Green Future Networks: KPIs and Target Values for Green Network Assessment

v1.0

www.ngmn.org

WE MAKE BETTER CONNECTIONS

GREEN FUTURE NETWORKS: KPIs AND TARGET VALUES FOR GREEN NETWORK ASSESSMENT

by NGMN Alliance e.V.

Version:	1.0
Date:	22.02.2023
Document Type:	Final Deliverable (approved)
Confidentiality Class:	P - Public
Project:	Green Future Networks
Project Lead:	Saima Ansari (Deutsche Telekom)
Editor:	Elena Meshkova (umlaut)
Contributors:	Javan Erfanian (Bell Canada), Saima Ansari (Deutsche Telekom), Lee Valerius (HPE), Marc Peters (IBM), Richold Van der Wal (KPN), Pary Arpoudam (Orange), Yuanyuan Huang (Orange), Ioana Lupu (Orange), Elena Meshkova (umlaut)
NGMN Programme Office:	Chris Hogg (Executive Programme Manager)
Approved by / Date:	NGMN Board, 25th January 2023

EXECUTIVE SUMMARY

The mobile industry – with its long-established history of acting and reporting on Environmental, Social and Governance (ESG) issues - has come together through NGMN Alliance to further address and accelerate the adoption of industry wide sustainability initiatives as part of our Green Future Networks programme. This publication addresses the challenge of developing Key Performance Indicators (KPIs) for Green Networks. KPIs are essential to enable operators to measure their progress against their sustainability goals and to act where needed to ensure they remain on target. However, at present operators take different approaches to what KPIs they report, and the methodologies used to calculate the KPI values. As operators face similar sustainability challenges – and as other stakeholders – investors, end-users – will increasingly wish to understand and review the sustainability of businesses – it makes sense to review the sustainability KPIs used in the industry and to seed the development of industry agreed KPIs. This publication takes up that challenge. A set of KPIs and target values is developed alongside a framework for consolidating these KPIs into an overall measure. The framework proposed encompasses two major pillars – Environmental KPIs and Energy & Quality of Experience KPIs. Energy and Quality of Experience KPIs are presented in a single pillar as we believe that greater energy efficiency should not negatively impact end-user Quality of Experience. Although the present set of proposed Energy and Quality of Experience KPIs treat each Energy and Quality of Experience as separate KPIs, possible future solutions for developing a combined KPI are suggested.

For each pillar – and for each KPI, discussion is presented regarding the rationale for the KPI, how to ensure consistency across the industry in its application, and how to set target values. Where possible, target values are proposed.

The following recommendations are made in relation to the adoption and use of Green Networks KPIs:

- There is a need for the industry to identify key metrics and develop a unified methodology for them.

- The industry should strive to develop and adopt KPIs that allow a higher level of granularity of reporting. For example, allowing operators to drill-down on the specific issues such as energy use in each part of the network – mobile, fixed, core – and ideally, at least for internal assessment, to the level of specific geographies and sites.

- It would be useful to define and adopt structured and evolving reporting standards to facilitate the evaluation of the KPIs in an automated manner.

Our proposals are intended to build upon and utilize the best practices of other telco sustainability benchmarking frameworks and related KPI definitions (such as ones proposed by GSMA [1]), and also leading consulting companies [2] [3] [4]. The KPIs and the review framework are presented as a first step. As the industry gains experience with the metrics, it is anticipated that the KPIs and the framework will be further developed to ensure that it is fit for purpose. This will include ensuring that the NGMN KPIs and framework continue to be aligned with work in other industry bodies – with the ultimate aim of ensuring a single set of industry wide agreed KPIs.

CONTENTS

01 INTRODUCTION

Climate change and its consequences represent the single largest common issue facing societies across the globe. Following the Paris agreement and more recently at COP27 in Egypt, governments – in acknowledgement of international scientific consensus of the source and effects of climate change – agreed measures to reduce carbon emissions through to 2050 with the aim of ensuring global warming does not exceed 1.5 °C warming [5] [6]. In light of these commitments, governments are effecting policy, regulatory and legal changes impacting their economies [7] [8] [9] [10]. Competitive industries are likewise responding to these challenges to align with the emerging regulatory environment and to ensure they can meet end-users' and investors' expectations [11] [12].

In many ways, the mobile industry has led the development of environmentally sustainable business models. For example, major operator groups in Europe, North America and Asia have produced Environmental Social & Governance (ESG) reports – some since as far back as 2001 - and today many have published their goals and strategies for reaching net zero emissions [13]. However, to fulfil these goals the industry – operators, manufacturers, advisors, and others – will need to work together to identify in-efficiencies in industry wide processes; share best practices; develop new industry wide requirements and standards; and help to shape and enable all other industries to use telecoms and IT to meet their own ESG goals. It is in this context that NGMN Alliance in 2021 launched its 'Green Future Networks' strategic project [14]. The project has already produced high-level analyses of the opportunities and challenges relating to energy efficiency [15], metering [16], eco-design and packaging [17] and Telco Supply Chain Sustainability [18].

In this publication we add to this body of work by outlining Key Performance Indicators (KPIs) and Methodologies for Green Networks. We believe that it is not only important to develop the tools, systems, processes, and technologies to enable the industry to become more sustainable – but that it is fundamentally important to enable the industry to measure and chart its progress in an open and transparent way.

There exists a number of organizations that assess either performance and user experience provided by a given network operator ("performance benchmarks") or the broader ESG and sustainability criteria without paying attention to the specifics of the service they provide [19] [20] [21] [22]. This NGMN white paper addresses the gap, and brings both aspects of network quality and sustainability together.

To encourage increased emphasis on sustainability while still accounting for the user experience delivered, NGMN Alliance has defined a **review framework that combines performance and quality of experience (QoE) KPIs with sustainability criteria** specifically tailored towards the telecommunications industry.

Having such a framework in place would allow operators to have a comprehensive view on their networks accounting for the environmental footprint and related KPIs as well as the delivered performance. A set of KPIs that take into the account current market behavior and trends would help operators to assess themselves both in the current and the historical context, delivering the necessary market push towards the green evolution. It is crucially important that such an initiative is developed with a wide industry collaboration to ensure that recommended KPIs and their crucial values are supported and agreed upon by the key industry players. As a practical example we know that operators are often conservative in enabling energy saving features, as these might have, though usually minimal, negative effects on the QoE of a user. Allowing the operators to demonstrate that energy saving network optimization actions brings a lot in terms of improving of their and, thus, users' environmental footprint would improve public acceptance of such actions.

In this publication we present the overall process towards such framework design, including the selection and mapping of the individual KPIs, as well as requirements and constraints for such a benchmarking methodology.

02 PURPOSE AND SCOPE

One of the main objectives of this Telco-specific instantiation of the environmental pillar of the ESG benchmarking frameworks [23] is to be helpful to investors, corporations, and regulators in making informed decisions on taking action towards a sustainable economy by measuring and understanding environmental impact. While, for example, Carbon Disclosure Project (CDP) [24] is focusing on the impact of the efforts any participating company takes with regards to climate change, NGMN focuses on selecting environmental sustainability KPIs and the resulting review framework for the telecommunication companies. It specifically evaluates both the current impact of their networks on climate change, as well as their long-term strategy in this field, while considering the quality of experience delivered to the users.

Key goals for this work are:

- to establish globally applicable KPIs,
- to outline an evaluation methodology or, in other words, the review framework,
- discuss on motivation and challenges of the chosen KPIs,
- indicate key target values for these KPIs that are in line with the market state and regulatory initiatives.

In this first step, the benchmark will focus on high level sustainability indicators, followed by more detailed assessments at subsequent stages.

03 DEVELOPING GREEN NETWORKS KPIs AND THE REVIEW FRAMEWORK

The key design criterion for our review framework is to follow existing standards and frameworks and industry best practices to the extent possible and further develop these for the telecommunications industry. In particular, we consider standard ESG metrics, e.g. like the ones used in Global Reporting Initiative (GRI) and CDP KPIs, as well as ITU-T L. 1471, SBTI Net Zero standard, UNFCCC Race to Zero framework, and the up-coming ISO IWA42 deliverable [25] [26] [27] [28] [29] [30]. Meeting of environmental sustainability criteria often plays a key role in the public image of the companies, and even plays a role in financing and other monetary aspects.

Environmental KPIs are one of the three core components of the ESG criteria, and our focus here is to select a range of KPIs relevant to networks and refining those KPIs specifically to tailor for mobile network operators' business. The other two core components (Governance and Social matters) are not included in the scope of this document. We believe that instantiating the environmental criteria specifically to the end-to-end network view would provide valuable insights to operators on the improvement potential of their operations, while giving both realistic expectations based on world-wide operator data and the sustainability guidelines stated by the most proactive governments and consortiums like "The Climate Pledge" [11].

Another key objective in our framework design is to provide guidance and insights for our industry in improving their environmental footprints, without unduly jeopardizing the quality of experience for their end-users. We therefore provide a framework and target KPI values for the operators to strive for in each category, enabling them to assess their current networks and operations against currently achievable lowest environmental impact and greenest operations practices.

