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RADIO SPECTRUM POLICY GROUP

Report

on

the role of radio spectrum policy to help combat climate change

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List of Abbreviations

AI	Artificial Intelligence
Arcep	Autorité de Régulation des Communications Électroniques, des Postes et de la Distribution de la Presse
BEREC	Body of European Regulators of Electronic Communications
BSC	Base Station Controller
ECN	Electronic Communications Network
ECS	Electronic Communications System
ECTA	European Communities Trademark Association
eMBB	Enhanced Mobile Broadband
EMF	Electromagnetic Field
ES	ETSI Standard
ESG	Environment, Social and Governance
ETNO	European Telecommunications Networks Operators Association
ETSI	European Telecommunications Standards Institute
EU	European Union
EWIA	European Wireless Infrastructure Association
FTTH	Fiber to the Home
GHG	Greenhouse Gas
GSM	Global System for Mobile communications
GSMA	GSM Association
ICT	Information and Communications Technology
IT	Information Technology
ITU	International Telecommunication Union
ITU-T	International Telecommunication Union Telecommunication Standardization Sector
KPI	Key Performance Indicator
LTE	Long-Term Evolution
MIMO	Multiple Input Multiple Output
ML	Machine Learning
MNO	Mobile Network Operator
NFV	Network Functions Virtualisation
NRA	National Regulatory Authority
OECD	Organisation for Economic Co-operation and Development

RNC	Radio Network Controller
RSPG	Radio Spectrum Policy Group
UE	User Equipment
UMTS	Universal Mobile Telecommunications Service
URLLC	Ultra-Reliable and Low-Latency Communication
VNF	Virtual Network Function

Executive summary

This report presents the findings of the RSPG sub-group on the role of radio spectrum policy to help combat climate change in response to the tasks set out by the RSPG in its Work Programme for 2022-2023.

The RSPG started by gathering information on work already undertaken by Member States, the European Commission, BEREC and industry.

The RSPG has learnt through this workstream that at least two regulators have sought information on energy consumption from operators, Traficom in Finland and Arcep in France. France has revised its national law to enable Arcep to gather an extensive amount of information.

According to the RSPG work programme for 2022 and beyond, the RSPG established a work item to provide advice to the European Commission regarding i) methodologies for analysing the impact of wireless technologies, including Wi-Fi, and ii) the potential effectiveness of spectrum policy to green policies in Europe. The sub-group noted information on relevant ETSI and ITU standards for measuring energy consumption and efficiency.

There are a number of parallel work streams being undertaken in the general area. Within BEREC, a Working Group on Sustainability has workstreams related to the environmental impact of ECS/N, including energy efficiency aspects, without a focus on radio specific elements. The RSPG is keen to ensure that it does not duplicate the work of BEREC. To that end, informal discussions took place with the co-chairs of the BEREC working group. The RSPG sub-group co-chairs also participated in some BEREC online events.

In order to gather further information, the RSPG prepared a questionnaire for stakeholders with a view to understanding the current energy measurement possibilities which can be undertaken without excessive burden on operators. Subsequent to receiving the responses to the questionnaire, the sub-group held an online workshop in order to better understand the status of the energy data available to operators and which they could pass on to regulators.

The responses to the questionnaire indicate that mobile operators focus on energy consumption, rather than efficiency. Various actions and technical solutions to save energy are being implemented by operators. These actions are motived by the cost of energy, sustainability ambitions and consumer expectations. Some actions may result in reduced coverage and capacity. Operators request more flexibility in coverage obligations in order to allow them to avail of these energy saving measures.

The RSPG acknowledges that power consumption is heavily related to the radio part of the Electronic Communication Network. Modern hardware and modern technology are key to overall power saving.

Administrations and NRAs could examine, in dialogue with the operators, what changes can be introduced in regulation in a balanced way in order to reduce network energy consumption without adversely impacting on the consumer experience.

Spectrum policy design, such as any public policy design, will benefit from an approach which is environmentally oriented as opposed to being only technically and economically oriented.

Introduction

The EU has set ambitious measures and goals to reduce its greenhouse gas (GHG) emissions in order to tackle climate change. The RSPG supports the fight against climate change and believes that tackling the negative consequences of climate change is of utmost importance. Therefore, in its programme of activities for the years 2020 and beyond, the RSPG responded by establishing a work item to focus on spectrum policy aspects which are closely related to the efforts of ensuring climate neutrality. In particular, the RSPG was requested to examine how spectrum policy can help to combat climate change, including by consulting with the relevant stakeholders.

The RSPG published a Report on this subject in June 2021. The Report described the aspects within spectrum management that relate to climate change and set out possible options in radio spectrum policy in order to help monitor climate change. The Report considered how radio spectrum could enable various sectors to reduce their impact on the environment and described some of the steps that the electronic communications sector itself could undertake in order to reduce its impact on the environment. The Report reflected on how the steps taken by the telecommunications industry could be assessed, verified and supported.

The Opinion subsequent to the Report contained recommendations as to what concrete actions could be taken at EU level. The Opinion suggests further avenues in terms of spectrum regulation, harmonisation, voluntary initiatives, information gathering, etc.

It was decided that the RSPG would continue work on two particular points raised by the Opinion:

- The need for a common set of methodologies in order to understand and assess the impact of ECS wireless technologies on climate change, involving ECS stakeholders and all interested parties, and with a particular focus on the ECS radio component.
- The importance of having accurate information on emissions and energy efficiency related to spectrum use on a national level (e.g., reports from network operators).

In its Work Programme for 2022-2023, the RSPG defined the scope of its activities relating to climate change as follows:

- Identifying methodologies to assess the energy efficiency of wireless technologies, including the influence of variables such as the frequency band, type of access technology, etc. Input from stakeholders (e.g. through a workshop) may be required.
- Collecting practices from Member States on how energy efficiency is measured and managed nationally in relation to the spectrum area, including how data to assess the energy efficiency is collected.
- Assess how efficient spectrum policies can facilitate a green digital transition of Europe, to reduce carbon emissions.

