The role of spectrum policy in tackling the climate change issue

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About this study

This study for the UK Spectrum Policy Forum (SPF) examines the ways in which climate change is impacted by spectrum policy decisions, and the availability of spectrum for different users. It considers spectrum users as both enablers (reducing environments impacts) and polluters and draws a series of recommendations on how regulators and governments can adapt their spectrum policies to be more environmentally responsible.

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Summary

Climate change is one of the most pressing issues facing the world today. The global community sees the gravity of this situation : various international treaties have been passed that aim to avert climate change, such as the Paris agreement and the EU Green Deal. In the same vein, legislation passed by the UK government in 2019, following a recommendation of the Climate Change Committee (CCC), will make the UK a net-zero emitter by 2050.

In this context, the Information and Communication Technologies (ICT) sector plays a two-pronged role when it comes to climate change – both as a potential emitter of greenhouse gases (GHG) and as a means to reduce those emissions. Integrating both green and digital issues is becoming a hot topic in the public debate in the UK and beyond. Understanding the relationship between climate change and the ICT sector will help regulators and governments frame climate sensitive telecommunications policies which could avert any negative climate change impact of the ICT sector. This would include spectrum policy as radio spectrum is one of the lynchpins of the ICT infrastructure.

Earlier this year, the RSPG (Radio Spectrum Policy Group) circulated a consultation[1] seeking comments on the Radio Spectrum Policy Programme (RSPP) – a five-year programme (first adopted in March 2012) which sets out the regulatory requirements, goals and priorities of the European Union relating to the radio spectrum.[2] This study, commissioned by the UK SPF, assesses the spectrum policy aspects related to climate-neutrality in the UK. Its scope includes the climate impact of spectrum policy not only in the mobile sector, but also in broadcasting, as well as other vertical sectors.

The two-fold role of the ICT sector in terms of climate change carbon

The ICT sector plays a two-fold role when it comes to climate change.

- **As a means to reduce those emissions:** The "*enablement effect*" could first be due to a change in behaviours (for example, through reduced travel, or through more efficient working practices). It could also be due to the use of digital technologies in different sectors: in the telecommunication sector through the use of Internet of Things (IoT) and Artificial Intelligence (AI) in base stations, in broadcasting through wireless production equipment, in the energy sector through smart grids, or in industry via digitalised manufacturing processes. Science services, as part of the ICT sector too, is of fundamental importance in understanding the processes leading to climate change and, therefore, to targeting action appropriately.

- **As a potential carbon emissions emitter:** In the entire ICT sector (including user devices, networks, and data centres), user devices account for the largest portion of the carbon emissions. The emissions mainly result from electricity consumption at the user end. In broadcasting and content services, set-top boxes and televisions are identified as key hotspots in the system.

Main research findings

Our research was based on a thorough literature search and discussions with different industry stakeholders. It has shown that despite an existing gap in research and existing literature, there was a strong interest in the

[1] RSPG, Public Consultation on the Draft RSPG Opinion on a Radio Spectrum Policy Programme, 15 Feb 2021- 26 Mar 2021. Available at: https://rspg-spectrum.eu/public-consultations/

[2] European Commission, Radio Spectrum Policy Programme: the roadmap for a wireless Europe. Available at: https://ec.europa.eu/digital-single-market/en/radio-spectrum-policy-programme-roadmap-wireless-europe

subject. It is also worth noting that, in terms of potential impact in combating climate change, spectrum is not a major issue compared to other IT issues (such as software and data centres) and consumer devices (e-waste and energy consumption).

The spectrum policy propositions offered by the main relevant organisations (ITU - International Telecommunication Union, RSPG; ETNO – European Telecommunications Network Operators' Association; GSMA - Global Systems for Mobile Communications Association; GeSI – Global e-Sustainability Initiative) have been studied. These have not been underpinned by quantitative data, and some of them logically show similar positions.

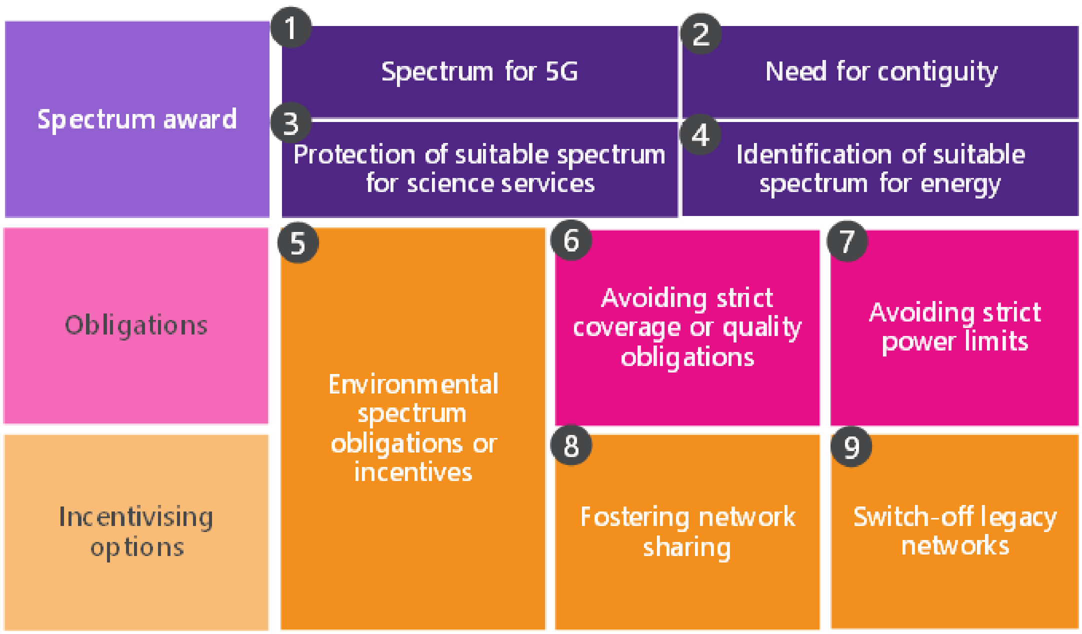
In terms of scope, our literature review covers mobile networks, fixed networks, satellite communications, broadcasting, science services, and radio navigation. However, on spectrum policy specifically, most of the literature is about mobile networks, and almost nothing is said on the other technologies. Taking a sectoral approach across verticals, the energy sector has the most information publicly available on spectrum and climate matters, compared to others (such as manufacturing, transport, and buildings).

Finally, before considering how different spectrum policies may impact climate change, it is crucial to understand how any policies may be implemented. The National Infrastructure Commission (NIC) recommended that Ofcom, Ofgem and Ofwat should have new duties to "*promote the achievement of net zero by 2050 and improve resilience*". [3] It is clear that such a recommendation is needed if Ofcom is to be able to act on the issues raised in this report.

Potential spectrum policy options

Potential relevant policy options have been identified and classified under three categories (spectrum award, obligations, and incentivising options) as shown in the figure below.

Figure 1.1: Spectrum policy options to combat climate change



Source: Plum analysis

[3] For more details see https://nic.org.uk/news/utility-regulators-must-have-new-powers-if-uk-is-to-tackle-climate-change/

These are discussed briefly in turn.

Option 1: There are three main ways in which spectrum awarded for use by 5G networks will have an impact on climate change effects:

- awarding sufficient spectrum will allow for 5G networks to be most efficient;
- low-frequency spectrum will allow for lower power consumption; and
- the use of 5G allows for better analytical computing power for industrial efficiency.

Option 2: When assigning spectrum between services and between operators, regulators must take account of previous use and the existing band plans. Where part of a band has already been assigned, this can lead to spectrum users being awarded several smaller lots. While these non-contiguous blocks can be used, it is often significantly less efficient in terms of both cost and environmental impact. However, there is considerable scope for minimising inefficiencies associated with non-contiguous spectrum. Moreover, even if mobile networks supported by contiguous spectrum might be more energy efficient, it might not be easy to reduce the fragmentation in the spectrum assignments in the first place, and moving from the current fragmented spectrum holdings would involve premature retirement of existing equipment.

Option 3: The critical role of weather forecasting, climate monitoring and earth observation makes it important to ensure that science services' spectrum is being protected. This spectrum policy option has been applied so far and does not require any specific deeper research. Nevertheless, the key position of science services makes the need for continued protection of the frequencies used for atmospheric sensing and meteorological services very important to tackle climate change issues.

Option 4: As it is the case for science services, the energy sector appears to be a key driver for combating climate change through the development of green energies. It is also the vertical sector needed for operation of all other sectors. The mission-critical role of this sector is illustrated by the heavily regulated penalties it must pay in case of breakdowns.

Option 5: Regulatory guidelines (binding or non-binding) for stakeholders on shifting to renewable sources of energy could be an option the regulator might consider. A detailed assessment would consider for instance the current energy mix of the operators, access to renewable options, scalability of off-grid options and associated construction clearances, financial implications, and potential timeline.

Option 6: According to ETNO[4] and GSMA[5], "*avoiding excess coverage and data speed obligations enables optimising network operations, energy consumption, and network equipment based on actual and timely demands.*" Not having such coverage or quality obligations can give the operators the liberty to deploy only in the regions with higher returns of investment, which could mean reduced deployment in less profitable rural regions – and a reduction in overall energy consumption and resultant emissions. However, there is a possibility this could result in the loss of consumer welfare through the digital divide between the urban and the rural areas. Market competition in developed countries such as the UK has meant that such a loss of consumer welfare has not occurred, but instead operators are able to optimise their investments from a cost and environmental point of view, when not constrained by regulatory obligations.

Option 7: Avoiding strict power limits of the base stations can allow for the utilisation of the same mobile site for deploying multiple spectrum bands and multiple mobile technologies. This has the potential to reduce network duplication and therefore be more energy efficient, in turn reducing emissions. Further, allowing high transmitter powers from the base station could increase the base stations' coverage, which could imply

[4] ETNO, Comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021
[5] GSMA, Response to Draft RSPG Opinion on RSPP, March 2021

deployment of fewer sites and result in energy savings and induce a positive environmental effect. However, higher power limits can increase interference potential and higher Electric and Magnetic Fields (EMF) emissions, raising health concerns. Further, increasing power limits would imply that the base stations could now consume more energy to reach the higher level of power which may counteract the positive environmental benefit from any reduction in the base station deployment.

Option 8: The amount of environmental benefit that arises from network sharing would depend upon which part of the network the operators share. Sharing of energy dependent elements (such as sites, masts, antenna, and radio network controllers) is likely to have a larger environmental benefit when compared to sharing elements like cabinets or site compounds. Further, the architecture of the shared network would also determine the amount of potential energy savings. However, network sharing in some cases could also affect the Quality of Service (QoS) of the host network if the existing network capacity is not able to support the additional traffic. In such a scenario, additional sites might be needed to increase the capacity or more spectrum would need to be deployed. Both will lead to potential additional emissions, although likely to be less than a scenario of network duplication.

Option 9: Because the latest mobile technologies are expected to be more energy efficient than older technologies, the closure of legacy networks has been considered as a possible option to combat climate change, and has started in many countries, including the UK. On the other hand, deployment of any new technology involves manufacturing of additional network equipment which in turn is likely to increase emissions. Also, the related data consumption increase has the potential to offset any positive environmental benefit at the network level by shifting to more advanced mobile technologies like 5G.

This report details and discusses the positive and potential negative impacts of these policy options on climate change, and proposes a methodology to rank them, based on their impact on climate change as well as on their timeline for implementation and real effect.

Recommendations based on current context

Based on our research and on the ranking of these potential policy options, the study closes with recommendations to inform policy makers on the more short-term and more impactful actions to look at in order to give a role to spectrum policy in combatting climate change. However, while these recommendations follow from the research detailed in this report, it is important to note the lack of quantitative research that has been carried out in this area, and before committing to specific policies, governments must carry out a full regulatory impact assessment to determine how much difference the changes would make. Our recommendations are as follows.