The framework we propose defines both the KPIs, which we consider important for the industry, as well as the key benchmark values for each KPI or the way to derive those based on the data available. The values are derived either based on the regulatory guidance or the "leading by example" principle, i.e. relying on the best achievement in the industry, and/or based in the industry landscape analysis. Those values are indicators for the companies to strive for and are based on the solid references in the field, thus they are realistic. This way an operator would have key KPIs highlighted alongside their values to reference against and aim at improvement.

To enable operators to compare themselves with these target KPIs it is important to define the respective KPIs to be fair across countries and different network deployment practices. For this, we, for example, suggest using different normalization strategies when discussing the energy intensity metrics, or even abstain from qualitative evaluation if we think that the current reporting practices for a particular KPI (e.g. Scope 3 CO2 emissions) are not mature enough.

Further, we focus on describing the relevant methodology, the KPIs and their thresholds, the respective challenges faced, and outline possible mitigation. All KPIs and assessments we propose are only dependent on data available from public reports of the companies themselves, or key third-party data sets. Confidential, company internal data was not used for this work. However, we consider the key recommended KPIs to be applicable with minimal changes for the internal assessment of the operator network.

3.1 HIGH-LEVEL DESIGN

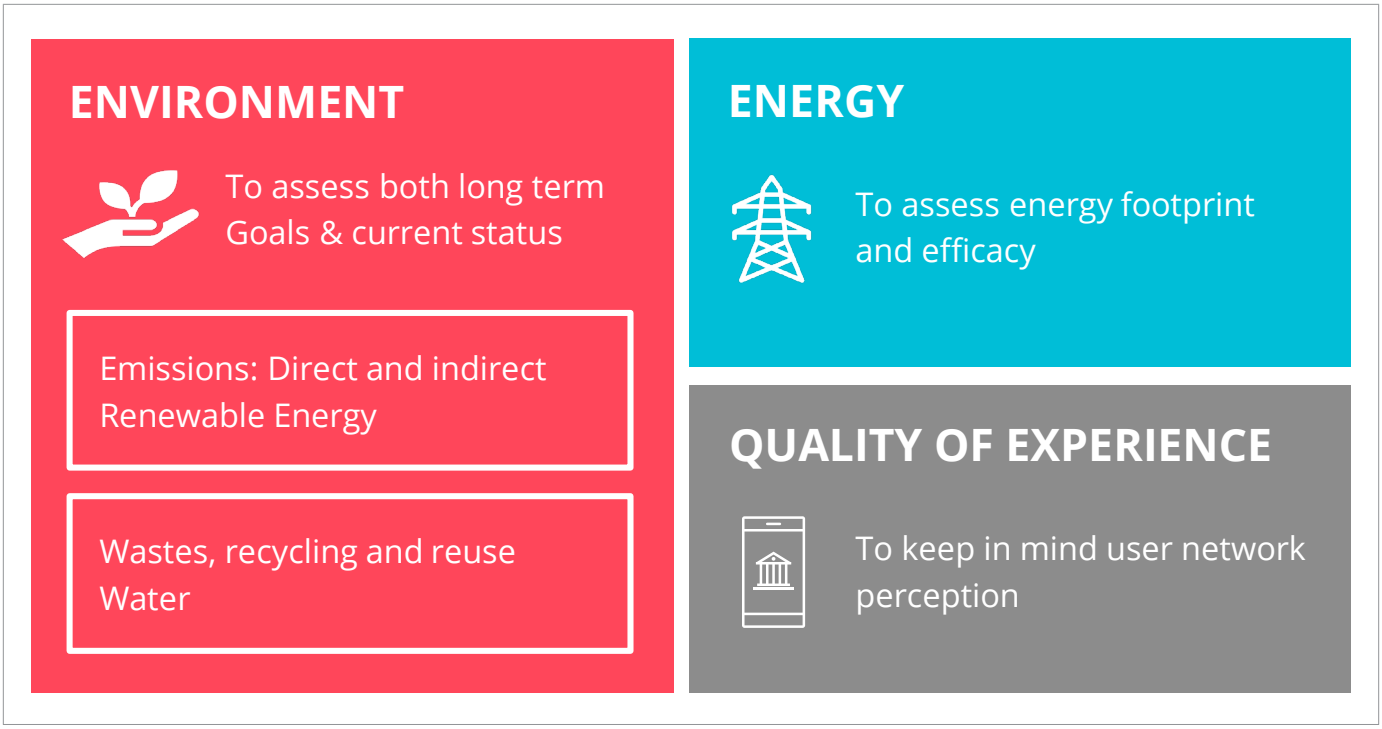

Figure 1: High level overview on the green KPI pillars along with QoE considerations.

In its current design, our framework is focusing on the two main KPI categories, or pillars, see Figure 1:

- **Environmental KPIs** – the CO2 equivalent emissions footprint [31] plays a major role in assessing the company impact on climate change. The circular economy efforts are another aspect of the environmental contributions of an operator. Those include waste generation and recycling activities, as well as use of additional resources like water. These KPIs are commonly available in the companies' sustainability reports. The pillar should also include KPIs that account for the long-term strategy of a company to operate with Net Zero emissions. As this is a long road likely lasting for nearly 20 years intermediate goals should be considered as well. Goals should include both direct and indirect emissions. Finally, a clear, realistic, and well-founded strategy towards the Net Zero is an essential item to be included in this KPI category[1].
- **Energy & Quality of Experience KPIs** – account for the total energy and electricity used by an operator, as well as the efficiency and intensity of its usage [17] [15]. All these criteria are crucial to understand different aspects of operators' network energy consumption (see Section 3.4). Energy KPIs need to keep a close link to quality of experience to keep transparency on the energy cost paid to achieve a certain level of network service quality.

This two-pillar approach is designed to be decomposable to individual constituent metrics, and to be measurable across different network segments, enabling companies to obtain actionable insight on how they can keep improving their KPI values in the future. Additionally, key KPIs are meant to be useful for internal green assessments (e.g., the ones focusing on green energy and energy intensity), by enabling operators to find domains for improvement on per region or even per-service or per-site level. These KPIs have also been selected to benefit from the metrics and principles presented in other NGMN publications and activities, for example [15] [17] [32].

[1] Currently we prefer to use the term Net Zero instead of carbon neutrality, as the latter, according to SBTi [29], is less strict and can include companies achieving their emission reduction goals through heavy offsetting instead of doing reforms aiming as reducing their own emission and emissions of the value chains. The ISO/CD 14068 standard under development [59] aims to clarify the ambiguity [8] of terms used currently.

Several of the KPIs we consider in this work are already widely used in the industry. Our proposals are intended to build upon and utilize the best practices of other Telco sustainability benchmarking frameworks and related KPI definitions (such as ones proposed by GSMA [1]), and also leading consulting companies [2] [3] [4]. Further in text we refer to the insights learned from some of these initiatives. Our focus is to highlight the opportunities and challenges of the chosen KPIs when considering the global context, and to comment on the key values of these KPIs.

We present here a first version of our framework, with the intention that it will be regularly reviewed and updated in the future. Sustainability and green networking are rapidly evolving topics, and any assessment frameworks related to them must also be regularly examined and updated if needed to ensure their continuous usefulness for our industry.

Finally, we have tried to ensure the results of our framework are as easy to communicate to all relevant stakeholders as possible. In particular, we suggest that the final outcome following the comparison against the target KPI values yields a familiar "energy class" from A+ to F, see Figure 2.

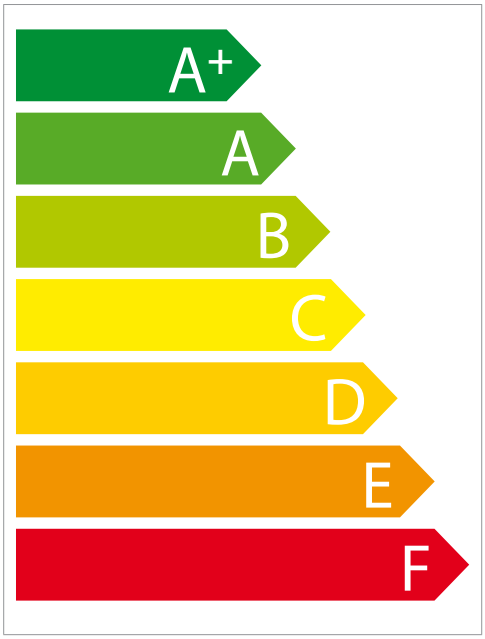

Figure 2: A typical label attached to home appliances to denote their energy efficiency classes.