When developing this report, RSPG engaged with stakeholders in relation to whether they gathered information on energy consumption or efficiency and the methodologies to do so.

In particular, the RSPG issued a questionnaire in March 2023 in which Industry stakeholders were also asked about the granularity of the data they could collect and the steps they were taking to

improve energy efficiency. They were asked to indicate i) if there were any barriers to collecting information and ii) to make any suggestions on actions which regulators could take or legislative changes which could be made to make it easier to collect data or reduce their energy consumption.

On 17 May 2023 the RSPG held an online workshop based on the responses to the consultation. The workshop helped clarify some of the comments received and provided further insight into the methodologies employed to monitor the energy consumption of networks and the work undertaken to reduce it.

This report presents a status of the work regarding the methodologies for measuring and assessing the energy consumption and/or efficiency of wireless technologies and summarises the main findings from the public consultation and subsequent workshop. Finally, we indicate a series of actions which an NRA may wish to implement in response to the comments received from industry stakeholders.

General context

The previous work of the RSPG

In its 2021 Report, the RSPG pointed to the work in standardisation fora. ETSI, for example, has a technical committee "Environmental Engineering" which defines the environmental and infrastructural aspects for all telecommunication equipment and its environment. The committee works on metrics and methods to measure the energy efficiency of ICT equipment, standardisation terms and trends in energy efficiency. The ITU is also committed to fighting against the adverse environmental impact of wireless technologies. The ITU Study Group 5 is responsible for studies on methodologies for evaluating ICT effects on climate change and publishing guidelines for using ICTs in an eco-friendly way.

IDEA Consult study for the Commission

A "Study on Greening Cloud Computing and Electronic Communications Services and Networks looking towards Climate Neutrality by 2050" was undertaken by IDEA consult, the Institute for Applied Ecology (Germany) and Visionary Analytics for the European Commission. This document contains useful information on the available recommendations and methods from the ITU-T (Study Group 5) and ETSI (TC EE). The study lists various ITU-T recommendations (cross-referenced to an ETSI equivalent if applicable) such as **ITU-T Rec. L.1410** on "Methodology for environmental life cycle assessment of ICT goods networks and services", where life cycle is a "cradle to grave" outlook. This ITU-T recommendation suggests the calculation of the overall energy consumption of a network rather than energy consumption of a service as a more practicable approach.

The IDEA consult study for the Commission notes that the Eco-design Directive applies to "energy-related products", in the sense of physical goods rather than services. Thus, the Eco-Directive might be applicable to handsets, indicating the energy used by the handset, and perhaps the aspects related to manufacture. It might also be applicable to the physical component elements purchased by MNOs to be placed in their network, including at base stations, but does not address the service which the MNO would offer.

Energy efficiency standards

The RSPG notes the following deliverables from ETSI and the ITU:

ETSI ES 203 228 V1.4.1 / ITU-T Rec L.1331 considers mobile network data energy efficiency, coverage energy efficiency and latency energy efficiency given that these are the key priorities which a network operator may seek to focus upon in their network. The data energy efficiency measurement is based on a given time period, whereas the coverage energy efficiency works with energy consumption over the longer term of a year. The document also looks at "Site Energy Efficiency", being the ratio between ICT equipment energy and total site energy (which includes the ICT equipment energy, the rectification losses, cooling, and other energy uses not directly in the "data/signal chain").

ETSI ES 201 554 V1.2.1 considers the Energy Efficiency Ratio, which is a ratio between useful output and average power consumption. Average power consumption considers low, medium and high load levels with weights of these in respect of their contribution to the average. The power consumption in ETSI ES 201 554 V1.2.1 does not include consumption associated with air-conditioning and other ancillary equipment.

The technical specification for LTE radio access technology (wireless access network equipment) **ETSI TS 102 706-2 V1.5.1** considers the base station energy efficiency, being a ratio between the

measured data volume in bits for low, medium and busy hour load and the total energy consumption of the base station. The technical specification defines reference base station equipment configurations and reference load levels to be used when measuring the efficiency.

ETSI EN 305 200-2-3 V1.1.1 for mobile broadband access networks has a KPI for task effectiveness, being a ratio between data (both upstream and downstream) at base stations and the total energy consumption (KPI for energy consumption). It also has a KPI for renewable energy contribution.

ETSI EN 303 472 V1.1.1 for Radio Access Network equipment considers capacity energy efficiency (Mbits/Wh), being the ratio between data volume of the base station (carried over the backhaul network) and the total energy consumption of the base station site including the support infrastructure.

An overview of ETSI and ITU standards relating to energy efficiency and consumption is presented in Annex 2.

Site equipment not directly in the radio signal chain

A particular certification system for power supply units called the 80 Plus certification could serve to point to benchmarks for that type of equipment.

Whilst the electronics needed for the radio signal and data handling are essential elements in a radio network, the cooling is also essential. As a general and obvious remark, the most efficient type of cooling system is when no cooling is needed at all. If refrigerants must be used, those with low global warming potential are preferable. The IDEA Consult Study notes that many base stations today can operate at temperatures of 45 degrees Celsius. Thermal management needs to be optimised by ensuring that equipment with different temperature requirements should be physically separate from each other.

Calculation of energy use of a site

It is possible to calculate the energy intensity in the planning phase based on planned technical equipment (network components, air conditioning and other equipment on site).

Thus, we can see that there are a variety of methods and standards for determining the energy consumption and efficiency of network equipment.

BEREC working group on sustainability

BEREC decided to "engage in working on sustainability considering the ICT-related parts of the (upcoming) Green Deal and the Agenda 2030 targets to identify the sustainable development goals that could be relevant for BEREC" in its strategy 2021–2025. The strategy also foresees that BEREC could contribute to the assessment of the digital sector's impact on the environment and identifies raising awareness of the above-mentioned impact as a relevant lever for end users' empowerment.