- **The regulator must have environmental impact responsibilities:** Our research has shown that each category of stakeholder logically represents its own interests, and approaches the climate issue from its own prism. A more systematic approach is needed for a broader view that will enable the ICT sector to tackle the climate issue. Spectrum policy options discussed in this report and those recommended below would be applicable depending on the role of Ofcom in climate issues. Like most telecommunications regulatory bodies, Ofcom does not have currently any specific responsibilities related to climate change. Extending Ofcom's statutory duties to include climate change and environmental impact would foster the national industry's momentum towards monitoring climate change.

- **A measurement and monitoring regime is required to help with regulation:** there is a lack of data on the net environmental footprint of the ICT sector. This recommendation directly relates to the first one. Collecting data from stakeholders and building relevant indicators will:

  - help with assessing and monitoring progress made by the industry on the climate subject;
  - encourage emulation between market players; and
  - enable detailed modelling to be able to compare the impact of different spectrum policies.

  This data collection should be done by a public authority and the telecommunication regulator appears as the most relevant one to be able to do so.

- **Science services spectrum must be protected:** The key position of science services makes the need for continued and better protection of the frequencies used for atmospheric sensing and meteorological services very important to tackle climate change issues.
- **Spectrum users should be compelled to use green sources of energy:** Regulatory guidelines (binding or non-binding) for stakeholders on shifting to renewable sources of energy could be an option the regulator might consider. A detailed assessment would consider for instance the current energy mix of the operators, access to renewable options, scalability of off-grid options and associated construction clearances, financial implications, and potential timeline.
- **Legacy networks should be switched-off when feasible:** Further studies would need to be undertaken to understand and monitor the switch-off of legacy networks in the different telecommunications sectors, in order to understand and assess the trade-off that needs to be found.
- **Suitable spectrum for the energy sector should be identified:** We would recommend spectrum policy makers consider a specific approach for the energy sector and enable it to tackle the different challenges it faces. This approach does not necessarily mean reserving specific spectrum for the energy sector. It may be more efficient for this industry to use part of the mobile networks through spectrum and network slicing, providing that this provides suitable reliability and resilience.
- **Sufficient spectrum should be provided to keep the number of mobile sites low:** Deployment of more radio spectrum instead of additional physical sites to increase network capacity would have a positive environmental impact since it would require less production of equipment, a lower deployment footprint, and lower power requirements. However, reducing the number of base stations may require a greater power use for transmission so that the coverage area can remain the same. Further studies would need to be undertaken to understand how these power needs would compare.
- **Spectrum should be awarded in contiguous blocks:** Ofcom already considers whether spectrum trading may allow for the market to resolve this issue, but it is unclear whether there would be a sufficient incentive for operators to work together and agree to a solution.

1 Introduction

Climate change is the most pressing issue facing the world today. The global community sees the gravity of this situation and as such various international treaties have been passed that aim to avert climate change:

- The Paris Agreement (2015) aims to keep global temperature rise to below two degrees Celsius (preferably 1.5 degrees Celsius) by 2100, above pre-industrial levels[6];
- Goal 13 of the UN Sustainable Development Goals (SDGs) (2030) seeks urgent action from countries to slow down climate change[7];
- EU Green Deal (2019) aims to have no net emissions in the EU region by 2050[8]; and
- EU climate Law aims to make the Green Deal's emissions target into a legal binding. The proposal has been passed in the EU parliament, waiting for final adoption.[9.]

1.1 Focus on the net-zero objective of the UK agenda

Following a 2019 recommendation of the Climate Change Committee (CCC), the UK government committed to reduce net emissions of greenhouse gases (GHG) by 100 per cent relative to 1990 levels by 2050, hence ending the country's contribution to global warming within 30 years. This is called the United Kingdom Net Zero Target. This policy is a continuation of the country's efforts in fighting global warming: the set objective is more ambitious than the previous target of 80 per cent GHG reduction set in 2008.

The net-zero target policy is also expected to deliver on the commitment that the UK made by signing the Paris Agreement. According to the CCC, it is the UK's "*highest possible ambition*", as called by Article 4 of the Paris Agreement and it surpasses the reduction needed globally to hold the expected rise in global average temperature below 2°C.

There is no doubt that reaching the net-zero target requires extensive and structural changes across the economy, and all the sectors have a role to play here. The Information and Communication Technologies (ICT) sector, for instance, has seen a growing concern regarding its environmental impact, although it has delivered significant socioeconomic benefits over the last thirty years. According to some estimates, digital technologies account for 4 per cent of global emissions[10] and the ICT sector[11] could account for up to 14 per cent of global emissions by 2040 if left unchecked, of which 24 per cent will come from communications networks alone.

It is however important to note that digital technologies can also be considered as opportunities for the green transition. According to Global Enabling Digital Sustainability report, "*SMARTer 2030 – ICT solutions for 21st century*", ICT has the potential to enable a 20 per cent reduction in global CO_2 emissions by 2030.

Understanding the relationship between climate change and the ICT sector is therefore important for regulators and government in order to frame climate-sensitive telecommunications policies which would contribute to

[6] United Nations, The Paris Agreement, 2021. Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[7] For more details, see: https://sdgs.un.org/goals
[8] European Commission, A European Green Deal, 2019-2024. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-greendeal_en
[9] European Commission, The European Climate Law, June 2021. Available at: https://ec.europa.eu/clima/policies/eu-climate-action/law_en
[10] Digital Watch Observatory, Digital and Environment, 2020. Available at: https://dig.watch/trends/digitaland-environment
[11] Belkhir, L. & Elmeligi, A., Assessing ICT global emissions footprint: Trends to 2040 and recommendations, 2018. Available at: https://www.sciencedirect.com/science/article/abs/pii/S095965261733233X (2018)

avert any negative climate change impact of the ICT sector. This would include spectrum policy, as radio spectrum is one of the linchpins of the ICT infrastructure.

1.2 Context and objectives of the study

The ICT sector plays a two-pronged role when it comes to climate change – both as a potential carbon emissions emitter and as a mean to reduce those emissions. Integrating both green and digital issues is becoming a hot topic in the public debate in the UK and beyond. The EU's new industrial strategy 2020 has identified climate neutrality and digital leadership as its twin goals.[12] In February 2020, the EC passed a digital strategy that aims to use digital technologies to help the EU reach climate neutrality by 2050.[13]

Understanding the relationship between climate change and the ICT sector will help regulators and governments frame climate sensitive telecommunications policies which could avert any negative climate change impact of the ICT sector. This would include spectrum policy as radio spectrum is one of the linchpins of the ICT infrastructure. Earlier this year, RSPG (Radio Spectrum Policy Group) circulated a consultation[14] seeking comments on the Radio Spectrum Policy Programme (RSPP) – a five-year programme (first adopted in March 2012) which sets out the regulatory requirements, goals and priorities of the European Union relating to the radio spectrum.[15] The GSMA responded[16] to this consultation, covering various themes including the role of spectrum policy in climate change.

In this context, the UK SPF commissioned this study to assess the spectrum policy aspects related to climate-neutrality in the UK. While the initial interest in this topic was raised from the RSPG consultation and GSMA's response, the scope of the present study includes the climate impact of spectrum policy beyond the mobile sector, considering all spectrum use. The study will inform policy makers on the short-term and more impactful actions to look at and implement, to be able to tackle climate change from a spectrum policy point of view. However, while this study aims to identify important policies from the point of view of environmental impact, it is important to remember that regulatory decisions should not be taken based solely on this criterion; policy must take into account social and economic welfare; the needs of consumers, businesses, emergency services and utilities; and other governmental objectives.

1.3 Structure of the study

The study reviews existing research in the area of spectrum policy and climate change. The first part of the literature review (**Section 2**) looks at the two-fold link between the ICT sector and climate change: the ICT sector as an enabler of carbon emissions reduction as well as a polluter. The section also examines some examples of initiatives taken by the private sector, starting with the measurement and monitoring of its own impact on the climate. The second part of the literature review (**Section 3**) looks more specifically lat the potential role of spectrum policy on climate change. Little has been analysed and written yet in the existing literature, confirming that the present study is ground-breaking.

[12] European Commission, A new Industrial Strategy for a globally competitive, green, and digital Europe, March 2020. Available at: https://ec.europa.eu/commission/presscorner/detail/en/fs_20_425

[13] European Commission, Shaping Europe's Digital Future, February 2020. Available at: https://ec.europa.eu/info/sites/info/files/communication-shaping-europes-digital-future-feb2020_en_4.pdf

[14] RSPG, Public Consultation on the Draft RSPG Opinion on a Radio Spectrum Policy Programme, 15 Feb 2021- 26 Mar 2021. Available at: https://rspg-spectrum.eu/public-consultations/

[15] European Commission, Radio Spectrum Policy Programme: the roadmap for a wireless Europe. Available at: https://ec.europa.eu/digital-single-market/en/radio-spectrum-policy-programme-roadmap-wireless-europe

[16] GSMAi , GSMA's response to the Draft RSPG Opinion on a Radio Spectrum Policy Programme (RSPP), March 2021. Available at: https://www.gsma.com/gsmaeurope/wp-content/uploads/2021/03/GSMA-response-to-RSPG-Opinion-on-RSPP.pdf

Potential policy options have been identified, including but not limited to those proposed by the GSMA in their response to the RSPG. They have been discussed (**Section 4**) and classified (**Section 5**) according to a discussion-based qualitative methodology

The study closes with recommendations (**Section 6**), informing policy makers on the more short-term and more impactful actions to look at to give a role to spectrum policy in combatting climate change.

2 Literature review part 1: The relationship between the ICT sector and climate change

This section presents the first part of the literature review which covers the relationship between the ICT sector and climate change. It offers a background for understanding the rest of the study, with the core statement that the ICT sector acts as both an enabler of carbon emission reduction, and also as a contributor. The section also describes some initiatives taken by stakeholders, including the key action of being able to measure the impact.

2.1 ICT as an enabler of carbon emissions reduction

Section 2.1 examines how the ICT sector may help combat climate change. Looking at the different communications technologies covered in the literature, research on ICT as an enabler of carbon emission reductions seems to be specific to mobile networks, and services or applications such as climate monitoring, Internet of Things (IoT), smart grids and utilities. Almost nothing specific on the matter has been analysed regarding broadcasting, fixed networks, satellite, and Radio Navigation.

2.1.1 ICT sector-wide enablement effect

The GSMA (Global Systems for Mobile Communications Association) estimates that the mobile industry is responsible for around 0.4 per cent of carbon emissions globally, but that it enables carbon reductions in other sectors that are ten times larger (around four per cent of global emissions).[17] Looking at the ICT sector as a whole, the RSPG notes that it has the potential to enable a 15 per cent reduction in other sectors, such as energy, industry, and transport. ETNO (European Telecommunications Network Operators' Association) confirms that figure,[18] underlines that "*high-capacity, stable, energy-efficient networks are key enablers for sustainable digitalisation*" and notes that telecoms networks are "*the backbones of major CO_2 reductions enabled by digitalization, across different sectors of the economy and society. Sectors as diverse as manufacturing, transport, healthcare and the public administration can only achieve carbon neutrality by accelerating their digital transformation.*"

A report[19] from GeSI (Global e-Sustainability Initiative) analyses the role of ICT as an enabler in carbon emissions reductions up to the year 2030. The key technologies it studies for the enablement effect are digital access, high speed Internet connection (for example 5G), cloud services, IoT, cognitive analytics (Artificial Intelligence - AI and machine learning), digital reality (for example virtual and augmented reality) and blockchain. The mechanisms or the 'impact functions' (as the report defines it) highlighted potential results as better connectivity and communication, automation, and improved real-time monitoring and tracking. Moreover, access to data through ICT devices (such as IoT sensors) would provide insight, analysis and predictions that could facilitate optimum resource utilisation.[20]

The report notes that the estimated key results of the higher adoption of these technologies up to 2030 are likely to be:

[17] GSMA, Mobile Net Zero: State of the Industry on Climate Action 2021, Page 28, 2021. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.)
[18] ETNO response to RSPG consultation, August 2021. See Section 3 below.
[19] GESI, Digital with Purpose: Delivering a SMARTer 2030, 2019. Available at: https://gesi.org/research/gesi-digital-with-purpose-full-report
[20] For examples of how frontier technologies can address climate change, see « The role of digital and mobile-enabled solutions in addressing climate change, GSMA, February 2021, Box 2 page 14

- carbon emissions abatement approximately seven times the size of the growth in the total ICT sector emissions (2019-2030); and

- potential reversal of the ICT sector footprint (in an optimistic scenario ambitiously deploying policy and sector interventions) and emissions reduction equal to 9 per cent of the total world emissions.