3.2 FOCUS OF THE FIRST VERSION OF THE FRAMEWORK AND RELATED METHODOLOGY

After considering the publicly available data of nearly 40 operators world-wide (collected from their corporate and sustainability reports, as well as accompanying web sites and data sheets), we chose to concentrate the framework on data transparency and availability for majority of the KPIs (i.e. taking the qualitative approach). This approach maps loosely, through the choice of the KPIs, to the basic assessment done by CDP (the very popular general assessment initiative among operators) [33]. We further have carefully assessed and selected from the available KPIs for which the reporting is mature enough to enable their quantitative assessment. Examples of such 'mature' KPIs include business climate neutrality goals or percentage of green (renewable or low-carbon) energy used. These KPIs overlap with those proposed by GSMA [1] with the particular choice being guided, as said, by the maturity and availability of individual metrics in the public reporting. The KPIs values are set by applying well-justified mapping functions and thresholds. We also set KPI values based on the observed trends: for example the present KPI value proposed for energy consumption is based on historical operator energy consumption, but later as metrics reporting advances, we would consider additional KPIs, e.g., the ones that look at water, emissions or wastes. Generally, assessment of historical trends has an advantage that operators' data is compared to itself thus differences in reporting methodologies between companies play a smaller role.

In the following we describe the KPIs divided into two categories: environment and energy along with QoE. The KPIs and their thresholds are summarized in Table 1 and Table 2. Below we provide the discussion including the challenges faced for each of the KPIs. These Tables reflect the status quo of the industry based on the data and the inputs as of 2021-2022. Sections 3.3 and 3.4 further explain each KPI, related challenges, and chosen thresholds in detail.

Table 1: Environmental KPIs and their thresholds

	KPI Name	Target value Maximum threshold	Other thresholds
1	Sustainability reporting with audit	Sustainability report with the auditing company mentioned	
2	Net Zero goal is set	2040	2045, 2050
3	Sustainability goals set with a clear path to achieving these goals	Passed if a clear path to achieving Net Zero goals is indicated. The operators are advised to follow the ITU-T industry standards L1470 [25] and L1471 [26]. The best assurance is if climate targets are verified by Science Based Targets Initiative (SBTi) or another competent third party [28].	
4	Target to reduce Scope 1 & 2 to near zero	2025	2030, 2035
5	Target amount of scope 3 emission reduction by 2030 (emission reduction compared to 2010 or later)	45% 22% if Scope 1 & 2 are near zero	30%
6	Investing in carbon compensation	KPI met if an operator has started investigating solutions to deal with the residual emissions	
7	Direct emissions, Scope 1, reported	KPI met if reported as tCO2 or metric tonnes in CO2 equivalent	
8	Indirect emissions, Scope 2, reported	KPI met if reported as tCO2 or metric tonnes in CO2 equivalent	
9	% of electricity used that is generated from renewable or low-carbon sources.	100%	Above world (~40%) and/ or country average
10	Largest downstream and upstream categories from Scope 3 reported	KPI met if categories 1 [purchased goods and services], and 11 [use of sold goods] and/or 13 [downstream leased assets] are reported in tonnes of CO2 or mtCO2 equivalent	
15	Number of Scope 3 categories reported	15	Linear mapping to 0
16	Avoiding emissions through innovative services (optional)	KPI met if a company offers customers "greener" products or services, such as repairable or upgradable phone, smart IoT solutions, etc.	
17	Wastes reported	KPI met if quantity of reported wastes is reported either overall or in a subcategory	
18	Recycling & reuse reported	KPI met if percentages of recycled and reused goods are provided either overall or in a (product) subcategory e.g., mobile phones	
19	Water usage reported	KPI met if the volume of consumed water is reported	

Table 2: Energy and Quality of Experience KPIs and their thresholds

	KPI Name	Target value Maximum threshold	Other thresholds
1	Quality-of-Experience (QoE) assessment	The top possible category or class, e.g., outstanding as in Figure 7. Corresponds to very high percentage of the points/values achievable	Other QoE classes
2	Energy and electricity consumption reported	Passed if both the energy and the electricity consumptions are reported	
3	Historical trend of network energy and/or electricity consumption	Decreasing	Stable
4	Power Usage Effectiveness (PUE) of data centres reported	KPI met if the company wide value is reported	
5	Historical PUE trend of data centres	Decreasing (improving)	Stable
6	Energy intensityw	Difficult to set at the current stage, more investigation is needed, see related KPI discussion	May be derived from historical performance of the operators, see related KPI discussion

3.3 PILLAR 1: ENVIRONMENT

Sustainability reporting with the audit: This qualitative KPI [pass/fail] aims to capture that the company shows that is aware of the sustainability topic and accounts for it in a consistent and transparent manner, by providing clear sustainability reporting with audited figures (auditing provided by well-known and trusted organization in this space). Discussion & Challenges: Figures and fact provided by an operator come from internal sources, and those need to be audited independently, which should be clearly stated.

Net Zero goal is set: This is a qualitative KPI with the stepwise mapping that assesses the target year of achieving the Net Zero status [34]. The more ambitious the goal the better. Companies are to be in line with leading climate neutrality requirements posed by governments and leading industry initiatives [10] [11] [9] [8]. Furthermore, emissions reduction is key part of governmental and enterprise sustainability requirements, so having a roadmap for it is essential. Figure 3 shows the present distribution of Net Zero goals in the industry (sample size: 39 operators).

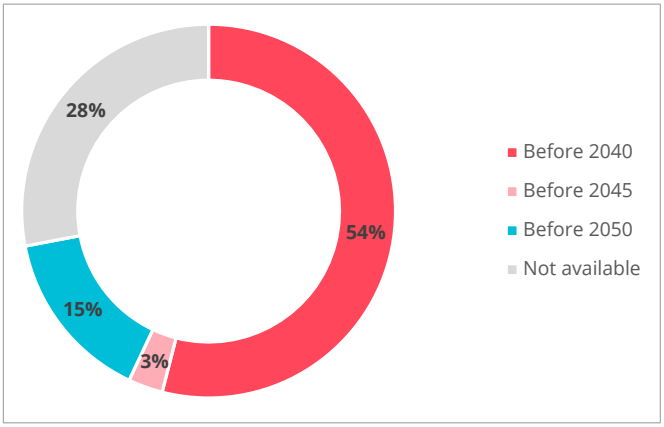

Figure 3: Climate Net Zero Goals as set by the operators. Assessment is done of the country level. The group level goals are assumed to be adopted on the country level. Data is for 2021-2022. Based on data from 39 operators.

Figure 3: Climate Net Zero Goals as set by the operators. Assessment is done of the country level. The group level goals are assumed to be adopted on the country level. Data is for 2021-2022. Based on data from 39 operators.

Sustainability goals set with a clear path to achieving these goals: There exist clear Net Zero targets originating from the Paris Agreement [5] and stated by many governmental bodies [7] [9]. Many companies declare their Net Zero targets as well. These goals need to be clearly stated and the well-founded roadmap for achieving those is to be developed. For climate targets, operators are advised to follow the ITU-T industry standards for reduction trajectories and Net Zero target setting, L.1470 [25] and L.1471 [26], respectively. The best assurance is if climate targets are approved by SBTi or another competent third party [28].This is a qualitative KPI [pass/fail].

Target to reduce Scope 1 & 2 emissions to near zero: This is the year based qualitative KPI, with stepwise mapping. Generally, it is easier for an operator to reduce its own Scope 1&2 footprint, the direct emissions, and the electricity-based indirect emission, rather than (indirect) Scope 3 emissions. Therefore, it makes sense, to set and track this target separately. The target values are based, among others, on the state of the industry review provided by GSMA [35]. Also, we consider that it would be difficult to meet the target of 45% overall carbon footprint reduction by 2030, pursued by UN [7] without eliminating the direct emission footprint of the company. Discussion & challenges: The major challenge of the direct footprint reduction brings is the backup energy provision for critical electricity infrastructure failures. This is often done through diesel generators. The alternative technologies, such as off-grid energy generation coupled with batteries for intermediate energy storage or hydrogen generators [36] are not mature yet. Therefore, this part of the Scope 1 emissions can be currently only offset, which is generally undesirable (for those along with avoided emissions do not count towards SBTs [37]).

Target of reducing Scope 3 emissions by 2030: As mentioned above, reducing indirect emissions of Scope 3 is a significant environmental challenge because the impact of these indirect emissions is much greater than Scope 1 & 2 emissions. Hence, it is important to set milestones to achieve the Net Zero target. This is a percentage-based target quantitative KPI with step-wise mapping, where the best value is awarded for the target of the 45% overall emissions reduction by 2030 as compared to 2010 as stated by UN [4]. From this statement the first threshold of 45% of Scope 3 follows under the assumption that Scope 1 & 2 are being reduced proportionally. However, if one considers that Scope 1 & 2 go to near zero till and assuming that Scope 3 is about 70% of total emissions [36] then the threshold is set to 22% (to reflect that less scope 3 emissions reductions are needed in this case because scope 1 and 2 emissions are already near zero). Discussion & challenges: Some of the companies provide the estimates for emission reductions for other years like 2025 or 2035 or 2040, which complicates the projection of the company plans for the target year of 2030.

Investing in carbon compensation: To achieve the Net Zero carbon target, even if the maximum efforts have been made to reduce CO2 emissions from Scopes 1, 2 and 3, there will still be residual emissions. It is important to start the negotiation from now to reconstruct the ecosystems, investigate and invest in compensation mechanisms. This is a quantitative KPI.

Direct emissions, Scope 1, reported: Transparency of emissions reporting is important for keeping track of the sustainability evolution of a company.

