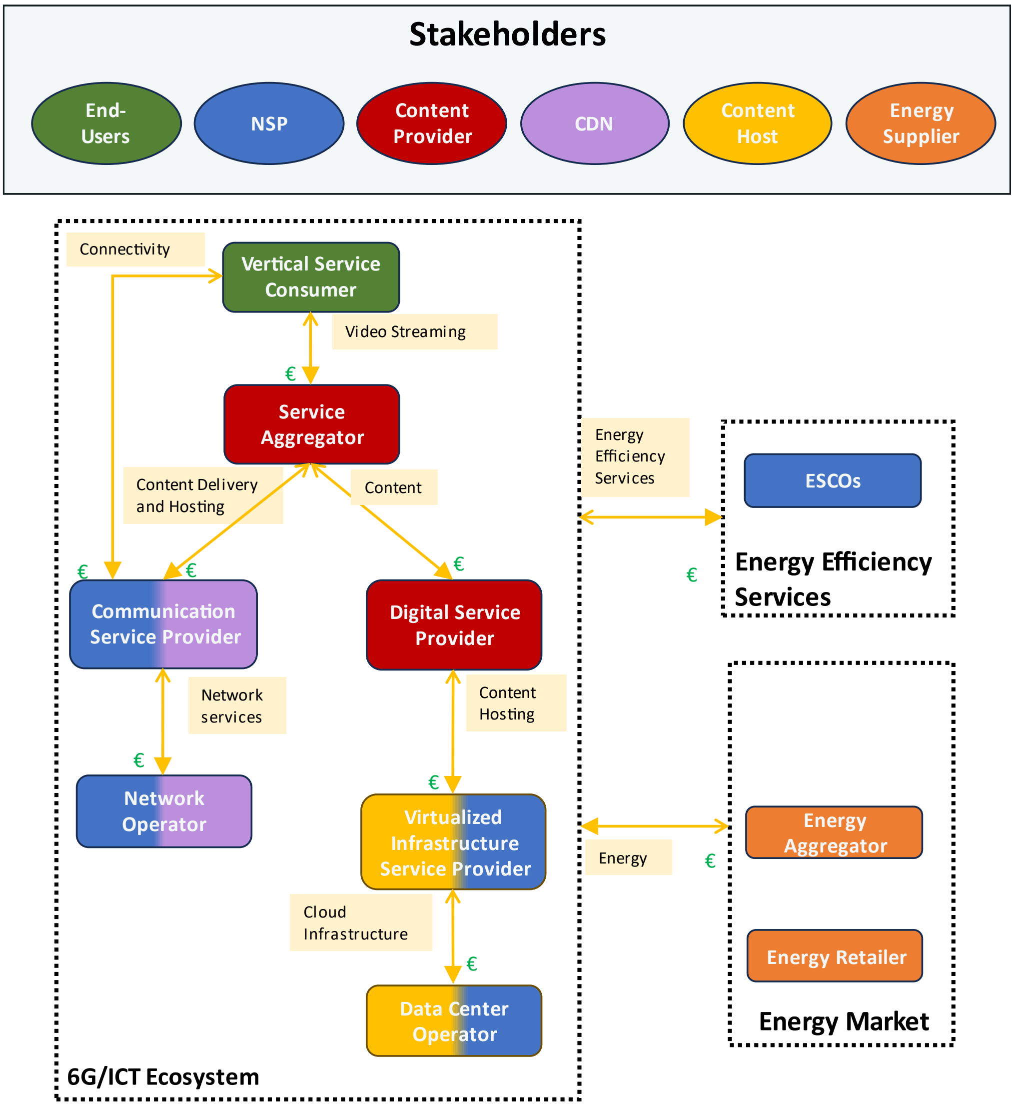

Figure 10: Stakeholder identification for UC 13

The Network Service Provider adopts the roles of Network Operator and Communication Service Provider, providing the necessary network connectivity for cloud and edge locations from the source content from the Content Provider towards multiple destinations. NSP also provides connectivity services to End-users for consuming the content. The NSP may also adopt the roles of Virtualized Infrastructure Service Provider and Data Centre Operator, offering edge computing service for hosting video streaming, web pages, or software and firmware updates. The NSP has a green service agreement with CDN service and have green energy contracts with energy suppliers. NSPs offers a discount to CDN if distribute and replicate content in green windows identified for different geographic locations. In addition, we assume that the NSP adopts the ESCOs role, being the responsible entity for aggregating end-to-end energy consumption information, and for making it available to the Content Provider for display on the application.

Content Providers assume the roles of Digital Service Provider (DSP), offering video streaming, web pages, or software and firmware updates through applications compatible with the end users' devices. The Content provider also assume the role of Service Aggregator for delivering these services to the End Users in combination with the content delivery service offered by the CDN. The Content Provider, under a green agreement with the CDN, receives incentives for scheduling energy-efficient content releases across various regions.