The "*enablement effect*" could first be due to a **change in behaviour** coming from the use of smartphones. In a study commissioned by the Carbon Trust[21] on the use of 6,000 smartphones in seven countries (UK, China, India, USA, Mexico, Brazil, and South Africa), the avoided emissions mainly come from:

- reduced travel for commuting and for leisure;

- increased use of public transport by using apps providing real-time updates;

- accommodation sharing for short stays and holidays; and

- reduced travel through the use of mobile shopping and mobile banking apps.

The "*enablement effect*" would also be due to the use of digital technologies in different sectors, starting with the **telecommunications sector**. Vodafone[22] uses IoT and AI to monitor its base stations in the UK, and "*smart sites*" enables the operator to manage issues remotely (without having to send field engineers to fix the problem). Moreover, the ITU (International Telecommunication Union) Study L.1507 elaborates on the role of ICT in the collection of environmental monitoring data. The study suggests the use of ICT sites as environmental sensing stations, because of their global distribution, reliable power, and network communications.[23] AI is considered another ICT driver of the positive environmental impact, including applications such as "*distributed energy grids, precision agriculture, sustainable supply chains, environmental monitoring and enforcement, and enhanced weather and disaster prediction and response*." AI is estimated to be able to reduce worldwide GHG by 4 per cent in 2030, while leading to productivity improvements.[24]

Other possible use cases are discussed below.[25]

- **Smart energy and smart grid:** Low latency electronic communication devices can enable more efficient energy use coupled with reduced costs. They can be used in smart grids to monitor processes in the grid and boost energy transmission efficiency, optimise energy consumption in real time, and implement distributed generation. Moreover, smart meters can induce more responsible behaviours in consumers through increased transparency and dynamic pricing.

- **Transport:** ICTs help to reduce the saturation of urban traffic networks which could potentially result in reduction of local pollutant emissions including fine particles and their associated greenhouse effect. For example, Urban Rail Intelligent Transportation Systems (ITS) use communication-based train control systems that help its operations to be more energy efficient due to better exchange of information between trains, resulting in swifter and focused response to traffic congestion. Other functionalities include the use of automatic driving strategies which could further reduce energy consumption. Optimised navigation through ICT in aviation and maritime services also lead to reduced emissions.[26]

[21] GSMA, The Enablement Effect, 2019. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf
[22] Vodafone, Connecting for Net Zero: Addressing the climate crisis through digital technology, Sept 2021. Available at: https://newscentre.vodafone.co.uk/app/uploads/2021/09/Connecting-Net-Zero-090921-Pages-1.pdf
[23] ITU, Use of ICT sites to support environmental sensing, 2019. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13965
[24] Microsoft &PWC, How AI can enable a sustainable future, 2020. Available at: https://www.pwc.co.uk/services/sustainability-climate-change/insights/how-ai-future-can-enable-sustainable-future.html
[25] RSPG, the role of radio spectrum policy to help combat climate change, 2021. Available at: https://rspg-spectrum.eu/wp-content/uploads/2021/06/RSPG21-027final-Draft_RSPG_Opinion_on_Climate_Change.pdf
[26] See the example of Aireon's ADS-B service at https://aireon.com/benefits/safety/)

- **Smart vehicles:** Vehicles supported by ITS could optimise traffic flows by providing real-time information on the traffic situation, in turn improving congestion, reducing commuting times and thus GHG emissions. The potential of emissions reductions here is estimated between 6.6 and 9.3 million tonnes.[27]

- **Powering vehicles:** The car industry is currently shifting to electric power. The trend is on-going and creates challenges for power generation, supply, and energy storage. In the light of the rising demand for electric vehicles, there is market demand for Wireless Power Transmission for electric vehicles (WPT-EV) systems, however its efficiency compared to wired charging is a matter of contention. The latter could offset the decrease in emissions by opting for an electric vehicle option at the first place. However, RSPG also notes the risk to the wireless power transfer systems, due to radio frequency interference.[28]

- **Industry 4.0:** Digitalisation could optimise manufacturing processes, including automation of some industrial processes, and make the overall production more efficient. Improved "*storage and inventory management greatly reduces the overall level of inventory and area needed, increasing efficiency and decreasing energy use for lighting and cooling.*"[29] IoT and 5G-enabled technology (for example 3D printing and smart sensors) would have the potential to reduce emissions by 2.7-3.3 million tonnes of carbon emissions annually in the UK.[30]

- **Smart agriculture:** Precision farming could help farmers reduce resource wastage, and increase crop yield (for example, using drones). IoT-enabled irrigation and soil monitoring systems could help improve soil quality and avoid deforestation. Vodafone has suggested that connected technologies in agriculture would contribute to reduce emissions by 2.4-4.8 million tonnes of carbon emissions annually in the UK.[31] Moreover, radio-location systems could facilitate precision fertilisation and target spraying. This would both increase yield and reduce pesticide consumption. For smart agriculture satellites can help overcome lack of coverage and so support use of wireless technologies. For example, EGNOS (European Geostationary Navigation Overlay Service) and Galileo are radiolocation systems of the European Union Agency for Space Programmes (EUASPs).[32] The potential of 5G and IoT for the agricultural sector to fight climate change is further studied in a report by Mobile UK.[33] As part of 5G testbed, 5G RuralDorset and the Department for Digital, Culture, Media & Sport (DCMS) are working on automated arable farming robots, which can remove weeds using electricity and limit the environmental impact of agriculture by reducing the use of chemicals and big farm machines in the fields. The testing is still in the early stage, and it is still not possible to assess the energy savings, but it is claimed to be the world's first agri-robot.[34]

- **Smart homes and offices:** Digitalisation in buildings could improve operational efficiency and cut energy consumption by about 10 per cent. Technologies like building management systems and smart meters improve energy efficiency by reducing gas and electricity consumption and enable more effective management and monitoring of the use of electricity, heating, and cooling.[35] One unintended consequence of improvements to the energy-efficiency of buildings is that these improvements tend to make indoor coverage of radio services worse. The additional path losses due to insulation can mean

[27] Vodafone, Connecting for Net Zero: Addressing the climate crisis through digital technology, Sept 2021. Available at: https://newscentre.vodafone.co.uk/app/uploads/2021/09/Connecting-Net-Zero-090921-Pages-1.pdf
[28] RSPG, June 2021, RSPG Report on the role of radio spectrum policy to help combat climate change. Available at: https://rspg-spectrum.eu/wp-content/uploads/2021/06/RSPG21-026final_RSPG_Report_on_Climate_Change.pdf
[29] GSMA, The Enablement Effect, 2019. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf
[30] Vodafone, Connecting for Net Zero: Addressing the climate crisis through digital technology, Sept 2021. Available at: https://newscentre.vodafone.co.uk/app/uploads/2021/09/Connecting-Net-Zero-090921-Pages-1.pdf
[31] Ibid
[32] For more details see: https://www.gsa.europa.eu/segment/agriculture
[33] For more details see: https://www.mobileuk.org/news/initial-research-from-mobile-uk-reveals-the-vast-potential-of-5g-to-fight-climate-change
[34] For more details see: https://5gruraldorset.org/2021/03/23/new-qualcomm-and-5g-ruraldorset-relationship/
[35] Ibid.

that indoor coverage of, e.g. 4G or broadcast (e.g. FM and DAB radio) is degraded. This may need to be allowed for by policymakers when setting coverage requirements or maximum transmitter power levels.

- **Smart city:** For example, waste management services including collection and recycling could be improved through data collection from IoT devices.

The different verticals and use cases do not have the same level of enablement effect. The GSMA states that "*categories of enablement such as agriculture and health are not currently showing a significant impact on avoided emissions. However, both are important as they hold significant future opportunities of enablement by mobile communications technology.*"[36]

Regarding **Radio Navigation**, none of the activities have been mentioned as enablers of carbon emissions reduction, although there is a brief mention of energy efficiency in a paper on e-Navigation.[37] It might be expected that the sector would wish to highlight the potential offered by Radio Navigation for efficient routing and thus energy minimisation – although there appear to be no existing studies on this. It may be relevant to note that the Radio Navigation sector is changing, with fewer ground-based aids and a move away from primary to secondary radar.[38]

Because **5G services** will facilitate the deployment of a number of the applications listed above, it may be seen as an enabler to combat climate change. New research from Mobile UK to be published later this year shows the role of 5G in the reduction of carbon emissions, through the capability it creates for IoT and as an enabler for other industries "*to work and operate more efficiently and ecologically.*"[39]

In the **broadcasting sector**, wireless digitalisation has some positive effects in terms of environmental impact.[40]

- On the production side:
  - wireless production equipment (such as microphones and cameras) reduces the set-up time and effort;
  - travel has been reduced thanks to the increasing use of distributed, remote or automated production workflows; and
  - specialised equipment and dispatching production vehicles have been less needed in news operations thanks to 4G services.
- Separately, on the distribution side, the discussion around 5G broadcast has seen the broadcasting sector claiming energy efficiency to be a reason to favour a hybrid 5G broadcast solution over 5G mobile.[41]

[36] Ibid.
[37] A.Weintrit, e-Nav, is it enough?,Transnav, 10(4), p567-574, 2016. Available at: https://pdfs.semanticscholar.org/eae8/365c16638c2c835be4b07b21f18b7845940b.pdf
[38] Jan Georgopoulos,, Reducing Aviation Navigation Aid Numbers, PagerPower, Sept 2014. Available at: https://www.pagerpower.com/news/reducing-aviation-navigation-aid-numbers-risk-2014/
[39] For more details, see: https://www.mobileuk.org/news/initial-research-from-mobile-uk-reveals-the-vast-potential-of-5g-to-fight-climate-change
[40] EBU, Response to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change. January 2021. Available at: https://www.ebu.ch/files/live/sites/ebu/files/News/Position_Papers/open/2021_08_31_EBU_response_RSPG_%20radio%20spectrum%20policy%20%26%20climate%20change.pdf
[41] For more details, see: shorturl.at/koyE4

2.1.2 The importance of science services (earth sensing, meteorological)

None of the activities within the science services sector have been mentioned as enablers of carbon emissions reduction in the literature. However, the science sector is of fundamental importance in understanding the processes leading to climate change and, therefore, to targeting action appropriately.

It seems unlikely that the Radio Astronomy Service has any role as an enabler of emissions reduction – certainly nothing was found in a brief search. Nevertheless, the Meteorological and Earth Sensing services are of primary importance to the topic. On the ITU-R web page[42] relating to climate change, most of the references listed relate to the Science Services, particularly to the EESS (Environmental and Earth System Science).

Numerous articles explain the role of ground and (particularly) space-based observations in understanding climate change.[43] The main EU programme is Copernicus,[44] in which the UK remains a partner post-Brexit. Ofcom also provides some useful summaries of spectrum use by the science services, particularly passive sensing, on its website[45] (see, in particular, the response from Eumetsat). Finally, the European centre for Medium-Range Weather Forecasts (ECMWF) published a report[46] of their 2018 workshop on radio frequency interference.

The radio spectrum is a relatively small part of the overall range of electromagnetic frequencies employed in sensing, but it is essential that it be protected to enable the work of science services in the country.

Focus on meteorological systems

In the light of an increasing frequency of extreme weather events (often leading to large scale loss of life), climate change monitoring and weather forecasting have become even more critical. Both ground-based and satellite-based communication systems play a role in this. These services have been discussed in detail in the ITU Handbook on the use of radio spectrum for meteorology.[47] Some of these services are:

- earth-exploration satellite service includes active and passive sensors on satellites and various emissions transmitting data from Earth-to-space, space-to-Earth and space-to-space;
- meteorological satellite service (MetSat) includes an Earth exploration satellite for meteorological purposes;
- meteorological aids (MetAids) service includes radiocommunication services for meteorological and hydrological observations; and
- radio location service includes ground-based meteorological radars and wind-profiler radars[48] used for weather prediction, aeronautical and maritime navigation, and atmospheric research.