Indirect emissions, Scope 2, reported: Transparency of emissions reporting is important for keeping track of the sustainability evolution of a company. Through most of the companies already report Scope 2 emissions, the form of reporting is not fully established yet. For example, it is not always clear if market- or location-based Scope 2 is reported (please refer to for the clarification of the difference in [38] [39]). Currently, as the first step towards establishing realistic green KPIs that are available or easily obtainable in the industry, we consider that it is more beneficial to quantitatively assess the percentage of renewable or low carbon (e.g. nuclear) energy that the company is using that is the major contributor of Scope 2.

Share of renewable or low-carbon electricity used: Renewable electricity is the major influential factor on the Scopes 1 and 2 for the Telecom sector [36], i.e., the emissions that an operator can relatively easy influence and reduce. Also, this is a relatively easy KPIs to track and report. Thus, we consider the share of the renewable and nuclear electricity currently one of the dominant quantitative KPI among green KPIs we discuss here. This is a qualitative KPI (stepwise or stepwise linear mapping) with a maximum possible score of 100%. However, we understand that currently it is almost impossible for some operators due to, e.g., existence of difficult to replace diesel generators that are also used to power poorly reachable sites. Thus, for particular geographies the above goal can slightly relaxed if justified. Further criteria are derived based on the comparison with the world average for renewable electricity consumption (with or without nuclear share being added on top, currently ~30%/40%, respectively) [40]. Also, the criteria might include the comparison to the nationwide portion of the renewable or low-carbon energy of an operator [41].
Discussion & challenges: It is disputable if one should consider the state of the local market when assessing the renewable electricity share. From one side it is already great if an operator is using more renewable energy than the local average. From the other all should strive for the ultimate goal of 100%.

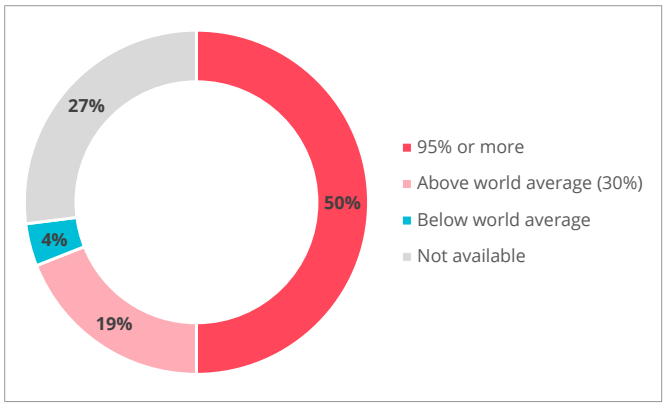

Figure 4: Distribution of companies reporting on their renewable or nuclear electricity consumption as percentage of the overall consumption. Data is for 26 operators for 2021-2022.

Largest downstream and upstream categories from Scope 3 reported: Scope 3 emissions are dominating the environmental footprint of an operator, but traditionally are hard to track in detail. Establishing transparency into how they are formed is critical for understanding the overall emissions of the business. The first step in this direction is to report the categories that are the largest for the operators. This is a qualitative KPI, passed if categories 1 [purchased goods and services], and 11 [use of sold goods] and/or 13 [downstream leased assets] are reported in tonnes of CO2 or mtCO2 equivalent. NGMN will continue to assess this area and may add further scope 3 categories to this scope 3 reporting KPI in the future.
Discussion & challenges: There exist different methodologies for calculating Scope 3, therefore absolute numbers of Scope 3 reporting can vary significantly between the operators even with the similar ecological footprint [42] [43]. It is important that operators become transparent on the methodology they employ, if possible, converting to the more precise ones [44] [45]. Otherwise, it would be very difficult to move to the quantitative assessment of this KPI.

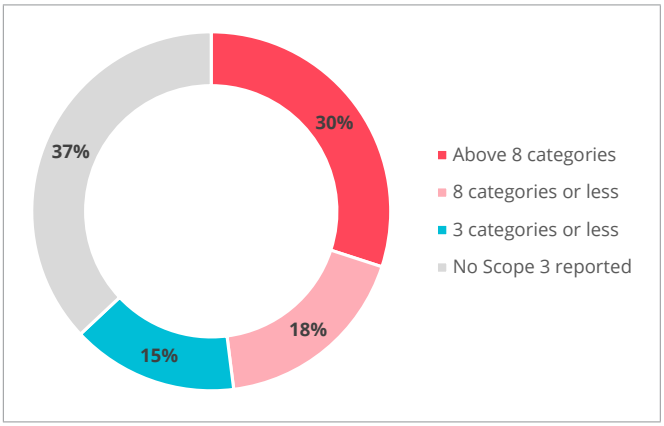

Figure 5: Number of Scope 3 categories reported by the operators at least on the group level worldwide. Based on data for 27 operators for 2021 or 2022.

Indirect emissions reporting: number of Scope 3 categories reported: This is a complimentary to the previous KPI metric. It allows us to bring the focus on how far operators are in their journey to Scope 3 accountability. The KPI counts the number of Scope 3 categories reported, with non-applicable categories being explicitly mentioned with a short motivation. This is a quantitative KPI with linear mapping, the outcome being proportional to the number of Scope 3 categories reported by an operator, including the non-applicable ones. Maximum is 15 categories.

Avoiding Emissions through Innovative Services: Mobile and fixed operators are the key enables for emission reductions for their customers through innovative "green" services and products. Some name those as part of Scope 4 or avoided emissions. The example enablers are extension of life of the products, or enablement of smart utilities and homes [46] [47]. It is important that operators are credited for their customer directed innovative efforts toward the greener future. This is a qualitative KPI [pass/fail]. Discussion & challenges: Avoided emissions is a disputed topic currently, for example SBTi does not count those towards Net Zero goal achievement, but suggests to report those separately [37] . From the other side operators widely report on their initiative to enable emission- saving initiatives for their end-users. There is also no established methodology to estimate the impact on the climate of the offered services in terms of the reduced emissions. Thus, though it makes sense to consider the innovative services as part of the "green transformation" journey, one can currently only assess if the company has offerings that aim to lower the carbon or waste footprint of their end-users.

Wastes reported: Different types of waste are an important contributor to the overall environmental impact of a company. This is a qualitative KPI, passed if quantity of reported wastes is reported either overall or in some subcategory like the non-hazardous waste, hazardous waste or electronic/telecommunications waste.
Discussion & challenges: The industry players do not seem to converge into a single waste reporting framework. Thus, we recommend starting the journey by checking if reporting the wastes produced by the company overall is stated, with further evolution into subcategories.

Recycling and reuse reported: Recycling and reuse is a major driver to the circular economy. It is vital that a company is putting high efforts in this direction and is transparent on those. This is a qualitative KPI, passed if percentages of recycled and reused goods are provided either overall or in some subcategory like mobile phones.
Discussion & challenges: As with the wastes no subcategories that most of the industry is reporting are established. The trend seems to be to report on the percentage of the recycled user devices and the eco-design and refurbishments efforts. More efforts should be put into comprehensive reporting of the recycling efforts.

Water used: Water is one of the key world resources. It is important that operators pays attention to their water consumption and are transparent on its usage. This is a qualitative KPI, passed if the volume of consumed water is reported.

3.4 PILLAR 2: ENERGY & QUALITY-OF-EXPERIENCE

Energy metrics are vital for the Telco industry in the sustainability context. They influence Scope 2 and, in case of the non-electricity network sourcing, Scope 1 emissions. We also believe that energy consumption and efficiency, though not as pronounced in the ESG context, is important in determining the environmental footprint of the companies due to the continuous investments in the energy infrastructure, not to mention the impact of the current energy crisis.

Our second pillar consists of evaluation of energy consumption, efficiency, and intensity, measured by several key KPIs. Here we also include Quality-of-Experience (QoE) KPIs. We cannot consider energy related metrics without having QoE in the view, as these two types of KPIs impact each other. One can have very low energy consumption

by just having, say one 4G layer, but this would imply very poor user experience in densely populated area where a single coverage layer simply does not provide enough capacity for modern data hungry applications. On the other side, one can deploy excessive number of 5G layers to boost user experience only slightly, as there a very few applications that would currently benefit from extremely high data rates. At the same time an operator would have to continue maintaining many 4G layers for coverage and capacity reasons and because of existing user device base. This would lead to significantly increased energy consumption while providing very limited benefits to user network performance perception. To reflect this trade-off, we propose to view network energy intensity as a function of energy consumption over both service volume and quality of this service. As a very basic example energy intensity depends not only on the volume of data transferred, but also the throughput achieved:

Network energy intensity = Energy consumption / Service (volume, quality, ...)

More practically, bringing this concept to the high-level operator assessment, we propose a 2D view on energy and performance, which captures this trade-off (see Figure 6). Here on the Y-axis we would have user experience in the rough grades from poor to excellent. On the X-axis one would capture a general operator energy class, also in broad categories from A+ to E or similar. The final conclusion then could come as a look-up table, a grid, of these two metrics.