The Content Host adopts the roles of Virtualization Infrastructure Service Provider (VISP) and Data Centre Operator, providing and maintaining a virtualized infrastructure for cloud and edge storage of various content types, including videos, web pages, and software updates, while also offering services like video processing. The Content Host maintains a green service agreement with the CDN and holds green energy contracts with energy suppliers. The Content Host, under green agreements with the energy suppliers, benefits from energy discounts during green energy windows. In turn, it provides the CDN with discounted rates for content storage and processing within green energy windows.

The Energy Supplier assumes the roles of Energy Aggregator, combining the production or consumption of energy from multiple small producers or consumers to participate in the energy market as a single entity. The Energy suppliers also provide a new dynamic energy expose service to maximize the use of removal energy sources providing discount incentives to Content Host and NSP for the energy consumed within green energy windows, maximizing the use of renewable energy during periods of high availability.

2.4.3 ENERGY DEPENDENCIES

The identified energy dependencies among the stake holders for this use case are depicted in Figure 11, along with a high-level diagram of business relationships at a (higher) stakeholder level.

The actions and decisions of the **Content Provider**, which strategically determine when and where to distribute content, directly influence the processing load and energy demands of the **CDN** that distributes the content to the required regions, as well as the **Content Host** that receives and hosts the content close to the End User and the **NSP** that provide the network connectivity.

As already mentioned, for the application of incentive mechanisms, the business relation between stakeholders shown in Figure 11, must be considered in parallel with energy dependencies. For instance, the use case assumed a direct business relation between a Content Provider with the CDN but no with the Content Hosts. The Content Provider receives incentives through the CDN for scheduling energy-efficient content releases across various regions during green energy windows. In turn, the CDNs direct influence the energy consumption of the NSP and content hosts when distributing the content. CDNs must optimize content distribution efficiently, while Content Hosts must ensure adequate storage and processing capabilities, both of which directly affect their respective energy needs.

Across the energy chain of dependencies, the Energy Supplier plays a critical role by providing energy to sustain operations primarily across CDNs, NSP, and Content Hosts. These energy demand depends on the decisions of the Content Provider, as previously elaborated. The Energy Supplier dynamically adjusts the energy supply to meet fluctuating demand. Additionally, the Energy Supplier can influence the Content Provider decisions providing discount incentives through stakeholders (i.e., CDN, NSP, and Content Host) to schedule content distribution replication within forecast green windows as described before.

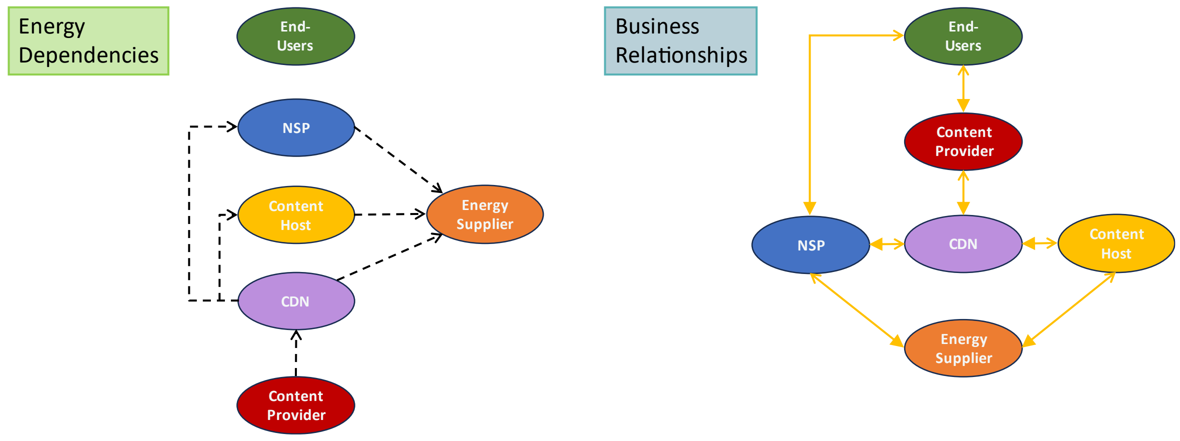

Figure 11: Energy dependencies and business relationships for UC13.

2.4.4 VALUE PROPOSITION

Value captured

The "Carbon-aware Pre-population of CDN Nodes" use case primally aims at reducing CO_2 emissions by maximizing renewable energy utilization during high availability periods. This use case leads to a more efficient use of renewable energy infrastructure for Energy suppliers, potentially reducing Product Carbon Footprint (PCF), and optimizing CAPEX. It also provides dynamic incentive benefits to Content providers, CDN and Content host without degrading the quality of service provided to end users.

By aligning content release schedules with green-energy windows, stakeholders can increase revenue through discounts and reduce their CO_2 footprint, aiding in achieving Net Zero targets. Additionally, NSPs can reduce costs by providing connectivity within green windows and save further energy by utilizing excess capacity.