[42] For more details, see: https://www.itu.int/en/ITU-R/information/Pages/climate-change.aspx
[43] ITU,, Monitoring our changing planet, ITU New Magazine, 2019 (1). Available at: https://www.itu.int/en/itunews/Documents/2019/2019-01/2019_ITUNews01-en.pdf
[44] For more details, see: https://climate.copernicus.eu/
[45] For more examples, see: https://www.ofcom.org.uk/consultations-and-statements/category-1/space-science-cfi
[46] ECMWF, Radio-Frequency Interference (RFI) Workshop: Final report, Sept 2018. Available at: https://www.ecmwf.int/sites/default/files/elibrary/2019/19026-radio-frequency-interference-rfi-workshop-final-report.pdf
[47] ITU-R, Handbook on Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction, 2017. Available at: https://library.wmo.int/doc_num.php?explnum_id=3793
[48] A type of weather observing equipment that uses radar or sound waves (SODAR) that detects the direction and the speed of wind at different points of elevation from ground.

Examples of some international and regional programmes catalysing the provision of these services through public sector funds are World Weather Watch program of the World Meteorological Organisation and EU's Copernicus initiative (previously known as Global Monitoring for Environment and Security, GMES).

2.1.3 ITU recommendations on the role of ICT in climate change *adaptation*

Climate adaptation is a short-term remedial response to climate change and is different from climate change mitigation, which is to do with trying to reverse or slow down climate change, for example by reducing GHG emissions. The following is a discussion on some of the key studies undertaken by ITU on this subject.

- ITU-T SG5 recommendations L.1500-L.1507 evaluate the role of ICT in climate change adaptation, that is adjusting or responding to ongoing climate change and its effects such as sea level rise, surface temperature rise, climate disasters, increase in surface rainfall, among others.[49]

- ITU-T L.1501 provides guidelines on how ICTs could be of assistance to countries adapting to the effects of climate change. It also recommends for the ICTs to be integrated into the national climate change adaptation strategy and provides a framework as well as a checklist for countries on how to do so. Ways in which ICT can contribute to climate adaptation could be environmental observation, climate monitoring and climate change prediction.[50]

- Other studies on climate change adaptation include L.1503 that specifically looks at the agricultural sector. Some methods suggested including site monitoring like land use planning using geographic information systems (GIS), remote sensing technologies (RS), promoting knowledge sharing including disseminating climate-smart agricultural information to and from farmers.[51]

- Recommendation ITU-T L.1504 provides a description of how the use of ICT can help sustain the agricultural sector in the event of poor yields or disasters triggered by climate change. The possible impacts of climate change on agriculture and farming communities are described. This is followed by an outline of what measures are needed to adapt the sector and how ICT can play a role in this. The Appendices of L.1504 share some examples of best practices in different countries with details of specific ICT implementations.[52]

- Study L.1505 looks at how ICT can adapt the climate impact on the fishing sector. Climate change (for example, rising or falling temperatures) is likely to affect the fish stocks, their habitats, their migratory patterns, and mortality rates. These climatic effects on fish stocks would have a negative socio-economic consequence for population dependent on fisheries and aquaculture for their livelihood. Like for agriculture, ICT could play a role in climate adaptation of the fishing sector by monitoring site conditions, weather forecasting and promoting knowledge sharing, to mention a few.[53]

[49] ITU, ITU-T recommendations: L.1500-L.1599: Adaptation to climate change. Available at: https://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5
[50] ITU, Best practices on how countries can utilise ICTs to adapt to the effects of climate change, 2014. Available at: https://www.itu.int/rec/T-REC-L.1501-201412-I
[51] ITU, Use of information and communication technology for climate change adaptation in cities, 2016. Available at: https://www.itu.int/rec/T-REC-L.1503-201606-I
[52] ITU, ICT and adaptation of agriculture to the effects of climate change, 2016. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13149
[53] ITU, Information and communication technology and adaptation of the fisheries sector to the effects of climate change, 2018. Available at: https://www.itu.int/rec/T-REC-L.1505-201801-I

2.2 ICT as a polluter

Because of the increasing efficiency of equipment, ICT has improved its efficiency regarding its impact on climate change. It is estimated for instance that, in developed countries, the electricity intensity of data transmission has decreased by half every two years since 2000.[54] This has been counterbalanced by the increasing demand of power-hungry communications services.

2.2.1 Mobile networks

According to the RSPG report on the role of radio spectrum policy to help combat climate change,[55] the use of radio spectrum impacts the GHG emissions associated with all equipment and devices throughout a product's lifecycle (from manufacturing to end-of-life), as well as the activities associated with or enabled by the spectrum use. It is expected that the environmental impact of the wireless technologies is majorly associated with the manufacturing and operation of network equipment.

From the entire ICT sector (i.e., user devices, networks, and data centres), user devices account for the largest proportion of the carbon emissions. The emissions largely result from electricity consumption at the user end. It is expected that more than 80 per cent of the ICT's carbon footprint could be reduced if the ICT industry and its users only consumed electricity produced by renewable energy sources. Regarding network equipment, the largest share of emissions comes from its operation. In future research, the focus should be on studying the emissions in the entire supply chain and over time, to make a correct assessment of the net emissions. For example, while energy efficient technology might have a lower carbon footprint, if it results in the earlier disposal of current equipment that might outdo any efficiency gains.

The RSPG highlights two ways to reduce the emissions:

- the use of greener electricity to operate equipment; and
- the use of energy-efficient equipment to optimise consumption.

The latter may be associated with a decrease in operators' operating costs. It has been asserted that cost savings are the main driver for reducing energy consumption, more than social responsibility, regulatory compliance, or customer demand.[56]

Energy consumption represents 15-40 per cent of the operating costs of mobile operators (MNOs) and is expected to keep rising with the increase in data traffic. The GSMA predicts that 78 per cent of mobile subscribers will be using 4G and 5G in 2025, with 21 per cent relying on 5G (Figure 2.1). Information from Opensignal indicates that 5G subscribers on average consume around 2.7 times more data[57] than 4G subscribers, meaning that there is likely to be a very large rise in traffic demand over the coming years. Even if the power required for 5G transmission is lower, this increase in traffic may negate any benefits. This reinforces the strategic aspect of reducing energy consumption for operators. Reducing emerging consumption is in the top three of the industry's priorities for the next five years.[58]

[54] J. Aslan & al.,Electricity intensity of Internet data transmission, untangling the estimates, 2017. Available at; https://onlinelibrary.wiley.com/doi/pdf/10.1111/jiec.12630

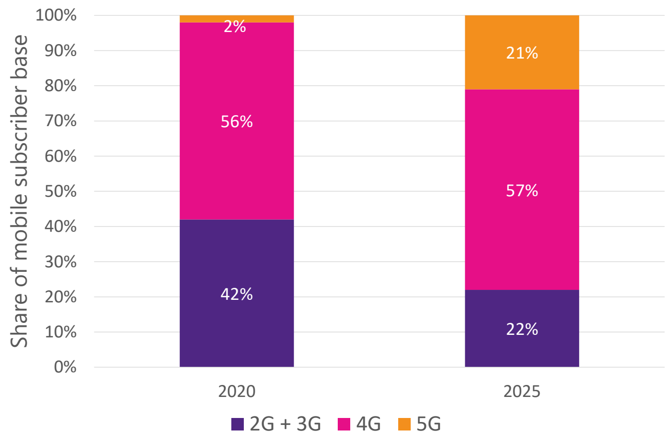
[55] RSPG, June 2021, RSPG Report on the role of radio spectrum policy to help combat climate change. Available at: https://rspg-spectrum.eu/wp-content/uploads/2021/06/RSPG21-026final_RSPG_Report_on_Climate_Change.pdf

[56] Interdigital, How sustainable are our mobile networks?, Mobile World Live, 2020. Available at: https://www.interdigital.com/white_papers/how-sustainable-are-our-mobile-networks

[57] Not that this may be biased upwards since most 5G subscribers so far are early adopters who are more likely to be high users. It is important that usage is closely monitored to identify long term trends here. Even so, experience from the 3G to LTE transition showed increases in data use for all users, not just early adopters.

[58] Ibid.

Figure 2.1: Expected rise in data use[59]



To better understand the specific impact of spectrum, there is a need to analyse the impact of spectrum related aspects such as, the operating frequency, the usage of higher frequency bands (such as mmWave), active antennas, and small cells, on the energy consumption of the wireless equipment, and the impact of the interaction of these elements on energy consumption. Various components can impact the energy consumption of the industry. These could include: the frequency band in use; the number of base station sites (including small cells); whether sites are shared; if dedicated spectrum is assigned; type of traffic (flow of data, size of data flow); uses (including spectrum assigned to or used by verticals); efficiency of signalling between base stations and terminals; antennas (Advanced Antenna Systems/Multiple Input – Multiple Output); and modulation. All impact on the energy efficiency of the network. The precise impact of the wireless technologies on the climate would depend upon the network structure, energy mix and the equipment used. All of these factors would be country and operator specific.

2.2.2 Other telecommunications sectors

The impact on climate of some other telecommunication sectors has been also considered in the literature but to a lesser extent than mobile services. This section highlights the main hot topics in each area.

Fixed networks. According to the RSPG, the operations of wired technologies (e.g., optical fibre, ethernet, cable, etc.) are usually found to be more energy efficient when compared to wireless technologies. While there are lots of studies looking into the economics of access technologies, the interest seems to be in the comparison between different fixed technologies including Fixed Wireless Access, and most studies focus on the financial costs (operating and capital expenditure, Total Cost of Ownership). There appear to be no existing studies on the carbon footprint. Malmodin & Lunden[60] investigate the electricity consumption and operational carbon emissions of telecom operators, based on uses measured and collected data on fixed and mobile telecom networks.[61] The study shows that between 2010 and 2015, the electricity consumption of the ICT networks grew by 31 per cent and the operational carbon emissions grew by 17 per cent. The increase trend looks approximately linear. Nevertheless, per subscription, the average annual operational electricity consumption for mobile has decreased slightly in the same period (from 27.6 kWh to 27 kWh per subscription). The overall increase in electricity consumption is mainly associated with the expansion of mobile networks. Prysmian[62] shows that the access technologies differ considerably in the number of required active network elements and

[59] GSMA Intelligence, Going green: can 5G be energy efficient? Online event, 22 September 2021 (worldwide mobile base, expected evolution)

[60] Malmodin, J. and D. Lundén,The electricity consumption and operational carbon emissions of ICT network operators 2010-2015. Report from the KTH Centre for Sustainable Communications Stockholm, Sweden 2018.

[61] The study excludes enterprise networks, data centers and end-user equipment.

[62] Prysmian, Energy consumption of telecommunications access networks, 2017. Available at :https://www.prysmiangroup.com/staticres/energy-consumption-whitepaper/8/index.html

locations, and in their power consumption, in a study comparing different broadband access technologies – VDSL2 Vectoring, DOCSIS 3.0 in HFC networks at 864 MHz, FTTH – PtP Ethernet, and FTTH – GPON. Obermann[63], in a study for Breko, found that the FTTH technologies were more sustainable than FTTC networks in every scenario assessed in the study and for almost every degree of utilisation. They are also cheaper in terms of power consumption and overall weight. The analysis also shows that the biggest share in the total power consumption or weight is held by the network elements at the subscriber end.

Broadcasting. The BBC has published two recent studies looking at energy consumption of TV[64] and radio[65] distribution and consumption. Schien et al (2020) assessed electricity used for the preparation, distribution and viewing of television over different distribution platforms[66]: satellite viewing was greatest (53 per cent), followed by terrestrial viewing (22 per cent), cable viewing (19 per cent), and iPlayer viewing (6 per cent). Set-top boxes and televisions are identified as key hotspots in the system. It is noted that TV technology had become increasingly efficient in the last few years, particularly as a consequence of efficiency improvements in flat-screen technology. Conversely, complex STBs, used for cable and satellite services, are becoming more widespread in the home and have more sophisticated functionality than the simple STBs they are replacing, resulting in higher energy usage both when on and in standby mode. The Broadcast Networks Europe (BNE)[67] refers to the same study to underline that "*digital terrestrial broadcast is the least electricity-intensive distribution platform, when compared to cable, satellite and streaming which can use up to 2.5 times more energy per device for each hour of viewing*".