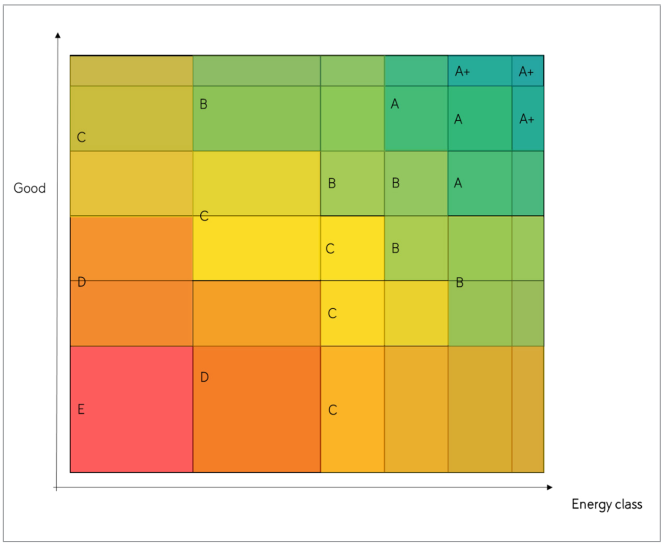

Figure 6: 2D view outlining one possible combination and mapping of the energy-related and QoE KPIs. Value of one metric can compensate or regress the other. Also, the split between classes is shown as not being even, as for example one can set the goal of achieving the top evaluation very hard and attribute a failure to a wide range of value. Clearly other 2D mapping functions are possible as well.

Further, we discuss the individual energy related metrics with regards to the Energy & Performance pillar. In Table 2 we summarized the thresholds for these KPIs. We also discuss briefly on the user quality-of-experience KPI, though it is not in the focus for this paper.

Energy reported: Energy consumption is key driver in the overall environmental footprint of a company, and enables measurement of several important derived KPIs, for example, energy intensity. This is a qualitative KPI, passed if the energy consumption is reported. Discussion & challenges: It is important to operate on accurate consumption figures rather than estimates.

Electricity reported: Some operators do not report energy consumption, just the electricity consumption. We want to enable qualitative KPI calculation in both cases if operators report energy or electricity. This is a qualitative KPI, passed if the electricity consumption is reported.

Quality of Experience: It is not a part of this work to define the methodology for estimating quality-of-experience. There exist a number of approaches some of which standardized [19], for QoE estimations [20] [48] [21] [49]. It is up to an operator or an interested party to choose and procure this KPI.

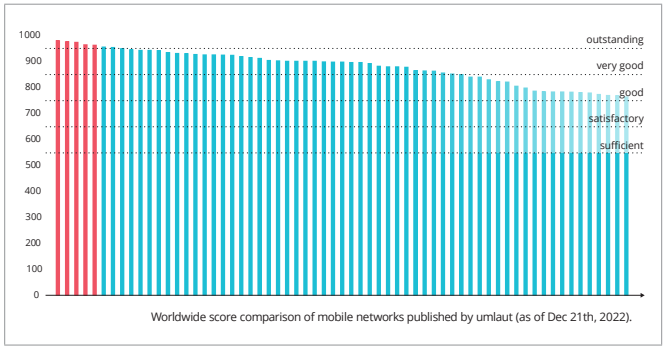

Figure 7: Possible conversion from the score points to the QoE classes for better understanding of the relative standing and further relation to the energy-related metrics [50].

Historical network energy or electricity consumption (total): This KPI shows how the energy or electricity consumption of a company is evolving, in particular, highlighting if the company is successful in reducing its energy consumption over time (or achieving expansion while retaining same level of energy consumed). This KPI reflects the "energy curve breaking" argument popularized in [51] [52]. The advantage of this KPI is that it compares the operator to itself (and thus there is no 'apples' to 'oranges' comparison as might be the case if the comparison was made – without normalizing the data - to other operators).

This is a quantitative KPI with the value being based on whether the trend line of consumed energy or electricity over the years descending, stays the same or increasing (unless there is a convincing reason for the jump, like significant increase in the coverage area or number of users). The best outcome is the steady decrease, but a stable power consumption is also acceptable in line with the "breaking the energy curve" argument.
Discussion & challenges: There can be a major network update, e.g., aggressive expansion of the network footprint. How to incorporate such an event into this KPI? One option is different normalizations, but then one needs to track regularly and ensure correctness of the normalization factors as well. Also, it is important to distinguish between a stable trend or a big jump versus yearly data fluctuations.

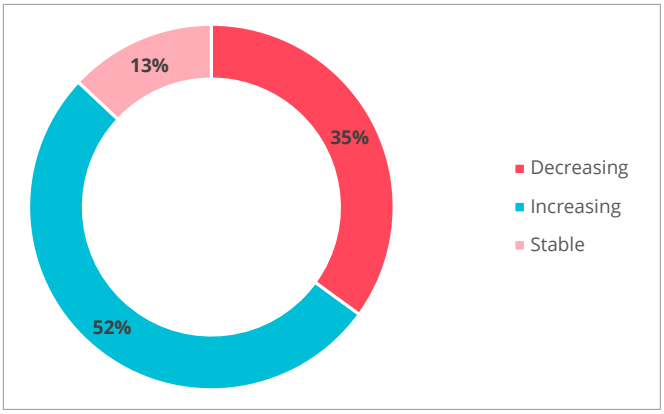

Figure 8: Overview of two-year historical energy and/or electricity consumption of operators worldwide. Based on data from 23 operators for 2021-2022.

Energy intensity: This measures the energy consumed in relation to the extent or volume of the service provided. In general, it is preferable to achieve similar service volume with less energy consumed, measured by lower energy intensity. This is a quantitative KPI. The energy intensity can be normalized over number of KPIs, such as customers, data volume, area [15] [53]. A mix of different energy intensity KPIs can help operators measure the relative efficiency of their networks in the era of multi-generational networks, including 2G, 3G, 4G and 5G. (See Figure 9 for a possible suggestion on the 2D combination of customer- and data-volume based energy intensities). Some of the normalization KPIs are discussed below, along with the threshold discussion.

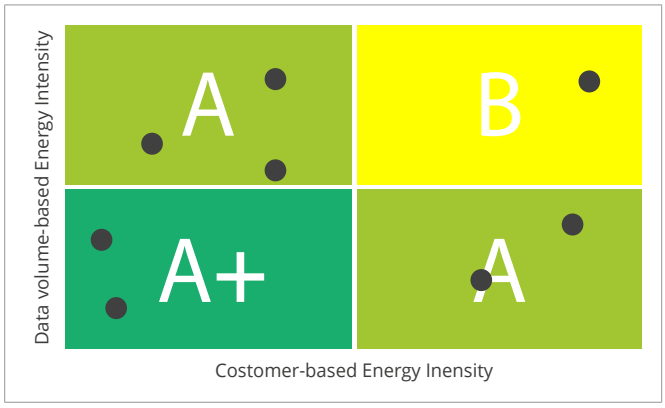

Figure 9: Possible 2D view on energy intensity normalized based on customers and data volume. Allows for a combined view of the energy intensity, potentially extensible to other normalization for a multi-dimensional consideration. (Black dots are actual operator data).

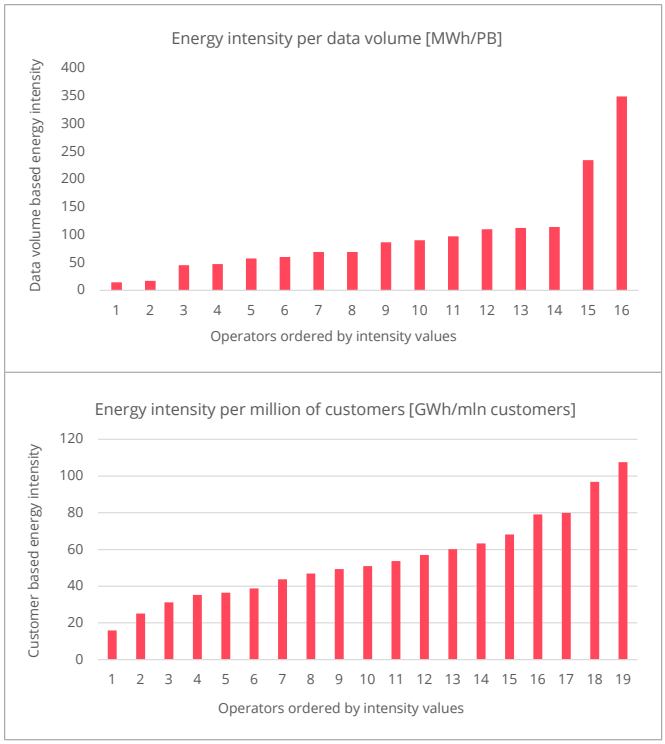

Figure 10: Energy Intensities based on number of customers estimates [GWh/million of customers] or the transferred data volumes [MWh/PB] in 2021.