Reducing CO_2e and optimizing energy infrastructure utilization create significant positive impacts on the environment, provide societal benefits, and offer new business opportunities for stakeholders. Additionally, End-users can receive incentives (environmental points) while getting access to expose information about the environmental contributions of the service, including energy efficiency and CO_2 information.

This efficient infrastructure and carbon-aware content service delivery leads to maximize the use of renewable energy and the share revenues to the ecosystem stakeholders, enhance end users' satisfaction and promote environmental awareness and contribute to Net Zero goals.

Challenges and risks

Despite the benefits, some challenges are foreseen for this use case. The first challenge is that for some stakeholders, processing and transmitting CO_2 information might be considered a service consuming additional resources and energy at an additional cost. This challenge can be mitigated to some extent through economic incentives and by emphasizing the environmental awareness value to society, encouraging active involvement from end users and also enhancing the stakeholders' brand reputation. The increasing importance of environmental impact and awareness to users will increase the risk for non-green providers to lose customers.

Another potential challenge is that content distribution depends on scheduling on green energy windows, limiting flexibility that could be valued more than the incentive provided through the energy supplier. Furthermore, to ensure privacy, transparency, and fairness, additional support from governments might be needed.

Opportunities

There are several opportunities provided by the implementation of this use case. For energy suppliers, besides enhancing their brand reputation, they can maximize the utilization of renewable energy. By incentivizing stakeholders to schedule activities during green energy windows, energy suppliers can significantly enhance the overall efficiency and sustainability of the energy distribution network.

Moreover, NSPs, content providers, CDNs, and content hosts can enhance their brand and corporate reputation by being green, leading to market share growth by attracting environmentally conscious clients to join.

Finally, end users have the valuable opportunity to contribute directly to reducing global warming and encourage others to join green service providers.

2.4.5 CHALLENGES AND NEXT STEPS

The implementation of this use case requires not only technological developments, which will be researched within the scope of Exigence, but also will face the regulatory framework challenge to support economic incentives for stakeholders through Energy suppliers. On the technical side, stakeholders will need standardized, integrated network functions that automate scheduling for content distribution during energy windows, measure energy consumption and manage incentives, and compute the CO_2e savings and deliver information to end users.

2.5 UC 14: GREEN NETWORK ORCHESTRATION ON THE EDGE

2.5.1 OVERVIEW OF THE USE CASE

For network operators it is imperative to handle and satisfy requests for network resources in a timely manner, which can be challenging with large, unexpected demands for costly or limited resources. While 4G and previous generations primarily dealt with radio resources, 5G and future generations will also face the need of optimising Edge Computing resources. Considering that extremely distributed edge infrastructures are not only very expensive to deploy and operate but also have a significant environmental impact, it would be very beneficial for operators to use the same computing infrastructure for network functions (NFs) and to host edge computing services whenever possible, thereby contributing to reducing the carbon footprint.

The edge computing services provided to End user can include:

- Crowd uplink video streaming on an event (e.g., concerts), facilitating real-time video streaming from event attendees. This is the primary use case for analysis,
- AI applications running in the edge to extent the mobile AI End user device power,
- XR Glasses video rendering by offloading computational tasks to the cloud.

The service involves providing edge computing using the same infrastructure as the mobile network functions, whenever possible. Hence, for these use cases, NFs would compete for resources with service processing functions. To allocate edge computing resources, admission control is applied based on available excess capacity (i.e., priority is given to MNO Network functions), performance requirements, energy consumption, and the CO_2 equivalent (CO_2e) necessary for delivering the service. The energy consumption and CO_2e are exposed to the end user.

2.5.2 ECOSYSTEM – STAKEHOLDER IDENTIFICATION & ROLES

The identified stakeholders for this use case are:

- **End-users:** Individuals or enterprise users who use devices to request Edge computing services, such as crowd uplink video streaming, AI as a service (AIaaS), or offloading computational tasks for XR Glasses video rendering.
- **Content Provider:** Providers of platforms and apps for crowd video streaming services (e.g., YouTube Live, Twitch), Social Media Platforms providing a platform and apps for users to connect, share information, and build online communities, and XR Providers that develop extended reality (XR) technologies and offer XR services (e.g., Meta, Apple, Microsoft, Google, Sony).
- **Content Host:** offers edge computing services that are utilized to process application and service data closer to the End User. Edge computing data centre can belong to MNO or Hyperscaller or another third company providing infrastructure. MNOs provide edge computing services using the same infrastructure utilized for the mobile network functions whenever they have excess capacity.
- **Mobile Network Operator (MNO):** Entities providing the necessary network infrastructure, such as 5G/6G connectivity and Edge computing resources (e.g., in the use case, is the excess capacity in Data Centres used for Network Functions), to enable the service. To allocate edge computing resources, admission control is applied given priority to the MNO Network functions.
- **Energy Supplier:** The energy supplier (in practice is more than one) sells electricity to all stakeholders maintaining network or cloud infrastructure, as well as the end-user devices. Provides energy related information (e.g., CO_2 emission) to the MNO.