BEREC has been working on developing its knowledge on environmental sustainability which constitutes a new subject for telecom regulators. In 2021, the BEREC Working Group on Sustainability commissioned an external study from WIK-Consult and Ramboll[1] as part of its workstream to assess the effects of electronic communications on the environment. This study mapped main sustainability-related actions in the sector and initial activities carried out by NRAs, and identified the levers available to minimize the adverse environmental effects of electronic communications.

BEREC acknowledges the lack of available standardised data and the heterogeneity of methodologies to assess the digital sector's environmental footprint, including in terms of GHG emissions.

Following the publication of a draft report in March 2022[2], BEREC held an online "Stakeholder Workshop on ICT Sustainability", which the RSPG sub-group on climate change co-chairs attended. The following points emerged from that workshop:

- The energy consumption of radio elements is impacted by the usage of the network, i.e. it is dependent on customer load. The equipment is designed/built to serve/operate efficiently at maximum capacity, but there may be parts unused a lot of the time. Sometimes the carbon emission intensity and energy consumption are quoted with respect to the amount of data transferred through the networks.
- However, energy consumption per bit can be a misleading metric, as it decreases with increasing usage of the network. The energy consumed per Gigabyte is not always a suitable metric, as there are sites in place not serving traffic but serving areas. It is hard to compare networks with different traffic profiles.
- Different locations/places give rise to different circumstances.

The first BEREC Report on Sustainability[3] assessing BEREC's contribution to limiting the impact of the digital sector on the environment was published in June 2022. Immediately afterwards, the BEREC Working Group on Sustainability started work on its Report on Sustainability Indicators "to conduct research on the indicators which might help evaluate the environmental sustainability ECN/ECS based on stakeholders' and authorities' initiatives on the matter and on indicators already used and promoted by the industry."

[1] https://www.berec.europa.eu/en/document-categories/berec/reports/external-sustainability-study-on-environmental-impact-of-electronic-communications
[2] https://www.berec.europa.eu/en/document-categories/berec/reports/draft-berec-report-on-sustainability-assessing-berecs-contribution-to-limiting-the-impact-of-the-digital-sector-on-the-environment
[3] https://www.berec.europa.eu/en/document-categories/berec/reports/berec-report-on-sustainability-assessing-berecs-contribution-to-limiting-the-impact-of-the-digital-sector-on-the-environment

In 2022 and 2023 BEREC pursued its work on the environmental sustainability of ECN/ECS. Following this report and to address one of the challenges identified (the lack of data and the need to harmonise methodologies and standards to assess the environmental impact of digital technologies) BEREC has decided to include in its 2022 and 2023 work program a workstream on sustainability indicators for ECN/ECS.

During the work, the BEREC working group called for input from public authorities, industry and academia. After launching a questionnaire in October 2022, the working group held a series of workshops on Environmental transparency in the Telecom Industry in the third quarter of 2022. The RSPG co-chairs participated in the last of those in December 2022.

Those workshops and questionnaire mentioned were conducted as part of this workstream. They fed into the draft report on sustainability indicators for ECN/ECS published in March 2023.[4] The final version of this report is expected on November 2023. The draft report seeks to highlight the need to harmonise the use of environmental sustainability indicators, to improve transparency and comparability of the environmental impact of industry. BEREC puts forward three Groups of indicators for this purpose.

The Sustainability Working Group is also currently engaged in a workstream which aims to empower end users through information on environmental transparency on digital goods and services. This workstream seeks to better inform the public on the overall environmental impact of ECS/N, which includes energy consumption. As the use of digital products and services, including data consumption, continues to increase across the EU and globally, it follows that the amount of corresponding energy consumption is also increasing to power these digital activities.

[4] https://www.berec.europa.eu/system/files/2023-03/BoR%20%2823%29%2046%20Draft%20Report%20on%20sustainability%20indicators%20for%20ECN%20ECS%20%20%281%29.pdf

Other reports and strategies

Industry reports and strategies

The RSPG notes the NGMN report "Green Future Networks"[5] which references ITU-T Rec. L.1210 "Sustainable power-feeding solutions for 5G networks" and addresses power feeding, cooling and monitoring of technical sites. Newer liquid cooling or passive cooling with sensors, fans and a controller can be low energy consuming means to keep equipment cool.

The report also sets out that a base station can reduce the energy it consumes by entering sleep modes, and ultimately powering down part of a site when traffic is expected to be low. In such circumstances, other carriers at a site or other base station sites may be required to address the customer needs in order not to result in loss of coverage as perceived by the customer. If all carriers at a site are in sleep state, unless there is coverage from a neighbouring site, there is a risk of consumers perceiving the effect as a loss of coverage and there would be a latent delay in recommencing service. However, energy savings can be made by shutting down capacity layer equipment whilst maintaining coverage layer equipment in operation. Thus, network planners will need to be careful to achieve the optimal balance between capacity and coverage and deliver this with the least possible power consumption. The report notes that receiver performance has a significant impact on coverage and capacity of networks and, by extension, base station energy consumption.

Networks have been able to obtain newer, more energy-efficient equipment for 2G and 3G in recent years. Switching off 2G and 3G would allow only the decommissioning of the base station controller (BSC) and Radio Network Controller (RNC) equipment and thus might not have a significant impact on energy consumption. However, where possible, networks should operate 2G and 3G networks in the minimum spectrum possible to deliver adequate service.

According to GSMA's 2021 Mobile Industry Impact Report: Sustainable Development Goals[6], the mobile industry was achieving 50% of its potential contribution to the 2030 Sustainable Development Goals (SDGs) as of 2020. In early 2021, more than a third of mobile operators by revenue had committed to the goal of reaching net-zero carbon emissions by 2050 at the latest. At the end of 2020, 80% of operators by revenue disclosed their climate impacts, while almost two thirds of operators by revenue had set science-based targets to cut their carbon emissions rapidly over the next decade, mainly by switching to renewable energy.