Normalization of Energy KPIs: Below we discuss some common energy-related normalization approaches. We believe that further work is needed to determine, which

of these approaches and in which combination are the most important for an operator to account for its energy efficiency. Also, more work is needed to bring more reporting transparency on these factors:

- Normalization using data volume (e.g. data traffic per unit of energy consumption) is the most common and widely cited KPI. This metric is widely standardized. Based on the standard of ITU-T and ETSI [54], mobile network data energy efficiency is the ratio between the data volume and the energy consumption during the same period, expressed in bits/J. However, not all operators report it, and data traffic is not always measured in a similar way. Additionally, to only refer to energy intensity based on data traffic also introduces a risk where modelling of increased network energy use and related carbon footprint lead to exaggerated numbers. This has historically been an issue. See Figure 10 for sample data volume-based energy intensity.

- Number of connections per unit of energy consumption is another approach to normalising energy efficiency that highlights connectivity service provided to users and concentrates on small volume basic network service, with apps like surfing or messaging. Normalization over the customer base can be considered a practical proxy to this KPI, if the number of connections is not reported by an operator. The customer base is easier to estimate from the public sources (country population combined with the fixed and wireless market share of an operator), but it is not that precise. However, if advanced user performance KPIs are considered this weakness can be mitigated. See Figure 10 for sample user-based energy intensity.

- Energy intensity based on the coverage provided is another important energy-related KPI. It allows to account for the cases when the coverage is provided in places with few or no users like sparsely populated area or nature recreation zone (e.g. national parks). Operators are to receive credit if they spend energy providing coverage in such areas as these are important, among others, for the security reasons, but not necessarily bring sufficient revenue. The normalization part of this KPI can also be established by the third party provided there is a public information on tower locations as, for example, in Netherlands [55].

- Number of sites based energy intensity correlated with OSS network usage KPIs allows operators to directly relate to efficiency of energy usage in their RAN deployment. This KPI is mobile networks related and is particular useful for internal network assessment but might not be optimal for the high level operator assessment until the breakage of energy consumption into mobile network, fixed network, and core network parts becomes the industry norm.

- Finally, revenue based normalization allows for cross-industry assessment, but has issues on cross-national assessment as at least differing purchasing power of people in different countries needs to be accounted for. The normalization factor of this KPI is easy to obtain, which is a definite advantage to using this approach. However, it is difficult to translate this KPI on the level of individual network elements, like a cell based or service based. Another approach to consider is a ratio of IT and energy OPEX expenses over revenue that is related to EBITDA; it is to be investigated and built upon in the future [53].

Energy KPIs thresholds definition: It is difficult to define the highest desirable threshold for this class of KPIs at the moment. More research is needed to come up with realistic and achievable numbers. Currently one can consider only utilizing the “leading by example” principle that can be used for the intermediate thresholds. Here we can use the historical percentile driven principle. One could adopt high percentile from the previous year that only few operators have achieved and employ it as the “good” threshold for the coming year. Next year the percentile-based thresholds would automatically slightly increase as market leaders would further boost their performance. The thresholds would be attached to the historical (say two-year-old data) of the energy intensities of the operators. For example, the 20th best percentile for data volume driven energy efficiency for 2020 would denote the “good” threshold for 2022, and the 50th percentile would only denote the “average” threshold.

Discussion and challenges: The methodology for Energy KPIs might be challenging to develop especially due to differences in wireless vs. fixed energy intensities [56]as well as the wide range of choices that could be used for normalization. In the ideal case an operator would report separately the consumption of its fixed and mobile networks, so that those can be accounted in a distinct manner. Alternatively, the network power consumption (without the contribution of data centers) could be analyzed and a weighting given to the result based on roughly the share

of fixed and mobile business. Energy intensity per traffic volume, as well as generally the volumes of data pushed, differ significantly between mobile and fixed networks [56] [57].

Reporting of PUE of data centres: Data centers play an increasingly important role in the energy consumption and efficiency of network operators. Power Usage Efficiency (PUE) is the key KPI for measuring their efficiency. This is a qualitative KPI, passed if the company wide value is reported.

Historical PUE trend of data centers: This KPI, similar to the energy-related historical KPI, shows how the PUE of a company is evolving over time, highlighting if the company is successful in increasing its data center efficiency over time, aiming towards the ultimate goal of 1.0.

Discussion & challenges: At present, operators do not tend to report numbers for the PUE of their data centres therefore the challenge is to encourage reporting and to encourage its use in driving improvements over time and across the industry. For this reason, we suggest to approach the evaluation of this metric in two steps. First, we consider if the value is reported at all. Second, similar to the historical energy consumption evaluation, we evaluate the PUE historical trends. One could adopt the percentile approach described previously for energy intensity to derive intermediate thresholds for the PUE, while the ultimate goal of 1.0 PUE is well established.aAlternatively one can consider evaluation of the absolute PUE values based on the ISO/IEC 30134-2 [58]. The target PUE thresholds stated in [58] are 1.2 and 1.5 for the best and average performances, respectively (categories 3 and 2). We might adopt this approach in the next versions of the framework once more operators start reporting their PUE values.

04 SCORING METHODOLOGY

In this section we present our overall scoring methodology, mapping the individual KPIs in each pillar into a single familiar "energy class" or in our case "green class". To keep the methodology simple and transparent, we propose to map each individual KPI first into a numerical score, and only then map these scores into the overall class outcome. For this we need to specify the mapping function for each KPI. For qualitative KPIs this is straightforward. The mapping function would simply assign zero points if the underlying criteria are not met, and constant positive number of points if they are. For quantitative KPIs we need choose the range of values to be scored, the shape of the mapping function itself, as well as the number of points that can be achieved for this KPI at maximum. Currently most of the quantitative KPIs are using stepwise mapping with fixed thresholds.

We advocate for providing both a final assessment result, as well as intermediate results on per pillar basis. Per pillar results are the sums of the respective KPI results. The final class outcome can be obtained in two different ways. In the first approach, we can combine the scores from different pillars together into a single score, which is then in turn mapped into the energy class using chosen threshold values. In the second or alternative approach, we can make the mapping for each pillar in the "green class", and then combine the individual per-pillar energy classes into a single final energy class through, for example, majority voting. The second approach provides a direct input to the operators if they should concentrate on the environmental or energy-saving measures and is therefore preferable.

Nevertheless, having individual outcomes on per pillar or category basis is seen as being important so as to make it easier to identify improvement opportunities and to make it easier to interpret the individual results. It is also clear that the higher the transparency on the individual KPIs and their combinations the easier it is to prioritize on KPI improvement efforts. However, it is important also to have a single outcome of the evaluation that is easy to communicate.

We note that it is very important to review the methodology regularly, including updating the scoring ranges of the individual KPIs and regularly assessing the status of the KPIs in terms of whether they should be qualitative or quantitative, and in the latter case their thresholds. Such reviews should always consider a wide study of information sources, such as the sustainability reports published by the operators, and suggestions from other frameworks and standards or government bodies, as information availability is critical for meaningful scoring outcome. The outcome of such a regular review would be an updated review methodology that is guaranteed to be valid for a given time period (for example, a calendar year).

In this document we derived the desirable individual KPI ranges or, for few KPIs, described approaches how those ranges can be obtained. Reviewing these recommendations based on either changing regulatory inputs or operator performance landscape would lead to necessary, but well justified evolution of the KPI thresholds, keeping the review framework up-to-date.

05 RECOMMENDATIONS FOR THE ASSESSMENT

With this methodology we aim to support the continuous quality improvement of corporate sustainability reports. We have identified a set of KPIs which will enable operators to measure and manage their progress on their journeys towards increasingly sustainable operations.

Although many operators already report some KPIs, currently the reporting details can vary significantly between operators and groups, and the methodology and breakdowns provided can also differ for the same metrics. We strongly promote converting to a unified methodology for all key KPIs. Also, currently, certain KPIs are reported on the country level, while others are reported on the group level. Generally, the finer the granularity of reporting better the insights the company can get on its performance. For example, reporting all KPIs on the country level would allow local subsidiaries to gain better understanding of their performance in both the group and the local market context thus deriving actions for improving their standings. In cases where the same KPI can be estimated using different methodologies, it is also important to specify which is the source used, as there might be methodological differences behind the numbers especially whenever estimation is required.

We also encourage the development of structured reporting standards to facilitate the evaluation of these KPIs in automated manner. At the present time much of the data is only available in textual or graphical format in the different reporting documents, or in some cases in machine readable formats but with detailed specification and layout being heavily operator dependent. We advocate to use the initial division between qualitative and quantitative KPIs to highlight domains where further granularity and transparency are probably needed. In this initial version of the methodology many KPIs are chosen to be qualitative as the currently reported data is simply not ready for quantitative assessment.

Additionally, it is worth to emphasize that currently lack of higher level of granularity of reporting might lead to inaccuracies when an operator would want to understand its position in the world context. For example, as discussed, only very few operators report on their mobile and fixed network energy consumption separately, as the energy intensities for these networks differ significantly the operator energy intensity profiles would differ considerably depending on the mixture of the fixed and mobile business. Different assumptions are to be made to put such operators in the same context, which, of course might lead to inaccuracies in their positioning.