Figure 12 illustrates how stakeholders assume various roles within the future ecosystem value network to contribute to end-to-end service delivery of this use case.

End Users assume the role of vertical service consumer (e.g., crowd download video streaming, XR service or AIaaS) and/or producer of content (i.e. crowd uplink video streaming). The End Users subscribe to and utilize green energy-efficient service through their apps or devices. End-users consume the service and view energy consumption information related to the services on their apps.

Content Provider assumes the role of Digital Service Provider and service aggregator for delivering these services to the End Users. They offer apps and platform for crowd video streaming services (e.g., YouTube Live, Twitch), Social Media Platforms allowing users to connect, share information, and build online communities, and XR extended reality (XR) technologies to offer XR services (e.g., Meta, Apple, Microsoft, Google, Sony).

The MNO adopts both the roles of Network Operator and Communication Service Provider, as illustrated, while Content Host providers adopt the role of Virtualization Infrastructure Service Provider (VISP) and Data Centre Operator to process application and service data closer to the End User. Content host infrastructure can be part of the MNO (as illustrated in Figure 12), Hyperscaller, or another third company providing infrastructure. As stated before, Content Host services provided by MNOs leverage dynamically the excess capacity available after given priority to the mobile network functions.

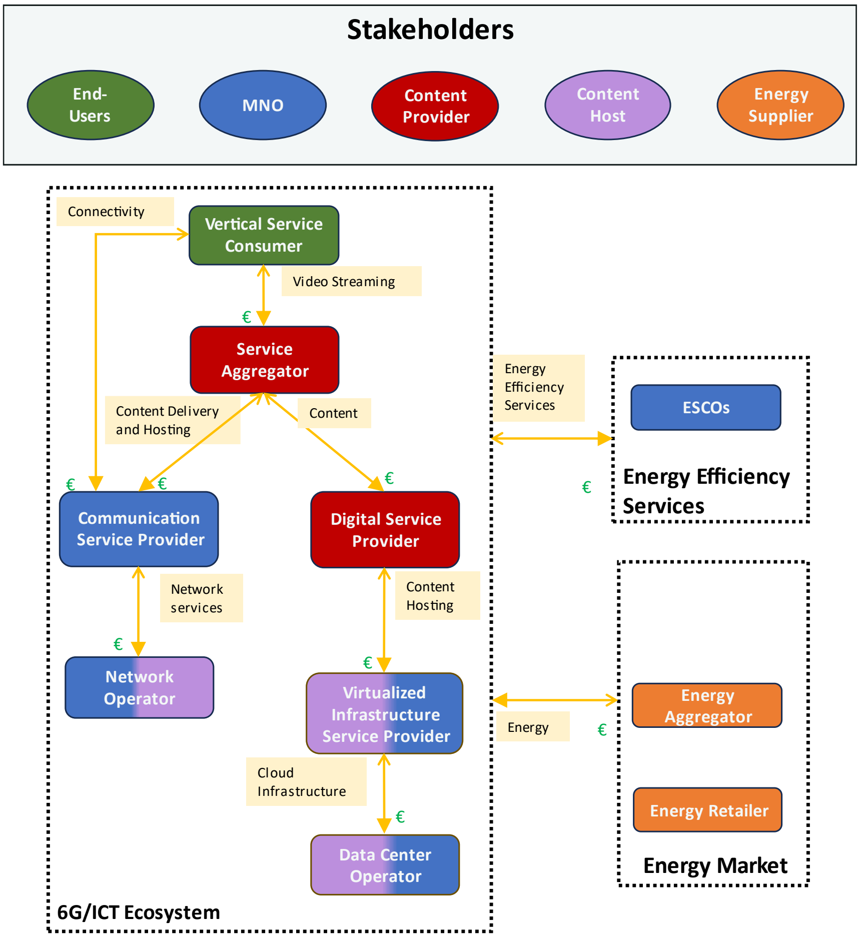

Figure 12: Stakeholder identification for UC14

Mobile Network Operator (MNO) adopt the roles of Network operator and Communication service provider, providing the necessary network connectivity to End-users. The MNO also adopt the roles of Virtualized Infrastructure Service Provider and orchestrates its RAN and computational Edge resources to provide their excess computational Edge capacity for hosting other services (e.g., crowd uplink video streaming, XR service, or AIaaS), considering, for admission control, performance requirements, energy consumption, and CO_2 emission. Furthermore, we assume that the MNO adopts the ESCOs role, being the responsible entity for aggregating energy consumption information, and for making it available to the Content Provider (e.g., OTT Platforms, Social Media Platforms and XR Providers) for displaying it on the application to the End-user.

The Energy Supplier assumes the roles of Energy Aggregator, combining the production or consumption of energy from multiple small producers or consumers to participate in the energy market as a single entity, and Energy Retailer, selling electricity to all stakeholders maintaining network or cloud infrastructure, as well as end-user devices, providing billing, customer service, and energy management services. The Energy suppliers also provide energy related information (e.g., CO_2 emission) to the MNO and Content Provider.