GSMA published in June 2022 a white paper entitled "ESG Metrics for Mobile"[7], which proposes a number of KPIs to be reported by companies in order to gain a better understanding of the environment, social and governance (ESG) performance of the mobile sector. The KPIs are organised into four categories: environment, digital inclusion, digital integrity, and supply chain. The environment KPIs cover Scope 1, 2 and 3 GHG emissions, total energy consumption, and the network energy mix (i.e. the percentage of grid/off-grid renewable and non-renewable energy).

Mobile World Live conducted an online survey of mobile operators, tower companies and cloud service providers, which was summarised in their 2022 report "Making mobile networks more

[5] https://www.ngmn.org/wp-content/uploads/211009-GFN-Network-Energy-Efficiency-1.0.pdf
[6] https://www.gsma.com/betterfuture/wp-content/uploads/2021/12/GSMA-SDGreport-singles.pdf
[7] https://www.gsma.com/betterfuture/wp-content/uploads/2022/06/ESG-Metrics-for-Mobile-June-2022.pdf

sustainable and energy efficient"[8]. Some of the most interesting findings of these survey are cited below:

- At the end of 2020, 69% of operators by connections and 80% of operators by revenue disclosed their climate impacts.
- About 31% of operators by connections worldwide and 36% by revenue worldwide have set carbon reduction targets of achieving net zero by 2050 or earlier.
- 26% of respondents said that their companies track carbon emissions from their data centres, their base stations, their towers and their operations centres. However, 31% of respondents said that their companies don't track carbon emissions from any of those sources.
- 5% of respondents said that they are relying 100% on renewable energy for their company's energy usage and only 10% said that 75% to 99% of their company's energy usage is from renewable energy.

Governmental reports and strategies

Finland, France and Germany have provided details of information they have gathered from operators or through studies to the RSPG. Other Member States have indicated that they are working towards collecting information on energy consumption from network operators in the near future. Some are currently in dialogue with their national stakeholders in order to ensure that useful information is collected in a way which does not place an unnecessary burden on the stakeholders.

Finland

The Finnish Ministry of Transport and Communications published a report on "Climate and environment strategy for the ICT Sector". It acknowledges that, over the last few years, the amount of electricity consumed per data bit transmitted has decreased. The report also notes that data transmission over a mobile network consumes more energy than over a fixed network. It points to developments in energy-efficient cooling solutions and the potential of renewable energy at network base stations. It suggests that operators need to study the potential for waste heat recovery at network base stations. As regards user devices, the report notes that these devices use materials in batteries and displays the extraction and processing of which burdens the environment. More recycling of these materials is essential and there is also a benefit where device life can be extended. The report also notes that the use of mobile data even when in a fixed location increases energy consumption for the task.

France

In France, triggered by reports (Shift project, Green IT, French Senate reports, including Arcep's "achieving digital sustainability" 2020 report) and public consultation (*Convention Citoyenne pour le Climat*), the law has recently been updated to provide new competencies to the regulator, Arcep, in order to achieve the following objectives:

- Assessment and monitoring of the digital environmental footprint;
- Measurement and monitoring the environmental impact of global digitization for France;
- Measurement and monitoring the environmental impact of broadcast and consumption of audio-visual media;
- Promoting the development of eco-design for digital services;
- Considering environmental aspects in new infrastructure deployment and spectrum allocation.

[8] https://www.mobileworldlive.com/mobile-networks-sustainable-and-energy-efficient

The French NRA is mandated to publish a yearly report, to contribute to the eco-design framework in cooperation with the audio-visual media regulator (Arcom) and the French agency for sustainability (Ademe). In addition, environmental protection is now explicitly mentioned as one of the regulatory objectives to be considered when allocating spectrum resources (L.42-1 article of the telecommunication law).

Arcep collection of information on environmental impact

The first annual report on the environmental impact was published in April 2022[9] and dealt only with the power consumption of telecommunication operators.

Arcep is now entitled to retrieve information on digital sustainability from a larger set of stakeholders than just the telecommunications operators: terminal manufacturers (handset, screen, PC, etc.), data centre operators, etc. This first set of new data collection is subject to public consultation. In particular, questions on mobile terminals are proposed (contribution to GHG emissions, renewal, number of mobile phones in operation).

The 2022 edition of Arcep's annual survey "Achieving digital sustainability"[10] shows a number of important findings:

- While the four main French electronic communications operators' total GHG emissions (Scope 1 and Scope 2) have been decreasing since 2019, the GHG emissions generated by their energy consumption (Scope 2) have increased. This is mainly due to mobile network deployments and increased traffic.
- Access networks, whether fixed or mobile account for 85% of electronic communications networks' total energy consumption (excluding data centres), including 58% for mobile local loops and 27% for fixed local loops.
- End-user terminals account for 79% of carbon footprint of digital in France. Operators' refurbished phone sales represent only 2% of the 8.1 million mobile handsets sold in 2020. 53% of unused smartphones are kept by their owners.

Some key findings of the second edition of the Arcep survey published in April 2023, which is based on data collected from telecoms operators for the year 2021, are listed hereafter:

- Operators' GHG emissions growth of 3% in one year.
- The growth of network energy consumption continues in 2021 but it is divided by two in one year. Mobile networks consume 3 times more energy than fixed fibre networks. A fibre line consumes nearly 4 times less kWh than a copper line.
- Mobile phones: Operators' sales stabilised at 8.1 million phones. The significant drop in sales of new phones was offset by the doubling of sales of refurbished phones. The share of refurbished phones in operators' sales remains very low (4%).
- Internet and set-top boxes - recycling, reconditioning: 70% of Internet boxes and 80% of set-top boxes processed by operators are refurbished.