Fletcher and Chandaria[68] adopt a similar methodology to Schien et al to estimate electricity consumption of radio distribution and consumption. Across radio delivery platforms, the mean energy for AM represents 7.7 per cent, FM 30.8 per cent, DAB 20.0 per cent, DTV 17.2 per cent, and IP 24.3 per cent. Consumer devices are the dominant component, representing 73.4 per cent of the mean energy, and almost three times that of distribution (26.5 per cent). Playout, encoding and multiplexing contributed a mean energy of (0.1 per cent). Sensitivity analysis around consumption demonstrated that removing all radio devices and smart speakers from their power supply instead of leaving in standby could lead to substantial savings in energy across all scenarios, averaged at 38.3 per cent.

A recent white paper published by the Carbon Trust identifies the viewing device as the most important driver of the carbon footprint (more than 50 per cent) of video streaming.[69]

Environmental impact of satellite launches. Space launches[70] can have a hefty carbon footprint due to the burning of solid rocket fuels. Many modern rockets are propelled by liquid hydrogen fuel, which produces 'clean' water vapour exhaust, although the production of hydrogen itself can cause significant carbon emissions. Rocket engines release trace gases into the upper atmosphere that contribute to ozone depletion, as well as particles of soot.

Rocket launches are nonetheless relatively infrequent, meaning that their overall impact on our climate remains much smaller than aviation. However, it is not just the immediate environment that is impacted: 'space junk' is a

[63] Obermann, IK, Nachhaltigkeitsvergleich der Zugangsnetz-Technologien FTTC und FTTH. University of Applied Sciences (Technische Hochschule) Mittelhessen, 2020. Available at: https://www.brekoverband.de/site/assets/files/4853/gutachten_nachhaltigkeitsvergleich_ftth_fttc.pdf

[64] Schien, D., P. Shabajee, J. Chandaria and C. Priest, Using behavioural data to assess the environmental impact of electricity consumption of alternate television service distribution platforms, BBC Research & Development White Paper, WHP 372. [updated June 2021]. Available at :https://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP372.pdf

[65] Fletcher, C. and Chandria, J. , The energy footprint of BBC radio services: now and in the future. BBC Research & Development White Paper, WHP 393, 2020. Available at : https://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP393.pdf

[66] Note the study did not consider energy usage from the production of TV content, manufacturing and use of DVDs, manufacturing of infrastructure and devices, or launching of broadcast satellites.

[67] BNE response to the Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change. January 2021.

[68] Fletcher, C. and Chandria, J., The energy footprint of BBC radio services: now and in the future. BBC Research & Development White Paper, WHP 393, 2020. Available at : https://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP393.pdf

[69] For more details, see: https://www.carbontrust.com/news-and-events/news/updated-calculation-released-on-the-carbon-impact-of-online-video-streaming

[70] For more details, see https://www.sciencefocus.com/space/are-space-launches-bad-for-the-environment/

growing concern as disused satellites and other objects accumulate in our planet's orbit, which has led to a focus on the development of Active Debris Removal.[71]

It is also reported[72] that "*upon reaching orbit, the world's heaviest operational rocket will have burned about 400 metric tons of kerosene and emitted more carbon dioxide in a few minutes than an average car would in more than two centuries. The kerosene-fuelled rockets transport large amounts of black carbon, also known as soot, into the upper layers of the atmosphere. There, it remains for a long time, creating an umbrella that may add to global warming. The fuel is widely used because it's easier to handle than fuels such as hydrogen.*" There are no regulations on rocket emissions, but the industry is developing less damaging options such as bio-propane that can cut emissions by 90 per cent compared with traditional launch fuel. The number of launches is expected to increase tenfold to roughly 1,000 annually.

Air pollution from re-entering mega constellation satellites.[73] When defunct satellites burn in the atmosphere,[74] they leave behind chemicals that could damage the ozone layer and affect how much light Earth absorbs. In the case of mega constellations expect tens of thousands of satellites. With the first generation of Starlink, one can expect about 2 tonnes (2.2 tons) of dead satellites re-entering Earth's atmosphere daily compared with 60 tons of meteoroid material; Pultrarova notes that "*meteoroids are mostly rock, which is made of oxygen, magnesium and silicon; [t]hese satellites are mostly aluminium, which the meteoroids contain only in a very small amount, about 1 per cent.*" The burning of aluminium is known to produce aluminium oxide, also known as alumina, which can trigger further unexplored side effects as it reflects light at certain wavelengths and over time could change the albedo[75] of the planet.

Sciences services (earth sensing, meteorological). On radio astronomy, there appear to be no existing studies on its impact on climate change. Climate change has an impact on observations though, and some astronomers call for change in computing strategy.[76] Recommendations include avoiding inefficient languages such as Python in favour of Fortran.

As for radio astronomy, the use of supercomputers in meteorological research will contribute to carbon emissions. Many sensors are passive or rely on solar power (satellite radar systems), but ground-based radars will have a significant energy consumption – these are very few, however.

Radio navigation. Primary radar systems are power-hungry, but they are few in number, so they are likely to have little impact. It seems that there is no existing study for now on the subject. It may be important to underline here the issues associated with interference to navigational aids (VOR, Radar) from wind turbines, thereby imposing restrictions on the deployment of turbines.[77]

2.2.3 Focus on e-waste and the circular economy

The manufacture and use of devices and equipment is considered the biggest source of emissions in the mobile sector. According to the GSMA, around 50 million tonnes of e-waste (electronic waste) are produced every year

[71] For more detail see https://www.esa.int/Safety_Security/Space_Debris/Active_debris_removal)
[72] For more details, see: Los Angeles Times, Can we get to space without damaging the Earth through huge carbon emissions?, 2020. Available at: https://www.latimes.com/business/story/2020-01-30/space-launch-carbon-emissions
[73] T. Pultarova, Air pollution from reentering megaconstellation satellites could cause ozone hole 2.0,Space 2021. Available at: https://www.space.com/starlink-satellite-reentry-ozone-depletion-atmosphere
[74] To combat waste in this area, there are a number of private initiatives to develop in-orbit servicing of satellites, which will increase the lifespan of equipment and potentially allow components to be recycled.
[75] Measure of the amount of light that is reflected by a material
[76] For more details, see: https://www.science.org/news/2020/10/we-re-part-problem-astronomers-confront-their-role-and-vulnerability-climate-change
[77] For more details, see: https://www.pagerpower.com/news/done-assessing-wind-farm-radar-interference/, and https://www.ofcom.org.uk/__data/assets/pdf_file/0024/62727/windfarm_report.pdf

and this number keeps increasing.[78] Globally raw materials valued at approximately $57 billion (in 2019) are dumped as e-waste, and mainly includes metals such as iron, copper, and gold. Less than 20 per cent of e-waste is collected and recycled.[79]

In this context, the circular economy is a "*model of production and consumption involving sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products*", in order to extend the life cycle of products and reduce waste to a minimum.[80]

The GeSI set up a group called the GeSI Circular Economy Task Force (CETF) with a focus on assisting in the achievement of SDG 12 i.e., responsible consumption and production. The group has produced an Internal assessment report (not publicly available) on the state of circular economy within the operations and services of GeSI members.[81]

The ITU Series L.1000-L.1199 provides recommendations on the adoption of a circular economy approach and principles within the ICT sector. For instance, ITU L.1020 suggests approaches of circular economy (CE) for ICT goods and networks. It emphasises the next steps to improve the circularity in the operators' supply chains. The study's objective is to provide options to enhance the circularity of operators' goods and networks, along with enabling the operators and their suppliers through various business models. The key points of focus put forward in the study are[82]:

- reducing the use of virgin materials through virtualisation and automation of networks, migration to software and service-based business models, dematerialisation of DVDs, CDs, and other similar measures;
- extending the use of products for a longer lifetime through network design and using them more efficiently;
- promoting reuse and recycling – having products that have been designed to be recycled, so designed with a life-cycle perspective in mind, promoting repair of goods, avoiding landfill; and
- enhancing the energy efficiency of network infrastructure and end-user equipment.

In order to implement the above suggestions, the study recommends that the operators and supply chain actors come together for a joint study to investigate new business models to promote circularity and set up and monitor key performance indicators. Appendix A of this document presents a list of some other relevant studies by ITU-T SG5 on promoting the circular economy in the ICT sector.

2.3 Measuring and monitoring environmental effects of ICT

"*Developing methods and tools to measure the net impact of green digital technologies on the environment and climate*" is one of the actions taken by the European Green Digital Coalition.[83] And it is noted that ETNO, GSMA and GeSI play a role in that matter.[84] The RSPG noted that the existing data on the impact of the wireless sector on climate change comes from multiple sources like academia, non-profit organisations, and the industry. These

[78] GSMA, Mobile Net Zero: State of the Industry on Climate Action 2021, 2021. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.pdf
[79] GeSi, *GeSI Circular Economy internal assessment report, 2021. Available at: https://www.gesi.org/research/gesi-internal-assessment-report-circular-economy*
[80] Source of definition: www.europarl.europa.eu
[81] GeSI, Internal assessment report circular economy, 2021. Available at: https://gesi.org/research/gesi-internal-assessment-report-circular-economy
[82] ITU, Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks, 2018. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13457
[83] For more examples, see: https://digital-strategy.ec.europa.eu/en/policies/european-green-digital-coalition
[84] For more details, see: https://etno.eu//downloads/news/why%20ict%20is%20the%20real%20green%20deal%20for%20europe.pdf

are based on different methodologies and data sources, which makes it complex to establish a comparison between them. RSPG emphasises on the need to have more transparent and trustworthy data that would be critical to enable policymakers to take the right course of action and empower the users to make more sustainable choices.

The ITU Recommendation L.1451 provides a methodology to assess the positive environmental effects of ICT on other sectors of the economy. The recommendation uses a computable general equilibrium (CGE) model to do so using a top-down economic approach with the help of economic input-output tables.[85] A basic CGE model would be based on the input-output tables of the baseline year and reproduce the economic equilibrium conditions of the base year. The model would calculate the energy consumptions and the resulting GHG emissions of both production and consumption activities of the sector. The output and overall GDP of the reference sector would also be calculated.

Looking at ICT services, it is expected that the sector would experience improvements in production efficiencies, and reduction in the amount of raw material and energy consumption. The latter potentially due to dematerialisation.[86] This would result in changes in the demand for intermediate inputs, goods, and services. These changes are then fed back into the input-output tables of the base year. As such, the input-output tables would be set temporarily out of economic equilibrium because of improvements in production efficiency and reduced intake of intermediate inputs. Eventually the equilibrium will be established again when the supply and demand of the product after the use of ICT services is balanced. Through the equilibrium calculation, the impact on the environment and economy, including economy-wide rebound effects caused by ICT use, would be evaluated.[87] For example, an enterprise is likely to see a reduction in the intermediate goods when using ICT-based supply chain management system than without it. This is likely to reduce the price of the goods which would impact their supply and demand in the market i.e., the demand for the goods would potentially increase because of lower price, in turn increasing the need for intermediate goods. This is referred to as the economy-wide rebound effect resulting from supply chain management.[88] Further ITU methodologies and guidelines to ICT sector emissions have been detailed in Appendix C of this document.

A benchmark initiative was launched by the GSMA to track energy efficiency by quantifying network energy consumption and efficiency levels, as well as fuel sources.[89] The study includes the data collected from 7 operators (BT, Deutsche Telekom, Etisalat, Globe, KPN, Smart and Vodafone), 31 networks, in 28 countries. The GSMA plans to expand it to other participants and to a multi-year view. The first average figures coming out of the study show that 73 per cent of the energy of the participating operators is consumed in the radio access network (RAN), with the network core (13 per cent), owned data centres (9 per cent) and other operations (5 per cent) accounting for the rest. Also, 46 per cent of total energy consumption was supplied by renewables, 43 per cent from traditional grid and 11 per cent from diesel (which is more concentrated in developing regions where grid and renewables access is less prevalent). The study reflects only the view of operators; other stakeholders holding RAN, core network, and data centres are not included (i.e. AWS, Microsoft, Google, CDNs, etc.). This initiative responds to the need for extended and accurate measurement of the energy consumption of stakeholders in the ICT sector. The GSMA identifies three challenges in this type of measurement.[90]

- how to define what constitutes MNO emissions;

[85] ITU, Methodology for assessing the aggregated positive sector-level impacts of ICT in other sectors, 2019. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14083
[86] Move from physical to the virtual space.
[87] ITU, Methodology for assessing the aggregated positive sector-level impacts of ICT in other sectors, 2019. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14083
[88] Ibid.
[89] GSMA Intelligence, Going green: benchmarking the energy efficiency of mobile, June 2021. Available at: https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60621137&file=300621-Going-Green-efficiency-mobile.pdf
[90] GSMA, Mobile Net Zero: State of the Industry on Climate Action 2021 2021. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.pdf

- how to measure emissions from MNOs; and
- how to measure emissions from MNOs' supply chain and from customers.