2.5.3 ENERGY DEPENDENCIES

The energy dependencies among the stakeholders are shown in Figure 13, along with a high-level diagram of business relationships at a (higher) stakeholder level.

The decision of End Users on when and which type of service to start consuming affects the energy consumption of the Content Provider that will receive the content created by the End User's device or deliver the content or service requested by the End-user's device. The end-user has a direct business relationship with the MNO and the content provider but does not have a direct business relationship with the Content Host provider, including the edge computing service that the MNO provides when having excess capacity to content providers. The business relationship for exploiting the excess capacity available at the MNO is between the MNO and the content provider.

Although end users do not have a direct business relationship with the Content Host, their decisions may impact on the energy consumption of the Content Host and the available excess capacity of MNOs.

The content provider strategically decides when and where to distribute the content for processing (e.g., to the MNO edge network or a third-party content host service provider), thereby exerting direct influence on the processing load and energy demands of MNOs or other Content Host providers. Content providers must ensure adequate storage, processing capabilities, and energy efficiency.

Across the energy chain of dependencies, the Energy Supplier plays a critical role by providing energy to sustain operations primarily across MNO, Content Host and Content Provider. These energy demand depends on the decisions of End Users, as previously elaborated. The Energy Supplier dynamically adjusts the energy supply to meet fluctuating demand.

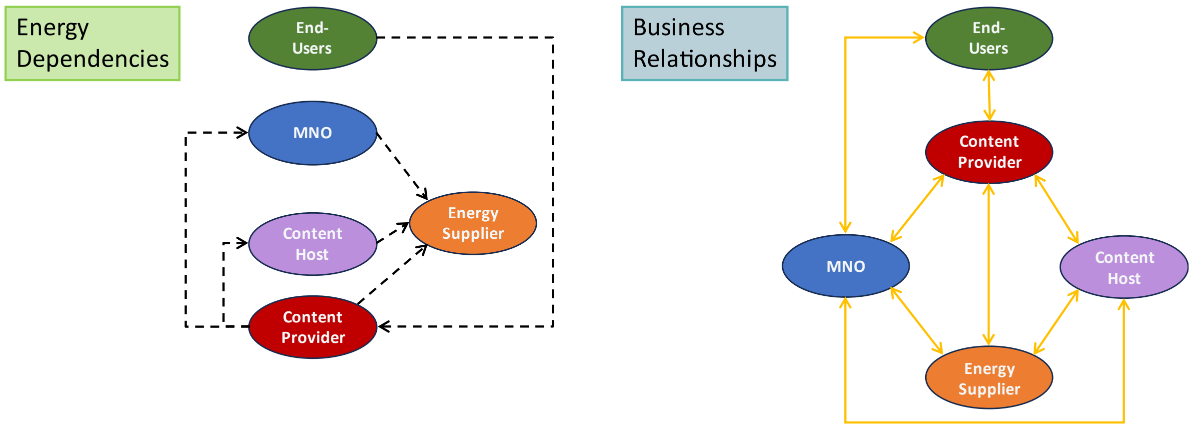

Figure 13: Energy dependencies and business relationships for UC14

2.5.4 VALUE PROPOSITION

Value captured

The "Green Network Orchestration on The Edge" use case primarily aims to reduce the environmental impact of ICT by leveraging the local Edge computing excess capacity of MNOs. This use case provides significant benefits to all stakeholders, including raising environmental awareness among End-users about their contribution to reducing CO_2 emissions. This empowers End-users to make informed decisions and allow them to adapt their service usage considering the environmental impact of their decisions.

Furthermore, this use case enables more efficient utilization of the existing Mobile Edge Computing (MEC) infrastructure, potentially reducing the Product Carbon Footprint (PCF) by providing computing capacity that would otherwise require additional new infrastructure to meet increasing demands. MNOs can form strategic alliances with Content Host and Content Providers, enhancing revenue opportunities and return on investment.

Moreover, the edge computing service orchestration performed by Content Providers reduces the CO_2 footprint (e.g., during the use phase) by optimizing the use of existing Edge computing infrastructure closer to the user, creating significant benefits to the overall environment. Furthermore, users are informed of this positive environmental impact, and Content Providers and MNOs can increase their revenue by attracting more users by offering these new green, energy-efficient services.

Finally, end users gain additional benefits by extending the processing capabilities of their mobile devices through edge computing, allowing them to access new services in an environmentally responsible manner.

Challenges and risks

Besides the identified benefits there are also challenges associated with the implementation of this use case.

First and common to other use cases related to energy efficiency as a service, implementing this use case leads to additional costs and energy consumption to integrate new functions into the network to compute the CO_2e savings that are displayed to the end user. These functions are at the same time used by the use case to optimize the use of Edge computing resources (e.g., energy consumption and CO_2e), which is expected to provide a positive economic benefit to MNOs, that is also part of the challenge.

Finally, there is no associated incentive provided to end users in this use case, and some users might not recognize the value of receiving CO_2 saving and energy consumption information or might not understand how it can benefit them.