06 FURTHER WORK / NEXT STEPS

The current framework can be enhanced in several directions in the future. Perhaps the most fundamental extension would be to include differentiation between individual business segments, such as fixed line operations, mobile wireless connectivity, and operating data centers for internal and, possibly, customer use. As each of these domains have highly different energy consumption and performance characteristics, introducing such differentiation would further improve fairness, and would, in particular, support derivation of actionable insights from the individual KPIs and per-pillar scores. Of course, the major challenge here is the availability of the related data, as current corporate reporting is not commonly done on such fine level of granularity. Further the transparency of the sustainability reporting is key for such assessment improvements as well. The energy related KPIs can be improved further as the reporting matures, both in the direction of comprehensive multi-dimensional assessment of energy intensity and in terms of defining of the appropriate thresholds, as well as developing further the data-center centric metrics.

Another key direction for extension is to go beyond quantitative assessment of the energy related KPIs,to start considering other key sustainability drivers. Examples of these are CO2 emissions, especially of the Scope 3 as the most influential one, waste management performance, and various metrics related to recycling. Currently the reporting of the related KPIs is still relatively inconsistent, making most of them unsuitable for inclusion at the present time. However, we hope that with improved transparency and level of detail inclusion of these aspects can be considered in the future as well. The first step in the direction of the qualitative assessment would be the introduction of the historical evaluation, similarly, as done for the energy-related KPIs. This is the most robust quantifiable evaluation as it does not consider thresholds derived based on the market situation and employs only single operator data, which makes KPI calculation methodology transparent and most coherent, thus avoiding the situations of comparing “apples” and “oranges”. The evaluation of the normalized values, similarly to the energy intensity proposal, would then come as the next step once the industry converges to a well-defined set of clearly articulated estimation methodologies that are, preferably, standardized as well.

Currently, we do not consider including any company specific measure employed by an operator as part of the developed KPIs, like fibre-centric upgrade of fixed networks or 2G/3G sunsetting. The decision on these measures is part of a company’s strategy. Rather we prefer to evolve the framework in the direction of quantitative assessment of the energy-, emission-, and circularity-related KPIs. We refer to the other documents developed by the community and industry for the guidance on the best practices [53] [52] [2].

We hope to be able to improve the temporal granularity and detail of the various goals towards Net Zero as stated in the KPI list. Currently, most companies give only few specific commitment dates, often coinciding with reaching net zero state for the corporation as a whole. Achieving regular statements and reporting of the progress towards individual targets would make it easier to gauge progress towards the Net Zero goal and provide further quantitative evaluation opportunities also in short to midterm. We also consider a possible future extension of our framework towards other ESG KPIs that are strongly influenced by the networking solutions, especially the “E” component.

We plan to take the Green KPI journey further towards enabling internal operator assessment. We will evaluate and bridge identified gaps between the high-level KPI used for company reporting that are in close connection to Net Zero goals, the company energy savings and QoE, and lower-level networking KPIs (like OSS data). These KPIs will be aimed to further enable drill-down to individual network elements (such as base stations) and services to enable assessment that could then be easily mapped towards high-level, company-wide, reporting. In this future work we will also integrate state-of-art KPIs discussed in the community, including the ones proposed by NGMN or other bodies like the GSMA.

07 REFERENCES

[1] GSMA, "ESG Metrics for Mobile," June 2022. [Online]. Available: https://www.gsma.com/betterfuture/wp-content/uploads/2022/06/ESG-Metrics-for-Mobile-June-2022.pdf
[Accessed 1 December 2022]

[2] ABI research, "Telco Sustainability Ranking: Leaders, Mainstream and Followers," 20 April 2022. [Online]. Available: https://go.abiresearch.com/lp-telco-sustainability-leaders-mainstream-and-followers
[Accessed 1 December 2022]

[3] STL Partners, "Telecoms sustainability scorecard," May 2022. [Online]. Available: https://stlpartners.com/tools/intro-to-the-sustainability-scorecard/
[Accessed August 2022]

[4] GlobalPartners, "ESG in Telecoms and Technology GDTMT-TR-S363," 5 August 2022. [Online]. Available: https://www.globaldata.com/store/report/esg-in-telecoms-and-technology-theme-analysis/
[Accessed 5 August 2022]

[5] UNFCCC, "Paris Agreement: Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21st Session, 2015: Paris)," 12 12 2015. [Online]. Available: https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[Accessed 29 11 2022]

[6] UNFCCC, "UN Climate Change Conference Egypt 2022, “COP27 Reaches Breakthrough Agreement on New “Loss and Damage” Fund for Vulnerable Countries”," 20 11 2022. [Online]. Available: https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and-damage-fund-for-vulnerable-countries
[Accessed 29 11 2022]

[7] UN, "United Nations NET Zero Coalition, “For a livable climate: Net-zero commitments must be backed by credible action”," 8 11 2022. [Online]. Available: https://www.un.org/en/climatechange/net-zero-coalition
[Accessed 29 11 2022]

[8] N. e. a. Kaufman, "A near-term to net zero alternative to the social cost of carbon for setting carbon prices.," Nature Climate Change , vol. 10, no. 11, pp. 1010-1014, 2020.

[9] Net Zero Tracker, "Net Zero Tracker, Interactive world map with countries’ net zero goals," Net Zero Tracker, 29 11 2022. [Online]. Available: https://zerotracker.net
[Accessed 29 11 2022]

[10] State Treasury of Finland , "Climate Neutral Finland 2035," 2022 June 2022. [Online]. Available: https://www.treasuryfinland.fi/investor-relations/sustainability-and-finnish-government-bonds/climate-neutral-finland-2035/
[Accessed 29 November 2022]

[11] The Climate Pledge, "Be the planet's turning point. Join the world’s top companies—and take action now to reach net-zero carbon by 2040.," [Online]. Available: https://www.theclimatepledge.com
[Accessed 31 October 2022]

[12] Net Zero Tracker, "Data on Net Zero target for 2000 publically traded companies," [Online]. Available: https://zerotracker.net
[Accessed 31 Octobe 2022]

[13] Vodafone Group, Verizon, NTT DOCOMO, "ESG Report archives from Vodafone Group, Verizon, NTT DOCOMO," [Online]. Available: https://www.vodafone.com/about-vodafone/reporting-centre/sustainability-reports; https://www.verizon.com/about/investors/corporate-responsibility-report-archive; https://www.docomo.ne.jp/english/corporate/csr/about/pdf/

[14] NGMN Alliance, " NGMN ALLIANCE LAUNCHES GREEN FUTURE NETWORKS PROJECT," 28 October 2020. [Online]. Available: https://www.ngmn.org/ngmn-news/press-release/ngmn-alliance-launches-green-future-networks-project.html
[Accessed 28 November 2022]

[15] NGMN Alliance, "NETWORK ENERGY EFFICIENCY," 9 October 2021. [Online]. Available: https://www.ngmn.org/wp-content/uploads/211009-GFN-Network-Energy-Efficiency-1.0.pdf
[Accessed 29 November 2022]

[16] NGMN Alliance, "Metering for sustainable networks," 15 January 2022. [Online]. Available: https://www.ngmn.org/publications/metering-for-sustainable-networks.html [Accessed 29 November 2022]

[17] NGMN Alliance, "Green Future Networks Network Equipment Eco-Design and End to End Service Footprint.," 19 July 2021. [Online]. Available: https://www.ngmn.org/wp-content/uploads/210719-NGMN_Green-future-Networks_Eco-design-v1.0.pdf [Accessed 29 November 2022]

[18] NGMN Alliance, "Telco Supply Chain Sustainability," 17 January 2023. [Online]. Available: https://www.ngmn.org/wp-content/uploads/230117-NGMN-GFN_Supply-Chain-Sustainability_v1.0.pdf

[19] ETSI, "TR103559 Speech and multimedia Transmission Quality (STQ); Best practices for robust network QoS benchmark testing and scoring," August 2019. [Online]. Available: https://www.etsi.org/deliver/etsi_tr/103500_103599/103559/01.01.01_60/tr_103559v010101p.pdf [Accessed 29 November 2022]

[20] Ericsson, "Ericsson blog on QoE," 18 January 2022. [Online]. Available: https://www.ericsson.com/en/blog/2022/1/who-cares-about-peak-download-speeds-in-5g [Accessed 29 November 2022]

[21] Umlaut, "Benchmarking," 2022. [Online]. Available: https://www.umlaut.com/en/benchmarking [Accessed 29 November 2022]

[22] Global Reporting Initiative (GRI), "ESG standards, frameworks and everything in between," 10 April 2022. [Online]. Available: https://www.globalreporting.org/media/jxkgrggd/gri-perspective-esg-standards-frameworks.pdf [Accessed 29 November 2022]

[23] GTM Hub, "ESG Frameworks," 2022. [Online]. Available: https://gtmhub.com/resources/articles/esg-frameworks [Accessed 1 December 2022]

[24] CDP, "Carbon Disclosure Project," 29 November 2022. [Online]. Available: https://www.cdp.net/en [Accessed 29 November 2022]

[25] ITU-T, "L.1470 Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement," 12 January 2020. [Online]. Available: https://www.itu.int/rec/T-REC-L.1470 [Accessed 1 December 2022]

[26] ITU-T, "L.1471 Guidance and criteria for information and communication technology organizations on setting Net Zero targets and strategies," 21 September 2021. [Online]. Available: https://www.itu.int/rec/T-REC-L.1471 [Accessed 1 December 2022]