[9] https://www.arcep.fr/cartes-et-donnees/nos-publications-chiffrees/impact-environnemental/enquete-annuelle-pour-un-numerique-soutenable-edition-2022.html
[10] https://en.arcep.fr/fileadmin/cru-1656678683/user_upload/19-22-english-version.pdf

Germany

The Federal Environment Agency (UBA) has published an environmental impact assessment of the German mobile communication networks (UTAMO)[11] for the reference year 2019 as well as a forecast of the development up to the year 2030. For this purpose, the Fraunhofer IZM developed a complex life cycle inventory model as part of the UTAMO research project, which includes the environmentally relevant aspects of the essential technical and infrastructure elements which constitute the radio access networks as well as the transport core networks. The life cycle-oriented environmental assessment balances the production and use phase of the mobile network technology in a baseline scenario as well as in several alternative scenarios that include environmental optimisation. In the baseline scenario, which multiplies the theoretical network capacity by a factor of 45 in 2030, the electrical energy demand of the German mobile communication networks will increase by 325% from 2.3 TWh in 2019 to 7.5 TWh in 2030. The largest share of the usage-related electricity consumption is accounted for by the radio access networks, well over 80%. A comparison of the manufacturing phase with the use phase shows that the electricity consumption in use strongly outweighs the manufacturing with an average of over 90%. The future environmental impact can be significantly minimised by various measures. These measures include aspects of network and location planning, device and infrastructure modernisation, as well as active load and energy management. The report explains the methodological approach of the modelling, the calculation results for the individual development scenarios, as well as the recommendations for decision makers from business and politics.

The report contains recommendations for MNO in the field:

- Network planning (user-centric planning)
- Site planning and locations
- Power supply
- Cooling
- Mobile technology and energy management
- Interoperability

The report contains recommendations for politics in the field:

- Eco-design directive
- Data basis for the energy demand of MNO networks
- Spectrum allocation and sustainable network expansion
- Technological sovereignty

RSPG reflections based on the reports and strategies of industry and governments

Noting the above information from industry and regulators, the RSPG observes that technology progress and rising energy costs have been the main drivers of energy efficiency in wireless networks. Operators of ECNs are using communications technology that is as energy-efficient as possible and in general sustainable (noting elements of eco-design requirements) when establishing new sites and/or completely new networks or for new technology deployments. As regards legacy

[11] https://www.umweltbundesamt.de/en/publikationen/umweltbezogene-technikfolgenabschaetzung-mobilfunk

networks and technologies, MNOs should continue leveraging industry experience to operate these, on a voluntary basis, in a climate-friendly manner.

The RSPG climate change group notes that regulators that have studied ECS power consumption observe that the overall energy consumption has been increasing over time.

Work of the RSPG sub-group on Climate Change

The RSPG questionnaire and responses

In March 2023 the RSPG published a question for stakeholders. The questionnaire appears in Annex 1. The RSPG analysed the responses to the questionnaire and noted the following points:

- Mobile operators focus on measuring/calculating energy consumption, not efficiency. Figures are available for the whole network, per site, and per equipment unit if individual meters are available. Manufacturers measure and provide average figures of energy consumption and efficiency which are used by the operators in their calculations. Comparisons between old and new hardware can help estimate the effect of specific network elements and frequency bands.
- Some operators are conducting technical studies on the variables that have the most significant impact on energy consumption.
- A number of technical solutions to save energy are being implemented by operators: sleep mode, reducing MIMO, replacing hardware, decommissioning old technologies, etc. Through ML and AI, network nodes can anticipate on a traffic pattern and (de)activate power efficiency features in a more efficient manner.
- New hardware and technologies are considered to be more efficient. Network equipment manufacturers point out the technical functionalities behind the increased energy efficiency of new equipment.
- The main motivations for operators to implement energy-saving measures have been energy costs, voluntary sustainability ambitions and consumer expectations.
- The main difficulties have been the coverage and capacity decrease as a result of these measures. Customers may be affected by decommissioning. AI/ML may help improve these mechanisms and reduce the negative impacts. Some countries may require approval of these measures by the NRA through lengthy administrative procedures, creating a burden for operators.
- Several respondents asked for more flexible mobile coverage obligations that would allow them to implement energy-saving measures during low traffic hours.
- A point was raised on EMF limits being unnecessarily restrictive in certain countries, thus requiring more base stations and lowering energy efficiency.
- Using peak performance as the main KPI for benchmarking and network evaluation has an impact on energy consumption. It would be better to focus on an agreed service level.

The following standards for measuring energy efficiency at equipment level (including the estimation of the energy efficiency of equipment in a lab environment) have been highlighted by the respondents:

- ITU-T L.1310: Energy efficiency metrics and measurement methods for telecommunication equipment
- ETSI EN 303 472 V1.1.1 (2018-10): Energy Efficiency measurement methodology and metrics for RAN equipment
- ETSI ES 201 554 V1.2.1 (2014-07): Measurement method for Energy efficiency of Mobile Core network and Radio Access Control equipment

- ETSI ES 202 706-1 V1.7.1 (2022-08): Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power consumption - static measurement method.
- ETSI TS 102 706-2 V1.5.1 (2018-11): Metrics and Measurement Method for Energy Efficiency of Wireless Access Network Equipment; Part 2: Energy Efficiency - dynamic measurement method
- ETSI TS 103 786 V1.1.1 (2020-12): Measurement method for energy efficiency of wireless access network equipment; Dynamic energy performance measurement method of 5G Base Station (BS).

The following standards can be used for energy measurements at the network level:

- ITU-T L.1330: Energy efficiency measurement and metrics for telecommunication networks
- ITU-T L.1331/ETSI ES 203 228 V1.4.1 (2022-04): Assessment of mobile network energy efficiency. This standard can be used to collect energy measurements at certain intervals when the equipment is in use.
- ITU-T L. 1333 defines a KPI for the carbon emission intensity of a network focused on network energy consumption in relation to data traffic. It encourages not only the reduction of network electricity consumption, but also the use of low-carbon energy supply and the improvement of energy utilisation efficiency.

The workshop

Following the questionnaire, the RSPG invited industry to an online workshop (on the energy use in the Wireless ECS Sector, monitoring, assessing and reducing its impact on the climate; Regulating for the future) on 17th May 2023 with a view to present the RSPG assessment of responses and to gather more information from industry. The workshop consisted of three presentations from the RSPG, Arcep (France) and GSMA intelligence, respectively.