Opportunities

There are several opportunities identified when implementing this use case.

First, the MNO can optimize the use of their existing Edge computing infrastructure and renewable energy. By being environmentally friendly, MNOs can attract more users through partnerships for the new environmentally aware services and content creation, contribute to sustainability goals, and enhance their brand reputation by promoting eco-friendliness.

Another opportunity provided by this use case is that Content Providers can expand their market by offering the service to users with devices that have lower processing requirements and lower prices. For example, complex XR services can be provided to users that utilize XR Glasses with lower hardware processing capabilities.

Finally, Energy suppliers can gain new revenue opportunities by providing energy-related information (e.g., CO_2 emission) to MNOs and Content Providers.

2.5.5 CHALLENGES AND NEXT STEPS

The main challenge lies in the potential adoption by MNOs for sharing access to their Edge computing resources which are used for their network functions. Traditionally, MNOs design their networks for worst-case traffic conditions (e.g., Busy Hours forecast), resulting in excess capacity during off-peak hours. This excess capacity can be better utilized by this use case, ensuring that the MNO's network performance is never at risk of being negatively affected and that network security is by no means compromised. Another challenge can arise for Content Provider regarding the QoS that can be provided to their End users if they need to be pre-empted from the MEC by the MNO.

2.6 UC 15: GREEN SOCIAL MEDIA & EMAIL DOWNLOAD

2.6.1 OVERVIEW OF THE USE CASE

This use case targets carbon neutrality, specifically in the scope of social media and email applications. Basically, this use case provides new revenue opportunities to MNOs additionally to the technical service flow of self-produced green energy sources. To achieve this, this use case reduces 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. It describes an approach to enable environmental awareness and engagement among billions of social media users and email users worldwide. Opportunities consider optimizing the usage of self-produced renewable energy at Base Stations and the cellular network capacity through CO_2-based user incentives, raising environmental awareness and brand reputation, and contributing to net-zero goals.