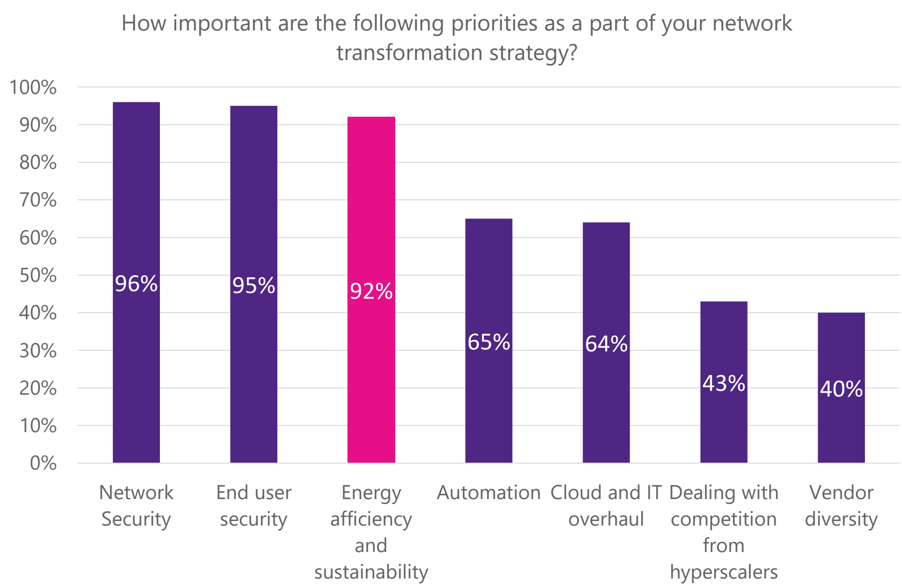
A practical methodology has also been developed by the GeSI to calculate the GHG emissions from ICT goods and services. More detail has been provided in Appendix B of this document.

2.4 Other actions from industry players to mitigate the negative impact of ICT on climate

European national regulators have started tackling the environmental issue of digital services: Arcep in France[91] has launched a working group to debate on this topic, and BEREC (Body of European Regulators for Electronic Communications) has integrated sustainability to its work.[92] But, as underlined by ETNO, industry is part of the solution and companies are now taking concrete actions to integrate environmental and sustainability issues in their strategic choices. Coalitions of companies, like "*Digital with Purpose*",[93] aim at delivering on the Paris Agreement and Sustainable Development Goals by 2030.

Figure 2.2 below shows the network operators' (MNOs and converged operators) priorities on network transformation, based on a GSMAi survey of 101 operators from around the world from May-June 2021. Energy efficiency and sustainability turns out to be the third highest priority.

Figure 2.2: Operator's priorities for network transformation strategy (2021)[94]



[91] For more details, see: https://www.arcep.fr/nos-sujets/numerique-et-environnement.html
[92] For more details, see: https://berec.europa.eu/eng/document_register/subject_matter/berec_office/decisions_of_the_management_board/9024-decision-of-the-management-board-of-the-agency-for-support-for-berec-on-the-appointment-of-the-co-chairs-of-the-expert-networking-groups
[93] For more details, see: https://digitalwithpurpose.org/#1
[94] Source: GSMAi

Setting climate targets

GSMA reports that 29 operator groups representing 30 per cent of the mobile connections worldwide are committed to science-based reduction targets.[95] Following are some examples of industry actors' reduction targets and other steps towards achieving sustainability.

Vodafone has committed to achieve a net zero emissions target by 2040. It also plans to half its emissions from its supply chain purchases, business travel and joint ventures. The targets have been reportedly approved by the SBTi and WWF (World Wide Fund) for Nature.[96] Also, Vodafone's net zero emissions target for the UK is 2027, much before its Europe wide target of 2040.[97]

Three (3) UK, is currently working to develop its net-zero targets. The targets are planned to be validated by SBTi in 2021.[98] O2, UK has launched a Green ad campaign called 'O2 vs CO2' and has set a target to achieve net zero emissions by 2025. [99] Further EE UK, has set the net zero emissions target timeline to be by 2045 and states it has reduced its carbon emissions by 57 per cent since 2016.[100]

Beyond the UK, Orange has also set net zero emission targets to be achieved by 2040, with reduction of emissions by 30 per cent, between 2015-2025. It has also taken some steps to promote the circular economy. These include using 20 per cent reconditioned equipment in their networks and data centres by 2025. They have also set a target of collecting 30 per cent of their equipment sales (volumes per year) by 2025 in each of the European countries they are operating in. [101]

It is interesting to note here that the GSMA's annual Mobile World Congress since 2017 has been certified as carbon neutral.[102] Amongst other steps, the essential action taken by GSMA to achieve this carbon neutrality is by purchasing carbon credits in the voluntary carbon markets. GSMA claims to ensure that the credits purchased are used for the implementation of projects and technologies that reduce emissions globally.[103]

Further to checking its individual emissions, GSMA has also been working with the operators across the world to encourage them to set net zero emissions targets and work with governments to achieve a fair and equitable net zero transition. To do so it has set up a group which it refers to as the Climate Action Task Force, comprising of 40 operator groups from all the regions of the world.[104]

As a part of this initiative, GSMA has released a study called 'Mobile Net Zero' which attempts to study the state of the industry on climate action as of 2021 and notes various case studies from operators across the world. This includes a case study of BT – which aims to achieve net zero carbon emissions by 2045 (in line with the plan of its subsidiary EE as mentioned above). The case study also notes the challenges that BT expects to face in fully decarbonising its operations worldwide. These are switching to 100 per cent renewable electricity worldwide and

[95] ITU, ICT industry to reduce greenhouse gas emissions by 45 per cent by 2030, 2020. Available at: https://www.itu.int/en/mediacentre/Pages/PR04-2020-ICT-industry-to-reduce-greenhouse-gas-emissions-by-45-percent-by-2030.aspx
[96] Vodafone UK News Centre, Vodafone commits to 'net zero' carbon emissions by 2040, 2020. Available at : https://newscentre.vodafone.co.uk/news/group-net-zero-carbon-emissions-by-2040/
[97] Vodafone UK News Centre, Vodafone hits renewable milestone in the UK achieving important next step in its 'net zero' ambitions, 2021. Available at : https://newscentre.vodafone.co.uk/press-release/vodafone-hits-uk-renewable-milestone-on-road-to-net-zero-carbon-emissions/
[98] Three (3), Environment A greener path, rain or shine. Available at http://www.three.co.uk/social-commitment/environment
[99] O2, O2 launches its greenest ever ad campaign, 2021. Available at https://news.o2.co.uk/press-release/o2-launches-its-greenest-ever-ad-campaign/
[100] EE, Our Environment, 2021. Available at https://ee.co.uk/our-company/corporate-responsibility/being-responsible/the-environment
[101] Orange, Environmental commitment: net zero carbon emissions by 2040, 2021. Available at : https://www.orange.com/en/environmental-commitment-net-zero-carbon-emissions-2040
[102] GSMAI, GSMA Wraps Up Hugely Successful MWC19 Barcelona, 2019. Available at : https://www.gsma.com/newsroom/press-release/gsma-wraps-up-hugely-successful-mwc19-barcelona/
[103] Factor CO2, Factor assists in the carbon neutrality of the Mobile World Congress in Shanghai, 2019. Available at : https://www.factorco2.com/en/factor-assists-in-the-carbon-neutrality-of-the-mobile-world-congress-in-shanghai/new/5210
[104] GSMA, Climate Action Taskforce, 2021. Available at : https://www.gsma.com/betterfuture/climate-action/climate-action-taskforce

decarbonising its fleet. Although, the extent of these challenges is expected to be country specific. It is working with the global renewable energy campaign initiative to improve its supplies.[105]

ETNO has reported that the EU telcos have slightly reduced their carbon intensity (i.e., grams of CO_2 used to make one unit of electricity in kilowatt per hour (kW/hour)) to 27 grams per EUR earned from 29 grams in 2018. The reduction is expected to have been affected by the gradual shift to renewable sources of energy.[106]

Further to the MNOs, supply chain actors like equipment vendors have also taken steps to achieve climate neutrality. Ericsson has set for itself a net zero target for before 2050. It reports to have reduced its emissions by 57 per cent (2016-2022) by setting for itself SBTi based reduction targets and working to achieve these through mechanisms such as optimising – facility energy usage, product transportation, business travel and fleet vehicles. Ericsson is also asking its supply partners (approximately 350 in number) to set their own 1.5°C aligned climate targets. It notes that over 80 per cent of its remaining carbon footprint comes from its products and to alleviate that it has set specific SBTi targets to achieve energy savings in their Ericsson Radio System.[107]

Ensuring 5G is sustainable

As of September 2021, Vodafone UK has reported to have completed the first new 5G radio deployment and claims that it has decreased daily average energy consumption by 43 per cent and by 55 per cent during off-peak times.[108]

Although 5G NR offers a significant energy efficiency over previous mobile technologies, new 5G use cases and adoption of mmWave will require more sites and antenna. To counteract this, operators are deploying holistic energy strategies which include retiring legacy network, increasing renewable energy consumption and buying power-efficient equipment.[109]

Hybrid and renewables

The GSMAi reports that so far, the rising share of renewables in the overall electricity consumption for MNOs is the most important driver for reductions in CO_2 emissions so far. The report notes that solar has become a competitive alternative to diesel in off-grid areas. This is because of the advancement of base-station battery solutions and fall in the price of photovoltaic panels. Hybrid energy solutions are also coming up – these involve a mix of solar/diesel/wind/electricity and grid. Further, the report expects that the shift to renewables will further accelerate as prices continue to decline and operators are able to buy more of their energy from larger, centralised renewable energy sources. [110] Below are some examples of operators' steps in making a transition towards renewable energy:

Vodafone had set a target of powering all of its European network (in 12 countries) with 100 per cent renewable energy by July 2021. In this context, it has reported to have achieved its target in the UK, where its data centres, network, retail stores and offices are now 100 per cent supplied with renewable energy. Also, Vodafone's net

[105] GSMA, Mobile Net Zero State of the Industry on Climate Action 2021. Available at : https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.pdf
[106] ETNO, New Report: Europe behind on key digital metrics, telcos essential to achieve leadership, 2021. Available at : https://etno.eu/news/all-news/8-news/694-state-of-digi-2021-pr.html
[107] Ericsson, The journey to net zero starts here, 2021. Available at : https://www.ericsson.com/en/about-us/sustainability-and-corporate-responsibility/environment/climate-action
[108] Vodafone UK News Centre, Vodafone and Ericsson halve energy consumption in breakthrough 5G trial, 2021. Available at: https://newscentre.vodafone.co.uk/press-release/vodafone-ericsson-halve-energy-consumption-5g-trial/
[109] GSMAi, Going green: benchmarking the energy efficiency of mobile, 2021. Available at: https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=60621137&file=300621-Going-Green-efficiency-mobile.pdf
[110] Ibid.

zero emissions target for the UK is 2027, much before its Europe wide target of 2040.[111] Further, since 2020, 94 per cent of Three (3)'s buildings and networks used renewable energy.[112]Also, O2 UK, has committed itself to work with its supply chain partners and reduce the related emissions by 30 per cent in the five years (2020-2025).[113] EE UK too reports to be using 100 per cent renewable energy for its networks and for over 575 stores. It also plans to move the majority of its vehicles (around 33,000) to electric or zero emissions model by 2033. [114]

Measures on e-waste

Operators are supporting and actively engaging with new e-waste policies and legislations. A case in point is the the GSMA ClimateTech Programme which has created an e-waste legislative framework map. This includes the summaries of e-waste policies of 76 countries. Further, GSMA We Care Initiative, is another example of industry led action to improvement the management of e-waste.