The RSPG sub-group on climate change presented the main findings of the questionnaire responses as summarised above, in order to gather further feedback from the respondents and other industry members alike. Meanwhile, Arcep presented the status of their work on gathering energy consumption information from operators. The industry stakeholders had no adverse comments on the conclusions that the RSPG had reached based on the responses to the questionnaire, nor had they any negative views on the processes outline within the Arcep presentation.

GSMA had recently published their 2022 Mobile Network Energy Efficiency Benchmarking project report[12], which they were invited to present. This GSMA project is a service to MNO members that helps them measure and monitor the relative efficiency of their networks. Networks are compared against four KPIs: Energy consumption per unit mobile traffic (primary), per mobile connection, per cell site, and unit of mobile revenue (all secondary). The study found that most of the energy is consumed in the RAN (87%), while data centres and the core account for 12% of the total energy consumption, and the remaining 1% is due to other operations. The average energy efficiency was estimated at 0.17 kWh/GB.

[12] GSMA 'Benchmarking of energy efficiency of mobile':
First edition - https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60621137&file=300621-Going-Green-efficiency-mobile.pdf
Second edition - https://data.gsmaintelligence.com/research/research/research-2023/going-green-benchmarking-the-energy-efficiency-of-mobile-networks-second-edition-

GSMA proposed the following ways to improve the energy efficiency of networks:

- Simplifying site design and modernising equipment at the same time as deploying.
- Refarming spectrum and migrating users to newer technologies.
- Using highly integrated hardware, which can enable operators to use shared power modules.
- Using advanced cooling solutions.
- Applying AI and resource optimisation to manage cell resources.
- Implementing sleep mode during low or moderate traffic hours.
- Configuring radio transmission parameters for greater energy efficiency.
- Advocating for technology neutrality to facilitate modernisation and refarming among countries.

Following the presentations, a dialogue between representatives from industry and Member States took place, during which the following points were raised:

- Even though newer network technologies tend to be more energy efficient on a per-bit basis, there is an initial period after a new technology has been implemented, during which the configuration has not been optimised yet, nor the number of connections has reached the necessary critical mass, leading to a lower energy efficiency.
- Industry members raised concerns about network sharing, which would certainly decrease energy consumption but risk impacting the market.
- Some participants raised the idea of performing a comparison of the energy efficiency of equipment from different vendors. Other participants expressed concerns about this approach, as it could lend itself to unfair comparisons unless performed by an independent testing organisation under laboratory conditions.
- No information is available yet regarding the relationship between frequency band and energy consumption, and it might be difficult to compare, due to e.g. the different number of connections.

Actions which NRAs can take in response to the comments of the industry stakeholders.

Administrations and NRAs could examine, in dialogue with the operators, what changes can be introduced in regulation in a balanced way in order to reduce network energy consumption without adversely impacting on the consumer experience.

The dialogue at EU level with network operators in order to determine what information on energy consumption may be useful and feasibly collected should continue.

The EU and Member States could inform the public and stakeholders about power consumption of ECNs and that it relates to choices over which users can have an influence, in line with efforts to empower end users through information on environmental transparency in relation to digital goods and services.[13]

[13] At BEREC, the Sustainability Working Group is currently engaged in a workstream which seeks to better inform the public on the overall environmental impact of ECS/N, which includes energy consumption.

Annex 1: Questionnaire on the Role of Radio Spectrum Policy to help combat Climate Change

Background

In its Work Programme for 2022 and beyond, the Radio Spectrum Policy Group (RSPG) decided to establish the following Work item:

The RSPG Opinion on the Role of Radio Spectrum Policy to help combat Climate Change provides a series of recommendations to the European Commission, Member States and stakeholders to continue the path towards a more environmentally-friendly society through the use of wireless technologies.

The Opinion suggests further avenues in terms of spectrum regulation, harmonisation, voluntary initiatives, and information gathering. It is also recognised that the relationship between sustainability and electronic communications is also covered elsewhere. For example, BEREC has published its Report on Sustainability in 2022 and the BEREC Working Group on Sustainability is aiming to complete another deliverable on indicators of sustainability of telecom networks and services. Therefore, this work should be followed closely in order to avoid a potential overlap.

Two particular points raised by the Opinion fall into the purview of activities of the RSPG and it is therefore proposed to continue working on those points in the RSPG:

1) The need for a common set of methodologies in order to understand and assess the impact of ECS wireless technologies on climate change, involving ECS stakeholders and all interested parties, and with a particular focus on the ECS radio component.
2) The importance of having accurate information on emissions and energy efficiency related to spectrum use on a national level (e.g. reports from network operators).

These activities will help Member States and the EC to take appropriate regulatory actions within the spectrum area in order to combat climate change.

Scope of RSPG activity:

- Identifying methodologies to assess the energy efficiency of wireless technologies, including the influence of variables such as the frequency band, type of access technology, etc. Input from stakeholders (e.g. through a workshop) may be required.
- Collecting practices from Member States on how energy efficiency is measured and managed nationally in relation to the spectrum area, including how data to assess the energy efficiency is collected.
- Assess how efficient spectrum policies can facilitate a green digital transition of Europe, to reduce carbon emissions.

Glossary

ECN	Electronic Communication Network
Energy efficiency	Relation between the useful output (such as bit rate to receiving devices or more generally output RF power, which is also related to the number of users in a service area) and energy/power consumption.[14]
MNO	Mobile Network Operator

Questionnaire

The following questions aim to gather relevant information from Member States and stakeholders (and all interested parties).

Please focus on spectrum-related aspects of your wireless network(s) (MNO / Radio Access Network/ECN).

Questions directed to Member States and stakeholders:

1) In your country, is information being collected on **energy consumption** of the wireless ECNs? If so, which entity is collecting the information? What is the purpose? Is this based on regulation? If so, please specify the regulation.

2) In your country, is the **energy efficiency** of the wireless ECNs being calculated? If so, which entity is responsible for this? What is the purpose? Is this based on regulation? If so, please specify the regulation.