2.6.2 ECOSYSTEM – STAKEHOLDER IDENTIFICATION & ROLES

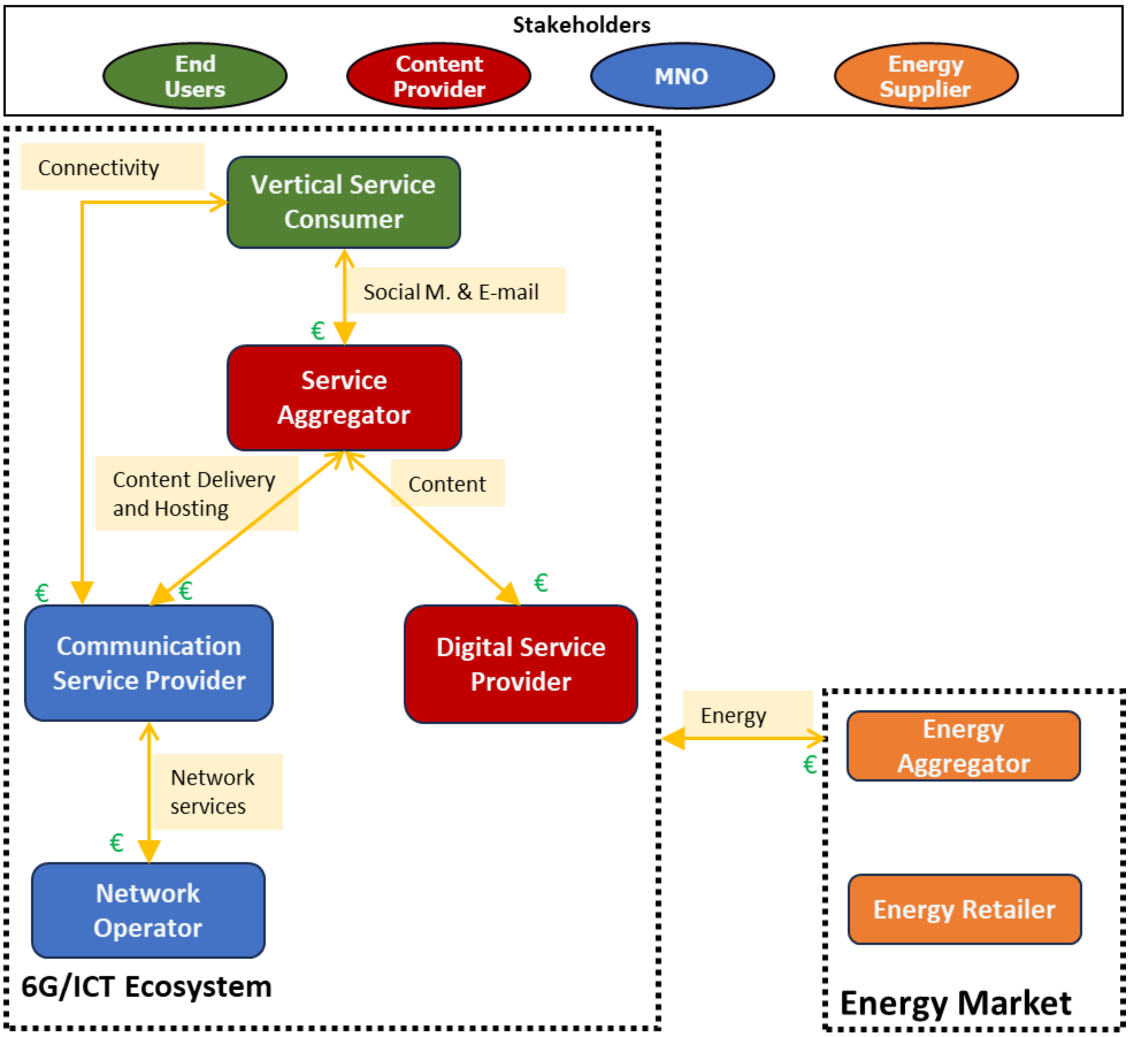

Figure 14: Stakeholder identification for UC15

This use case considers the following as the stakeholders:

- **End-users:** individuals who use their connected devices to access e-mail or social media services, and are able to configure the respective apps indicating that they want to postpone the download of attachments (i.e., the text part of the message is not postponed) to a moment in time when a high rate of renewable energy is available and/or the radio signal conditions are favourable.
- **Content provider:** Entities providing a social media and e-mail platform and apps for users to connect, share information, and build online communities, or to access e-mail and e-mail exchange services. Also subbed as "External Green Content Delivery (GDC) Server"
- **MNOs (Mobile Network Operator):** Entities providing the necessary network infrastructure, such as 5G/6G connectivity and Edge computing resources (e.g.,

Data Centres used for Network Functions), to enable the service. Additionally, some of the MNO's cells have self-produced energy, and is able to broadcast renewable energy rate information to listeners.

- **Energy Supplier:** plays the role of energy aggregator, combining the production or consumption of energy from multiple small producers or consumers to participate in the energy market as a single entity, and Energy Retailer, selling electricity to all stakeholders maintaining users and content providers and/or MNOs (in case MNOs do not get sufficient energy supply from their self-produced green energy sources), providing billing, customer service, and energy management services. The Energy suppliers also provide energy-related information (e.g., CO_2 emission) to the MNO and Content Provider.

2.6.3 ENERGY DEPENDENCIES

The MNO energy is self-produced in some cells, and the forecast does not depend on the exchange of Energy suppliers' incentives or exchange of green energy window information. Social media sources and email services requested by end users (i.e., Vertical Service Consumer) define the selection of network path and computing capabilities utilized. This selection could be aligned with the periods of high green energy self-produced at the serving site, which potentially contribute to the reduction of carbon footprint. The developed Green & energy efficient UE-assisted RAN protocol combines self-produced removal energy & forecast, cell broadcasting, and the received signal strength and quality for Energy Efficiency Optimization. Across the energy chain of dependencies, the Energy Supplier plays a critical role by providing energy to sustain operations primarily across users, MNOs (if needed) and Content Providers. It is highlighted that in this use case the energy demand of MNOs depends on the decisions of cell selection, as well as the energy supply from the self-produced green energy resources in the cells.

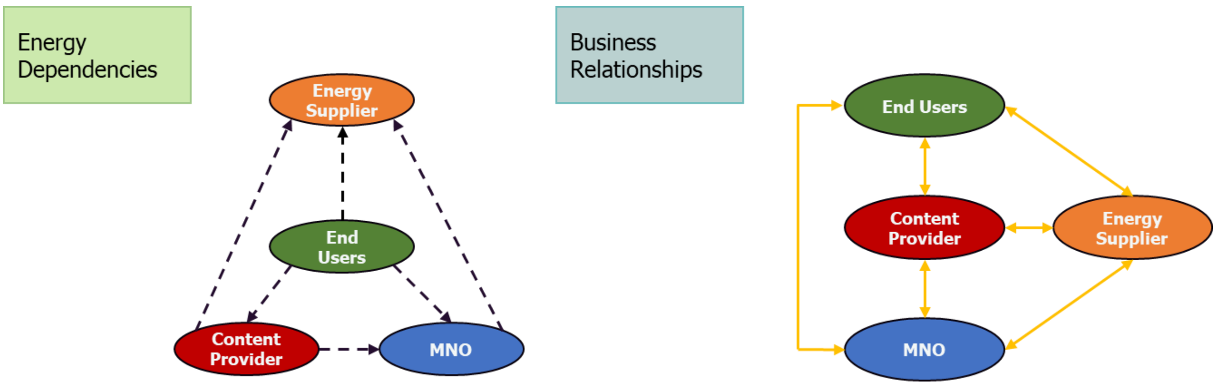

Figure 15: Energy dependencies and business relationships for UC15

2.6.4 VALUE PROPOSITION

This use case targets carbon neutrality, specifically in the scope of social media and email applications. Consequently, there is significant value brought by the UC, but also questions and opportunities.