Engaging with supply chain actors

Some operators around the world are making attempts to engage with the supply chain actors to ensure that they too take climate responsible steps. For example, Deutsche Telekom has specified several requirements to motivate their supply chain partners to apply sustainable design principles including applying circular economy principles, plastic free packaging, and avoidance of harmful substances in their products. As a result, many partners have changed their device packaging – stopping the use of plastic and increasing the percentage of postconsumer fibre. They have also limited the use of harmful substances beyond the limits set by law.[115]

Another case in point is Telefonica, which is proactively influencing its suppliers' emissions in line with the Paris treaty. Two of its initiatives include a Supplier Engagement Program and the 1.5°C Supply Chain Leaders Program. It has been working and supporting its suppliers to set reduction targets. It has also created a working group within the Joint Audit Cooperation initiative to drive climate action in the Telco supply chain.[116]

Apart from the environmental benefit, energy-savings kit could be a competitive advantage for the equipment vendors as well. As such, Huawei, Ericsson, Nokia and ZTE have been investing in energy-saving research and development as it could be a key selling point. In the case of Huawei – it has released 'Zero Carbon network solutions' with an objective of supporting the operators to move towards a greener future. The solution consists of simplified – site, equipment room; DC and Green Power for All. These elements would help the operators in reducing their energy consumption and also enabling them to have access to renewable energy sources such as solar.[117]

Green initiatives in broadcasting

In the broadcasting sector BBC has a "*Greener Broadcasting*" strategy which commits to reducing carbon emissions by 24 per cent and energy consumption by 10 per cent between 2015 and 2022.[118] The strategy targets primarily focus on emissions the BBC has direct control over, such as those from on-site generators and

[111] Vodafone UK News Centre, Vodafone hits renewable milestone in the UK achieving important next step in its 'net zero' ambitions, 2021. Available at https://newscentre.vodafone.co.uk/press-release/vodafone-hits-uk-renewable-milestone-on-road-to-net-zero-carbon-emissions/
[112] Three (3), Environment A greener path, rain or shine. Available at http://www.three.co.uk/social-commitment/environment
[113] O2, O2 launches its greenest ever ad campaign, 2021. Available at https://news.o2.co.uk/press-release/o2-launches-its-greenest-ever-ad-campaign/
[114] EE, Our Environment, 2021. Available at https://ee.co.uk/our-company/corporate-responsibility/being-responsible/the-environment
[115] GSMA, Mobile Net Zero State of the Industry on Climate Action 2021. Available at: Available at : https://www.gsma.com/betterfuture/wp-content/uploads/2021/04/Mobile-Net-Zero-State-of-the-Industry-on-Climate-Action.pdf
[116] Ibid.
[117] Huawei, Huawei Digital Power Zero Carbon Network Solution is Released, Helping Operators to Achieve Carbon Neutral Targets, 2021. Available at : https://www.huawei.com/en/news/2021/2/huawei-digital-power-zero-carbon-network-solution
[118] BBC, Greener broadcasting. Available at : https://downloads.bbc.co.uk/outreach/Greener_Broadcasting_2018_ENG-FINAL.pdf

company vehicles, and indirectly from the electricity purchased and consumed across its sites. Other major UK broadcasters – ITV,[119] Channel 4,[120] Sky[121] – all have targets to achieve net zero carbon emissions by 2030 and publish their carbon footprint annually.[122] [123] [124]

[119] ITV, ITV commits to Net Zero carbon emissions by 2030, 2020. Available at : https://www.itvplc.com/socialpurpose/news/2020/itv-commits-to-net-zero-carbon-emissions
120 For more details, see: https://www.channel4.com/corporate/about-4/operating-responsibly/environment
[121] Sky, Sky commits to become net zero carbon by 2030, 2020. Available at : https://www.skygroup.sky/article/sky-commits-to-be-net-zero-carbon-by-2030
[122] ITV, Social Purpose report, 2020. Available at : https://www.itvplc.com/~/media/Files/I/ITV-PLC/download/itv-social-purpose-impact-report-2020.pdf
[123] Sky, Impact report, 2020. Available at : https://static.skyassets.com/contentstack/assets/bltdc2476c7b6b194dd/blt413353949e85b2cd/Sky_Impact_Report_2020_Seeing_the_Bigger_Picture.pdf
124 Channel 4, Emerging better together, 2020. Available at : https://assets-corporate.channel4.com/_flysystem/s3/2021-06/Channel%204%20-%20Annual%20Report%202020%20-%20FINAL%20%28Accessible%29.pdf

3 Literature review part 2: The role of spectrum policy in combating climate change

Our primary research on the link between spectrum policy and climate change was in academic research databases (JSTOR, EBSCO, EcoLit) and using search tools (Google Scholar, Connected Papers). While both climate change and spectrum policy are topics which have been extensively covered in literature, it is important to note that these have not been linked yet in academic research, and there is a general lack of targeted studies on the role of spectrum policy in combating climate change.

Outside academia, international organisations have started looking at the potential spectrum policies that could help combatting climate change. GSMA,[125] ITU, ETNO,[126] RSPG, EBU (European Broadcasting Union),[127] and BNE[128] have recently made some proposals in this area, but as expected, even if some propositions are quite specific, no quantitative impact has been assessed to date.

This section provides an overview of policy position of the main regulatory bodies and industry representatives.

3.1 Spectrum management issues

This section aims at showing how spectrum management, at international and at national levels, can contribute to mitigating climate change.

In order to support the development of use cases as described in section 2.1.1, ITU recommendations have been made to harmonise and allocate spectrum at World Radio Conferences in 2015 and 2019 (WRC-15 and WRC-19). Bands 1427-1518 MHz, 3300-3400 MHz, 3400-3700 MHz, 4800-4990 MHz have been allocated for IMT across the world, and 470-694/698 MHz, 694-790 MHz for Region 1 in WRC-15[129] and mmWave bands 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71 GHz in WRC-19.[130] These spectrum allocations are expected to support services like enhanced mobile broadband (eMBB), massive machine-type communications and ultrareliable and low-latency communications. All three of these would be required to work in tandem with each other for smooth functioning of the identified use cases. While the latter two would be needed to enable data transmission between devices, eMBB might be important for enabling an efficient centralised user-device communication for monitoring and control.

RSPG underlines that, at the EU level, much of the spectrum has been harmonised in line with ITU recommendations. For example, harmonisation of spectrum for 5G,[131] for the use by short-range devices,[132] 5.9 GHz for intelligent transport systems,[133] M2M (Machine-to-Machine) cellular,[134] PMR,[135] and PAMR.[136] Further, additional work is being carried out in ETSI (Electronic Telecommunications Standards Institute) to address co-channel and adjacent-channel co-existence methods between ITS-G5 (the European standard for vehicular

[125] GSMA, Response to Draft RSPG Opinion on RSPP, 2021. Available at: https://www.gsma.com/gsmaeurope/resources/rspg-opinion-rspp/
[126] ETNO, Comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[127] EBU, Response to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change. January 2021.
[128] BNE, Response to the Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change. January 2021.
[129] ITU, Results and Implications of World Radio Conference, 2015. Available at: https://www.itu.int/en/ITU-R/seminars/rrs/2017-Africa/Documents/Plenary/03_%20WRC-15%20Outcomes.pdf
[130] ITU, Key Outcomes of WRC 2019. Available at: https://www.itu.int/myitu/-/media/Publications/ITU-News-Magazine/2019/En---Key-outcomes-of-the-WRC-2019.pdf
[131] For more details, see: https://cept.org/ecc/topics/spectrum-for-wireless-broadband-5g
[132] Short range devices, RLAN (Wi-Fi), Internet of Things, ultra-wide band (UWB) equipment and Intelligent Transport Systems (ITS). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:l24131
[133] Ibid (Short range devices, RLAN (Wi-Fi), Internet of Things, ultra-wide band (UWB) equipment and Intelligent Transport Systems (ITS))
[134] European Commission, Commission Implementing Decision (EU) 2018/637. Available at: https://eur-lex.europa.eu/eli/dec_impl/2018/637/oj
[135] ECC, Private/ Professional Land Mobile Radio. Available at: https://cept.org/ecc/topics/private-professional-land-mobile-radio
[136] Ibid.

communications[137]) and LTE (Long-term Evolution)-V2X (vehicle to machine communication). Further work is also under development regarding Wireless Power Transmission for electric vehicles (WPT-EV) systems. It would require High Frequency (HF) spectrum (3 to 30 MHz), which is also deployed for radio communications, and therefore there would be concerns regarding interference.

The availability of adequate spectrum to support the use cases and enablement effects identified in Section 2.1 is crucial to supporting reductions in carbon emissions. By ensuring that there is sufficient spectrum, and more importantly spectrum is in the bands demanded by different services (both IMT and others), regulators can encourage the uptake of new technologies and systems. Further, the international harmonisation of these bands will lead to more efficient use of the spectrum – there will be fewer areas in which spectrum cannot be used due to interference, and equipment manufacture will be more efficient as a single type of device can be made to cover multiple countries and regions.

In making spectrum allocation decisions, it is important for policymakers to take account of environmental impacts. While it is generally recognised that IMT spectrum, particularly those in the low-band (sub-1 GHz) and mid-band (1-6 GHz) ranges, is usually the highest value use, a reallocation decision may lead to the discontinuation of services which are relatively efficient in terms of energy consumption and carbon emissions.

In broadcasting, BNE[138] argues that a co-primary allocation for IMT in 470- 694 MHz band would have a negative impact on the digital terrestrial TV broadcasting (DTT) which is the least electricity-intensive distribution platform, compared to cable, satellite and IP streaming.[139] Thus, for services with multiple means of distribution, such as TV and radio, spectrum management decisions can have a role in determining the future of distribution networks which will have important consequences on the overall energy use relating to the delivery and consumption of these services. Such decisions will need to consider technology trends (e.g. 5G broadcast, FTTH) and consumer behaviour and preferences.[140]

Also, science services are often particularly vulnerable to changes in spectrum use by other services[141]. A recent case in point has been the requirement to protect meteorological sensors such as the AMSU-A, operating at 24 GHz from interference due to unwanted emissions from IMT services at 26 GHz.

Significant issues have also been raised regarding active services; there continue to be numerous examples of WLAN interference to weather radar at 5 GHz. These cases are often cited to highlight the perceived shortcomings of current spectrum management strategies which may rely on mandating technical solutions[142] which may not work reliably or may not be implemented by some manufacturers.[143]

3.2 Spectrum provision issues

At a national level, ETNO advises regulators to look holistically when approaching spectrum provision: "*When taking climate change related measures, spectrum policymakers should […] look not only at the energy use or GHG emissions of the spectrum licensees, but also at how the incentives they place on them impact the environmental behaviour of end users.*" ETNO justifies this view by the fact that "*higher network deployment costs caused by*

[137] Katz and Tahir, Heterogeneous (ITS-G5 and 5G) Vehicular Pilot Road Weather Service Platform in a Realistic Operational Environment, 2021. Available at: https://www.mdpi.com/1424-8220/21/5/1676
[138] BNE, Response to the Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change. January 2021.
[139] BNE cites the findings from Schien et al (2020).
[140] In recent years TV viewership has been evolving rapidly with audiences migrating towards on-demand streaming services delivered over broadband and consuming less live TV – traditionally delivered over broadcast networks. For example see Ofcom's Media Nations 2021 Report.
[141] This is due to the use of passive sensors detecting subtle changes in noise temperature due to physical processes.
[142] In this case, Dynamic frequency Selection (DFS)
[143] E. Saltikoff and Al, The threat to weather radars by wireless technology, 2016, available ate: https://journals.ametsoc.org/view/journals/bams/97/7/bams-d-15-00048.1.xml

stringent environmental restrictions in licences, or by higher spectrum fees, could negatively impact end-user prices or coverage of wireless services, thereby reducing their 'enablement effect'."