3) For the items described in Questions 1) and 2) above, which methodology/ methodologies are being used? Please name any standards that are being used. Is the information available for all wireless ECNs, or only for a part of these? Which data breakdowns are available: e.g., by operator, by service, by frequency band, by technology (e.g., 2G/3G/4G/5G), by region, by site, by network element, etc.? Please mention also the cases when incomplete breakdowns are available.

4) In your analyses related to energy consumption and/or energy efficiency, what are your reflections on the influence of parameters such as frequency band, type of radio access technology, coverage addressing different areas (urban, suburban, rural)?

5) Is the energy efficiency of the wireless ECN not only measured / calculated but also subject to regulations in your country? If so, by which entity and for which purpose or objective? If so, please describe the provisions in place, including how these provisions are enforced and controlled (if applicable), and the experiences with these provisions so far.

[14] Examples of the definition of energy efficiency for mobile networks can be found in the ETSI standard ES 203 228 1.3.1 (section 5).

6) Taking into account the scope of the work of the RSPG above, do you wish to share other thoughts or ideas which could be helpful to the RSPG to identify the role radio spectrum policy can play to help combat climate change and mitigate other adverse environmental impacts?

Questions directed to ECN stakeholders:

7) What information on **energy consumption** of the wireless ECNs does your company / the Members of your stakeholders' association collect? Which methodology/ methodologies are being used? Please name any standards that are being used.

8) Does your company / the Members of your stakeholders' association measure or calculate **energy efficiency** of wireless ECNs? Which methodology/ methodologies are being used? Please name any standards that are being used.

9) For the items described in Questions 7) and 8) above, which data breakdowns are available to your company / association[15]: e.g., by operator (if applicable), by service, by frequency band, by technology (e.g., 2G/3G/4G/5G), by region, by site, by network element, etc.? Please mention also the cases for which incomplete breakdowns are available.

10) Are you considering collecting any additional information that you could collect with reasonable effort?

11) Which actions is your company / the Members of your association taking to improve the energy efficient use of radio spectrum (e.g. switching to new technologies, advertisements to make energy efficient technologies more attractive, sleep mode for base stations, or other actions)?

12) What were the triggers for these actions (e.g. legal requirement, economic interests, consumer expectations, competitiveness, etc.)?

13) Were there any difficulties when you attempted to introduce or perform these actions? Please specify.

14) What further actions would enable you to foster a (more) energy efficient spectrum use, if any? Should such an activity be done by national spectrum regulators / ministries / European entities? Please specify and explain.

15) Would some kind of spectrum regulation facilitate your motivation to use radio spectrum in a (more) energy efficient way?

16) Taking into account the scope of the work of the RSPG above, do you wish to share other thoughts or ideas which could be helpful to the RSPG to identify the role radio spectrum policy can play to help combat climate change and mitigate other adverse environmental impacts?

[15] In order to consolidate the responses of your association's members, a table is proposed in the Annex

Annex 2: Overview of ETSI and ITU standards

Table 1 presents an overview of relevant ETSI and ITU standards.

TABLE 1. OVERVIEW OF RELEVANT ETSI AND ITU STANDARDS

Number	Title	Last update	Scope	Note
ETSI TS 128 310 V17.5.0 (2023-04)	LTE; 5G; Management and orchestration; Energy efficiency of 5G (3GPP TS 28.310 version 17.5.0 Release 17)	2023-04	5G	"The present document specifies concepts, use cases, requirements and solutions for the energy efficiency assessment and optimization for energy saving of 5G networks."
ETSI ES 202 706-1 V1.7.1 (2022-08)	Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power consumption - static measurement method	2022-08	GSM, WCDMA, LTE, NR base stations	

ETSI TR 132 972 V17.0.0 (2022-05)	5G; Telecommunication management; Study on system and functional aspects of energy efficiency in 5G networks (3GPP TR 32.972 version 17.0.0 Release 17)	2022-05	5G	Technical report (not a standard), covering: “- energy efficiency KPI definitions, including already existing definitions from other 3GPP WGs and other SDOs and potentially new ones for 5G networks; - measurement methods, including already existing measurement methods from other 3GPP WGs and other SDOs and potentially new ones for 5G networks; - potential solutions to improve energy efficiency of 5G networks; - energy efficiency control framework, as a SON-like framework for the control of energy efficiency of 5G networks.”
ETSI ES 203 228 V1.4.1 (2022-04)	Environmental Engineering (EE); Assessment of mobile network energy efficiency	2022-04	GSM, UMTS, LTE, 5G Network sites and network sections ("sub-networks") including base stations, site equipment, multi-access EDGE equipment, backhaul equipment required to interconnect the BS used in the assessment with the core network, Radio Controller (RC), gateways to connect to the Cloud	Equivalent to ITU-T L.1331. "The present document describes energy consumption and MN energy efficiency measurements in operational networks. As a complete and detailed energy consumption measurement of the complete network of a country or MNO is in most cases impossible or economically not viable, the total network is split into a small number of networks with limited size ("sub-networks")." These include: urban, sub-urban and rural networks. "A possible example of a network covered by the present document consists of a Radio controller (whenever applicable), its supported access nodes as well as the related network elements."

ETSI TS 103 786 V1.1.1 (2020-12)	Environmental Engineering (EE); Measurement method for energy efficiency of wireless access network equipment; Dynamic energy performance measurement method of 5G Base Station (BS)	2020-12	5G NR base stations (eMBB use case only)	"The present document covers only enhanced Mobile Broadband (eMBB) use case of 5G. Other use cases such as massive Machine-Type Communication (mMTC) and Ultra-Reliable and Low-Latency Communication (URLLC) will be subjected for future version of the present document. Energy consumption of terminal (end-user) equipment is outside the scope of the present document however, how a user equipment (UE) affects a base station energy performance will be considered for further study. "
ETSI TS 102 706-2 V1.5.1 (2018-11)	Environmental Engineering (EE); Metrics and Measurement Method for Energy Efficiency of Wireless Access Network Equipment; Part 2: Energy Efficiency - dynamic measurement method	2018-11	LTE base stations	"Energy consumption of terminal (end-user) equipment is outside the scope of the present document however, how a UE affects a base station energy performance will be considered for further study."
ETSI EN 303 472 V1.1.1 (2018-10)	Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for RAN equipment	2018-10	UMTS, LTE, GSM base stations	Repeaters and 5G not included, but considered for further study. "UE is outside the scope of the present document, however, how a UE affects a base station energy performance is considered for further study."
ETSI TS 103 881	Environmental Engineering (EE); Requirements for a global digital sustainable product passport to	Under preparation		