Value captured

UC15 contributes to the energy consumption optimization in the scope of social media and email applications, which utilizes services when located within one MNO site with a high ratio of self-produced renewable energy. Regarding the stakeholders involved, UC15 ensures that end users still receive services with the fulfilment of SLA. On the other hand, content platforms (social media and mailing) could also be ensured with the SLA-fulfilled service delivery, meanwhile reducing energy consumption during the process. Network service providers could also have transparency of energy consumption monitoring of each single entity involved in the service chain, which will further contribute to the energy consumption reduction in this stakeholder. UC15 also provides new revenue opportunities to MNOs in addition to the technical service flow of self-produced green energy sources.

Challenges and risks

There are some challenges embraced by UC15.

In general, new functions introduced by UC15 might increase energy consumption, decreasing energy consumption reduction achieved by the UC.

From the perspectives of end users, subscription of "green social media and email content download" might not be transparent to the users, e.g., threshold of the carbon reduction and influence on QoS of the services the users receive, etc. Extra efforts from the users might need incentives of potential price discount, as expected by the users.

To the content platforms, promised network services might not be fully used by content providers which might cause resource waste, e.g., latency and data rate requirements of email services might be lower than certain social media platforms (e.g., video streaming of whatsapp, etc.). Content providers might also face a hazard of loss of users, due to the extra need from the users. Another issue falls to the resource waste from the perspective of content providers, where not every service requested by the users need energy efficient solutions. Expectation from the users to be rewarded due to their efforts towards carbon neutrality might also cause extra cost to the content providers.

Besides, services (e.g., developed RAN protocols) provided by the network service providers might not be fully operated, when some cells do not have self-produced energy. In this case, they might have to put extra expense for carbon neutrality (e.g., acquisition of energy/carbon related data, cost of more complicated management processes, delay caused by cell selection, storage of self-produced energy, etc.). CO_2 credit incentive might only cover the users, instead of network providers.

Opportunities

There are opportunities identified and granted by the implementation of UC15, based on the challenges. Concretely, users might gain discount/ "substantial" reward due to their efforts towards carbon neutrality. Those content providers who manage to merge all the functions into one app for the end users might gain more market share. Network providers will also gain benefit by energy consumption optimization based on the AI/ML algorithms powered by energy consumption monitoring data collected.

2.6.5 CHALLENGES AND NEXT STEPS

At the Network Exposure Function NEF, this use case faces challenges, with the demand of new functions to request the admission-control based on the self-produced renewable energy ratio in a specified cell. Besides, NEF should perform the analytics related to CO_2 ratio admission-control based on high renewable energy ratio. The Network Data Analytics Function (NWDAF) also requires new functions, including the measurement of self-produced renewal and non-renewal energy flows at the site, data analytics related to the admission control, and energy policy control for the serving cell(s), and determination of the optimal thresholds for the high renewable energy ratio and received signal strength and quality.

3 CONCLUSION

This deliverable presented an innovative generic value network of the combined 6G and energy ecosystem of the future. The prior works on value networks for 3-5G have focused so far on the telecom/ICT players and on the vertical providers. On the other hand, this deliverable extended the state-of-the-art by accompanying the "typical" roles from the broader ICT sectors, with roles from the sector of smart energy grids that are relevant and important for the future 6G-energy ecosystem, towards the goal to verifiably improve the net energy consumption and, with it, the carbon footprints of ICT services in the context of next-generation mobile systems (i.e., 6G). The deliverable focused in the interplay between 6G and the energy ecosystems, identifying the stakeholder relationships, and also highlighting the interplay with energy dependencies, which influence the definition of incentive mechanisms. The latter will be the focus of a following deliverable that will focus on incentive mechanisms appropriate to motivate all stakeholders (from end-users to providers) to adopt energy efficient and carbon-aware behaviours.

Furthermore, this deliverable explored the future energy ecosystems for each of the use cases proposed by the Exigence project focusing on the interdependencies between energy consumption, carbon footprint, and stakeholder roles within the value chain of the future 6G-energy ecosystem. Based on the analyses presented in this document, it becomes clear that to achieve greater energy and environmental awareness - which is one of Exigence's main objectives - it is essential to address the situations holistically. While technical solutions deliver significant value to the ecosystem, it is crucial to go further and identify the stakeholders and their roles, understand their business relationships and energy dependencies, and analyse the overall impact that these interventions have on the ecosystem.

This comprehensive analysis helps us gauge the likelihood of acceptance of new solutions, allowing us to refine initial proposals to minimize adoption resistance and maximize value for all stakeholders. Additionally, it helps identify the support needed from other entities, such as policymakers, to achieve the desired outcomes. Recognizing that technical solutions do not exist in a vacuum enables us to complement them with other essential approaches, such as business incentives for consumers.

Ultimately, to reduce overall energy consumption and related emissions, it is essential to move beyond technical approaches and consider the broader interactions within the ecosystem.

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