[27] ISO, " IWA 42:2022, Net zero guidlines," 1 November 2022. [Online]. Available: https://www.iso.org/standard/85089.html [Accessed 1 December 2022]

[28] Science Based Targets Initiative (SBTi), "Science Based Targets Initiative," 2022. [Online]. Available: https://sciencebasedtargets.org/ [Accessed 1 December 2022]

[29] Science Based Targets Initiative (SBTi), "Net Zero jargon buster - a guide to common terms," 24 November 2021. [Online]. Available: https://sciencebasedtargets.org/blog/net-zero-jargon-buster-a-guide-to-common-terms [Accessed 1 December 2022]

[30] UNFCCC, "Race to Zero Campaign," 2022. [Online]. Available: https://unfccc.int/climate-action/race-to-zero-campaign#Minimum-criteria-required-for-participation-in-the-Race-to-Zero-campaign [Accessed 1 December 2022]

[31] EC Eurostat, "Statistics explained: Carbon Dioxide Equivalent," 9 March 2017. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Carbon_dioxide_equivalent [Accessed 1 December 2022]

[32] NGMN Alliance, "Green Future Networks Sustainability Challenges and Initiatives in Mobile Networks.," 19 July 2021. [Online]. Available: https://www.ngmn.org/wp-content/uploads/210719_NGMN_GFN_Sustainability-Challenges-and-Initiatives_v1.0.pdf [Accessed 1 December 2022]

[33] CDP, "Scoring introduction 2022," 11 March 2022. [Online]. Available: https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/000/233/original/Scoring-Introduction.pdf?1639144388
[Accessed 1 December 2022]

[34] IPCC, "IPCC Glossary, Net Zero definition," 2022. [Online]. Available: https://www.ipcc.ch/sr15/chapter/glossary/
[Accessed 1 December 2022]

[35] GSMA, "Mobile Net Zero: State of the industry on Climate Action," April 2021. [Online]. Available: https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.pdf
[Accessed 1 December 2022]

[36] Oliver Wyman, "THE NEXT LEVEL OF EMISSION REDUCTIONS IN TELECOM OPERATORS," May 2021. [Online]. Available: https://www.oliverwyman.com/our-expertise/insights/2021/may/next-level-of-emission.html
[Accessed 1 December 2022]

[37] Science Based Targets Initiative (SBTi), "SBTi Manual on offsetting," April 2017. [Online]. Available: https://sciencebasedtargets.org/resources/legacy/2017/04/SBTi-manual.pdf
[Accessed 1 December 2022]

[38] US Environmental Protection Agency, "Indirect Emissions from Purchased Electricity," December 2020. [Online]. Available: https://www.epa.gov/sites/default/files/2020-12/documents/electricityemissions.pdf
[Accessed 1 December 2022]

[39] GHG Protocol, "GHG Protocol Scope 2 Guidance," 2015. [Online]. Available: https://ghgprotocol.org/sites/default/files/ghgp/standards/Scope%202%20Guidance_Final_0.pdf
[Accessed 1 December 2022]

[40] Various, " World renewable energy status," [Online]. Available: https://www.iea.org/reports/global-energy-review-2021/renewables; https://lowcarbonpower.org/
[Accessed 1 December 2022]

[41] Our World In Data, "Example of individual renewable power levels," [Online]. Available: https://ourworldindata.org/grapher/share-electricity-low-carbon
[Accessed 1 December 2022]

[42] GHG Protocol, "Scope 3 assessment methodologies," [Online]. Available: https://ghgprotocol.org/sites/default/files/standards/Scope3_Calculation_Guidance_0.pdf
[Accessed 1 December 2022]

[43] Partnership for Carbon Accounting Financials (PCAF), "PCAF (2020), The Global GHG Accounting and Reporting Standard for the Financial Industry. First edition page 54.," 18 November 2020. [Online]. Available: https://carbonaccountingfinancials.com/files/downloads/PCAF-Global-GHG-Standard.pdf
[Accessed 1 December 2022]

[44] GHG Protocol, "Corporate Value Chain (Scope 3) Accounting and Reporting Standard (page 74)," September 2011. [Online]. Available: https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf
[Accessed 1 December 2022]

[45] GHG Protocol, "Product Life Cycle Accounting and Reporting Standard," September 2011. [Online]. Available: https://ghgprotocol.org/sites/default/files/standards/Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf
[Accessed 1 December 2022]

[46] GHG Protocol, "Scope 4 / Avoided Emissions," January 2019. [Online]. Available: https://ghgprotocol.org/estimating-and-reporting-avoided-emissions
[Accessed 2 December 2022]

[47] STL Partners, 2022. [Online]. Available: https://stlpartners.com/articles/sustainability/from-aspirational-claims-to-scope-4-time-to-tidy-up-telco-net-zero-enablement-claims/
[Accessed 2 December 2022]

[48] OpenSignal, "Open Signal Methodology Overview," 2022. [Online]. Available: https://www.opensignal.com/methodology-overview
[Accessed 1 December 2022]

[49] Rohde & Schwarz, "QoE in broadband telecommunication networks," November 2018. [Online]. Available: https://www.itu.int/en/ITU-T/Workshops-and-Seminars/qos/201811/Documents/S4P2-berger-slides.pdf
[Accessed 1 December 2022]

[50] Umlaut, "Benchmarking. The international score comparison 2022.," December 2022. [Online]. Available: https://www.umlaut.com/uploads/documents/202212_umlaut_InternationalScoreComparison.pdf
[Accessed 17 February 2022]

[51] Ericsson, "Breaking the energy curve," March 2020. [Online]. Available: https://www.ericsson.com/en/news/2020/3/breaking-the-energy-curve
[Accessed 1 December 2022]

[52] Ericsson, "On the road to breaking the energy curve," 2022. [Online]. Available: https://www.ericsson.com/4aa14d/assets/local/about-ericsson/sustainability-and-corporate-responsibility/documents/2022/breaking-the-energy-curve-report.pdf
[Accessed 1 December 2022]

[53] GSMA, "Blueprint for Green Networks," October 2022. [Online]. Available: https://data.gsmaintelligence.com/research/research/research-2022/a-blueprint-for-green-networks
[Accessed 1 December 2022]

[54] ETSI, "ES 203228 Environmental Engineering (EE); Assessment of mobile network energy efficiency v1.3.1," October 2020. [Online]. Available: https://www.etsi.org/deliver/etsi_es/203200_203299/203228/01.03.01_60/es_203228v010301p.pdf
[Accessed 1 12 2022]

[55] Antennekart.nl, "Netherlands maps and towers," 2022. [Online]. Available: https://antennekaart.nl/kaarten
[Accessed 1 December 2022]

[56] IEA, Fixed vs. wireless energy efficiency, see fig. 15, May 2019. [Online]. Available: https://www.iea-4e.org/wp-content/uploads/publications/2019/05/A1b_-_DC_WAN_V1.0.pdf
[Accessed 1 December 2022]

[57] Analysys Mason, "Driving energy usage across Telekom networks," August 2022. [Online]. Available: https://www.analysysmason.com/contentassets/4c9966823c1c4011a6bbab9bb6dcd03d/analysys_mason_reducing_telecoms_energy_aug2022_sample_rdnt0_rdfi0.pdf
[Accessed 1 December 2022]

[58] ISO, "ISO/IEC 30134-2:2016 Information technology — Data centres — Key performance indicators — Part 2:Power usage effectiveness (PUE),," 2016. [Online]. Available: https://www.iso.org/standard/63451.html; https://www.ictfootprint.eu/en/isoiec-30134-00-factsheet
[Accessed 2021]

[59] ISO, " ISO/CD 14068, Greenhouse gas management and climate change management and related activities — Carbon neutrality," 2022. [Online]. Available: https://www.iso.org/standard/43279.html
[Accessed 1 December 2022]

NEXT GENERATION MOBILE NETWORKS ALLIANCE E.V

NGMN, established in 2006, is a global, operator-led alliance of over 80 companies and organisation spanning operators, manufacturers, consultancies and academia.

VISION

The vision of the NGMN Alliance is to provide impactful guidance to achieve innovative and affordable mobile telecommunication services for the end user with a particular focus on supporting 5G's full implementation, Mastering the Route to Disaggregation, Sustainability and Green Networks, as well as 6G.

MISSION

The mission of the NGMN Alliance is

- To evaluate and drive technology evolution towards 5G's full implementation and the three major priorities for 2021 and beyond:

  Route to Disaggregation: Leading in the development of open, disaggregated, virtualised and cloud native solutions with a focus on the end to end operating model.

  Green Future Networks: Building sustainable and environmentally conscious solutions.

  6G: Emergence of 6G highlighting key trends across technology and societal requirements plus use cases to address.

- to establish clear functional and non-functional requirements for mobile networks of the next generation.

- to provide guidance to equipment developers, standardisation bodies and cooperation partners, leading to the implementation of a cost-effective network evolution

- to provide an information exchange forum for the industry on critical and immediate concerns and to share experiences and lessons learnt for addressing technology challenges

- to identify and remove barriers for enabling successful implementations of attractive mobile services