	achieve a circular economy			
ITU-T L.1333 (09/2022)	Carbon data intensity for network energy performance monitoring	2022-09	Public telecom network, non-public network and enterprise network.	Defines a KPI called network carbon intensity energy (NCIe).
ITU-T L.1310 (09/2020)	Energy efficiency metrics and measurement methods for telecommunication equipment	2020-09	All network technologies	See section 10 on wireless technologies, with a bird's-eye view on a number of fixed and wireless technologies. For wireless, refers to ETSI ES 202 706-1 and ETSI TS 102 706-2 (which is to say, to cellular networks only).
ETSI GS OEU 020 V1.1.1 (2020-03)	Operational energy Efficiency for Users (OEU); Carbon equivalent Intensity measurement; Operational infrastructures; Global KPIs; Global KPIs for ICT Sites	2020-03	Any ICT site	The document offers an alternative methodology for assessing efficiency, looking at carbon usage by operational infrastructure components at an ICT site, based on energy consumption, but looking at related GHG emissions, effectiveness of energy generation over GHG emissions, avoided GHG emissions, and reused GHG emissions. It "does not deal with other CO_2 emissions related to ICT equipment manufacturing, transportation and end of life. [. . .] It does not deal with other GHG emissions coming from equipment leakages. [. . .] The Global KPI alone is not designed for comparison of ICT sites or group of sites. It does not define an ICT site as good or bad unless combined with other parameters considered relevant for a comparison, such as local climatic conditions, availability requirements or purpose of ICT site."
ITU-T L.1316 (11/2019)	Energy efficiency framework	2019-11	All ICT technologies	Collection of references to ETSI, ITU, and ATISA standards available at the time of publication.

ETSI ES 203 539 - V1.1.1 (2019-06)	Environmental Engineering (EE); Measurement method for energy efficiency of Network Functions Virtualisation (NFV) in laboratory environment	2019-06	VNFs	Equivalent to ITU-T L.1361 (11/2018) General methodology, which could be theoretically applicable to radio systems as well.
ETSI EN 303 471 V1.1.1 (2019-01)	Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Network Function Virtualisation (NFV)	2019-01	VNFs	General methodology, which could be theoretically applicable to radio systems as well.
ITU-T L.1351 (08/2018)	Energy efficiency measurement methodology for base station sites	2018-08	All equipment at base station site. Technology agnostic.	Represents conformity assessment standard for Recommendation ITU-T L.1350
ETSI EN 305 200-2-3 V1.1.1 (2018-06)	Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 3: Mobile broadband access networks	2018-06	UMTS, LTE, GSM	Relies on EN 303 472 for energy consumption measurement methodology. Contains KPI methodology for task efficiency (per bit), and for renewable energy consumption. The methodology is "primarily intended for trend analysis - not to enable comparison between mobile access networks."
ITU-T L.1332 (01/2018)	Total network infrastructure energy efficiency metrics	2018-01	Any comms networks	General methodology background

ETSI ES 203 475 V1.1.1 (2017-11)	Environmental Engineering (EE); Standardization terms and trends in energy efficiency	2017-11	Any comms networks	Equivalent to ITU-T L.1315. General methodology for components, devices, networks
ITU-T L.1350 (10/2016)	Energy efficiency metrics of a base station site	2016-10	All equipment at base station site. Technology agnostic.	General methodology background. Not an ETSI standard
ETSI TR 103 352 V1.1.1 (2016-06)	Satellite Earth Stations and Systems (SES); Energy efficiency of satellite broadband network	2016-06	Satellite network, satellite terminal	Technical report (not a standard). "The present document reviews the assessment of energy consumption during the operational phase of satellite networks [. . .] In the present document a method of assessing the energy efficiency of satellite networks and terminal has been given. This can represent the basis for further detailed assessment procedures leading to a Technical Specification about satellite network energy efficiency assessment. However, it is desirable to be able to assess the energy efficiency of a satellite network over the full life cycle and a methodology for this should be provided in a future document."
ETSI TR 103 820 V1.1.1 (2015-11)	Fixed Radio Systems; Energy efficiency metrics and test procedures for Point-to-point fixed radio systems	2015-11	Point-to-point links	Technical report (not a standard), concluding among others: "The different field applications and the consequent different operating conditions heavily influence the overall performance of the links and the related energy consumption. The present document identifies the main parameters that characterize the functionality of a microwave link and their variation according to the different system architectures, propagation conditions and frequency used. The different phenomena influencing the propagation characteristics and

				different field applications requires a separate analysis of the Energy Efficiency for frequencies where multipath effects have the predominant influence on the propagation and the frequencies where the rain is the main influencing factor. Due to the peculiarity of fixed wireless systems, the target to define the Energy Efficiency with a single formula valid for all the categories of systems is very challenging and potentially misleading."
ITU-T L.1330 (03/2015)	Energy efficiency measurement and metrics for telecommunication networks	2015-03	GSM, UMTS, LTE Radio access part of networks: radio base stations, backhauling systems, radio controllers and other infrastructure radio site equipment.	Equivalent to an earlier version of ETSI ES 203 228
ETSI ES 201 554 V1.2.1 (2014-07)	Measurement method for Energy efficiency of Mobile Core network and Radio Access Control equipment	2014-07	UMTS & LTE mobile core functions (GGSN, HLR, MGW, MME, MSC, SGSN and PGW/SGW), and Radio Access Controllers (RNCs).	Radio Access not covered by the document directly. However, networks functions that support Radio Access are included.