This relationship is well established; any increase in the cost of network deployment will generally lead to lower coverage since some base stations will become unprofitable when the associated revenue is compared. This is even more important with 5G, where not only coverage but also a high-quality ubiquitous network is needed for some of the benefits to be felt.

More specifically, organisations discuss different ways to tackle the climate change issue through spectrum provision:

- accompanying spectrum assignments by environmental obligations;
- providing enough spectrum to avoid network densification; and
- enabling block continuity.

These are discussed in turn below.

Environmental requirements

Policy makers may be tempted to introduce climate change considerations when assigning spectrum, with better ratings given to "*greener*" bidders. ETNO[144] raises awareness on the importance of clear environmental requirements, in order to avoid a suboptimal outcome. As a matter of fact, open requirements would make estimation and comparison of compliance costs difficult. ETNO proposes "*to mandate compliance (knowing that this would be based on bidders' estimates) but design a rebate mechanism with compensations that grow with the intensity of the future target.*" Rebate mechanisms could come in the form of financial incentives, like reduction of spectrum fees, price of renewals of licences, partial redemption of price obligations. "*The licence could incorporate a discount on yearly licence fees contingent on meeting energy efficiency or GHG emission targets defined at the time of award.*"

Environmental obligations accompanying spectrum assignments would be based on metrics and methodologies like emissions trajectories and the circular economy as described in Section 2.3.

Availability of enough spectrum to avoid densification

In its different reports on the climate issue, the ITU does not directly talk about the impact of spectrum policy on climate change, although it talks about the role of ICT in climate change enablement and adaptation. For both to function in an efficient manner it could be inferred that enough spectrum would be key for ICT enablement use cases and climate change adaptation. This is based on the studies that ITU has undertaken on both of these

[144] ETNO, Comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.

topics. These studies have been discussed in other sections of the report. These include ITU-T SG5 L.1451,[145] L.1501,[146] L.1503,[147] L.1504,[148] L.1505,[149] L.1507,[150] amongst others.

The RSPG[151] highlights the importance of spectrum planning that would ensure that enough spectrum is allocated for the wireless technologies such that it facilitates its role as an enabler. This should be coupled with timely award of spectrum to enable enterprises to develop innovative services to mitigate climate change. The GSMA and ETNO both underline the necessity of the "*availability of sufficient spectrum resources*,"[152153] based on the fact that it would decrease the number of mobile sites needed, leading to lower energy consumption, and a smaller amount of network equipment. In particular, they mention that the availability of sub-1GHz spectrum resources would decrease the number of macro sites needed for a coverage network.

Block contiguity

RSPG,[154] GSMA,[155] and ETNO[156] all advocate that large contiguous spectrum blocks per operator lead to smaller energy consumption (due to less carrier aggregation and to less network equipment needed), and therefore this should be taken into account when assessing new spectrum bands. ETNO specifies that "*unnecessary fragmentation of spectrum band, for example setting aside spectrum for local/vertical use without proper analysis, including socioeconomic and climate impacts should not be allowed.*"[157]

3.3 Convergence and sharing

Some use cases described in Section 2.1.1 like agri-tech services or manufacturing, could suffer from a lack of coverage in rural areas. RSPG highlights that fixed networks could complement or even substitute mobile coverage to underpin the provision of services. On the other hand, the GSMA proposes to allow operators to deploy shared networks, as it will lead to smaller number of network equipment. This position is shared by ETNO.[158]

Therefore, while also helping to accelerate network deployment investment, policy and regulatory support for network sharing agreements appears relevant also from the sustainability viewpoint. On the other hand, it is also important to maintain competition objectives and ensure fair competition in national markets.

[145] ITU, Methodology for assessing the aggregated positive sector-level impacts of ICT in other sectors, 2019. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14083
[146] ITU, Best practices on how countries can utilise ICTs to adapt to the effects of climate change, 2014. Available at: https://www.itu.int/rec/T-REC-L.1501-201412-I
[147] ITU, Use of information and communication technology for climate change adaptation in cities, 2016. Available at: https://www.itu.int/rec/T-REC-L.1503-201606-I
[148] ITU, ICT and adaptation of agriculture to the effects of climate change, 2016. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13149
[149] ITU, Information and communication technology and adaptation of the fisheries sector to the effects of climate change, 2018. Available at: https://www.itu.int/rec/T-REC-L.1505-201801-I
[150] ITU, Use of ICT sites to support environmental sensing, 2019. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13965
[151] RSPG, Public Consultation on the Draft RSPG Opinion on a Radio Spectrum Policy Programme, 15 Feb 2021- 26 Mar 2021. Available at: https://rspg-spectrum.eu/public-consultations/
[152] GSMA, Response to Draft RSPG Opinion on RSPP,March 2021
[153] ETNO, Ccomments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[154] RSPG, Public Consultation on the Draft RSPG Opinion on a Radio Spectrum Policy Programme, 15 Feb 2021- 26 Mar 2021. Available at: https://rspg-spectrum.eu/public-consultations/
[155] GSMA, Response to Draft RSPG Opinion on RSPP,March 2021
[156] ETNO comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[157] Ibid.
[158] Ibid.

3.4 Enabling flexibility and fostering self-regulation

Flexibility is another potential policy option for network operators who could decide on how to best improve their environmental efficiency. ETNO[159] is for instance in favour of "*an adequate mix of self-/ co-regulation/other voluntary initiatives*" that could be "*equally or even more effective instruments to reach environmental goals, even in a more innovative way.*" RSPG sees self-regulatory measures as a potential future action to combat climate change; these measures could include research and development, increasing the share of renewable source of energy sources, as well as developing energy efficient standards and to design services and equipment based on such standards. This is what some stakeholders have already undertaken (see Section 2.4).

Policy flexibility would also include avoiding unnecessary limitations.

- **On deployment** (for example, unnecessary restrictions to transmission power, stricter EMF limits than recommended by ICNIRP). ETNO and GSMA advocate that this would lead to less network equipment, and would enable net energy savings.

- **On coverage and quality of service** (QoS). According to ETNO and GSMA, "*avoiding excess coverage and data speed obligations, enables optimising network operations, energy consumption, and amount of network equipment based on actual and timely demands.*"

On the equipment vendor side, EBU[160] states that there is a role for policy makers to ensure that the consumer device industry does improve equipment performance in terms of energy consumption. The GSMA position is more balanced towards "*no overly strict power limits*": It advocates that on one side, regulators shall ensure that the energy consumption limits of equipment are "*made with environmental factors in mind*"[161] and on the other side, regulator shall be realistic regarding available and competitively priced technologies. There is indeed a potential impact on the price paid by the final user.

3.5 Switch off legacy networks

Decommissioning legacy networks like Public Switched Telephone Network (PSTN), 2G, 3G, and analogue TV is mentioned as a way to reduce climate impacts, because older technologies and equipment consume more energy, while recent active antennas irradiate only where and when it is necessary. Based on a stakeholder response, RSPG noted that during the 2G/GSM period the efficiency of the power amplifier was typically below 20 per cent. However, in the past 2 decades, the efficiencies of power amplifiers have improved due to changes in the structure design and semiconductor material technology. For example, the use of Gallium Nitride (GaN) technology has increased the efficiency of the power amplifiers to more than 50 per cent. It is expected that the shutdown of legacy 2G/3G networks would significantly reduce the energy consumption per transported bit, thus lowering the climate footprint. Further, the number of users of legacy networks is constantly falling, meaning they are becoming increasingly inefficient. However, this needs to be assessed in tandem with the role of legacy networks in providing important emergency services and supporting smart metering.

The GSMA suggests that "*allowing operators to switch-off older mobile technologies (2G/3G) would lead to less, more efficient network equipment*", and would enable "*more efficient spectrum use with newer technology, and thus smaller energy consumption*". ETNO[162] also underlines that "*broader service implementation of radio networks can provide solutions to potentially phase out energy intensive legacy networks, for example with the*

[159] Ibid.
[160] EBU, Response to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[161] GSMA, Response to Draft RSPG Opinion on RSPP,March 2021
[162] ETNO, Comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.

implementation of Fixed Wireless Access (FWA) solutions. This leads to reductions in aggregated network energy consumption, in combination with reduced operations and maintenance interventions."

However, switching off legacy networks will mean that users of those networks will be forced to invest in new equipment, which may have an environmental cost. We are aware of some agricultural connections which use 2G technology for communication, and users of this equipment will need to make the choice of additional investment or losing the functionality of connectivity.

Analogue television broadcasts were switched off in the UK by region between 2007 and 2012; the EU directed Member States to switch off analogue signals by the end of 2012, and while a few countries did not achieve this date all Member States have now completed switchover. There remain some countries where analogue television remains; largely developing countries in Africa and Latin America. Analogue television is inefficient for the information it carries, using a large spectrum bandwidth for few channels.

As discussed in Section 2.2.2, the BBC study by Fletcher and Chandaria indicated that switching off analogue broadcast networks (AM/FM) could deliver energy savings compared to a business-as-usual scenario.

3.6 Approach of specific systems that are key for the climate

As previously described, there are some specific systems that are used in monitoring and analysing climate.

3.6.1 5G and IoT

The potential of 5G as an enabler has been raised by several organisations. The EBU[163] explains that "*online distribution of media content is currently entirely based on unicast technologies*". But "*mobile broadband standards such as 4G and 5G also include multicast and broadcast mode which could, for a certain type of content, reduce the network traffic – and this may lead to reduced impact of mobile networks on the climate.*" GSMA underlines how 5G can act as an enabler for development of technologies like IoT and how availability of 5G spectrum helps operators "*develop and offer network solutions needed for IoT and big data*", knowing that "*these solutions enable new energy efficient and environmental solutions across several sectors, transport, manufacturing, agriculture, building and energy.*" This is also raised by ETNO.[164]

3.6.2 Science services

The application and vulnerabilities of science services relevant to climate change studies are described on the ITU-R website.[165] Although the RSPG published an Opinion on the scientific use of radio spectrum in 2006,[166] this makes no concrete recommendations beyond urging administrations to respect Article 5.340 of the Radio Regulations (protection of passive bands). It does, however, provide a useful survey of the sector.

The main importance of these services is not as a polluter, nor as an enabler of carbon reduction, but rather to provide the information needed to guide our response to climate change. WRC have taken into consideration the availability and the protection of radiofrequency bands for the World Meteorological Organisation.[167] There was intense debate at WRC-19 about the limits needed for IMT operating at 26 GHz to protect the EESS at 24 GHz, based on the fact that appropriate protection was very important to ensure the future of reliable data

[163] EBU, Response to Questionnaire of the Sub-group on Role of RSPG to Help Combat Climate Change, January 2021.
[164] ETNO, Comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[165] For more details, see: https://www.itu.int/en/ITU-R/information/Pages/climate-change.aspx
[166] For more details, see: https://rspg-spectrum.eu/wp-content/uploads/2013/05/rspg06_144_final_rspg_report_opinion_scientific_use_pectrum.pdf
[167] For more details, see: Handbook on use of radio spectrum for meteorology, 2017, ITU-R, WMO. Available at: https://library.wmo.int/doc_num.php?explnum_id=3793

gathering on atmospheric processes.[168] A recent Ofcom paper on the terrestrial use of frequencies[169] above 100 GHz contains useful information on scientific/sensing use by the EESS of these frequencies, and the approach taken to ensure protection.

The RSPG acknowledges the key position of science services in combating climate change, by stating that "*spectrum planning should ensure enough spectrum is allocated for ground and satellite-based communication systems supporting climate change monitoring and weather forecasting.*" This has been confirmed by our conversation with the Met Office. The Met Office is dependent on global data sets, so the issue of protection and spectrum access does not stop at UK borders and remains an international issue. They work with, or depend on, agencies such as EuMetSat in this regard. Moreover, the Met Office is keen to exploit the opportunities that come with new technologies such as 5G, such as the possibility of using autonomous vehicles for unattended data gathering.

In a nutshell, the biggest issue with science services in terms of spectrum policy will be the need for continued and better protection of the frequencies used for atmospheric sensing and meteorological services.

3.6.3 Energy sector

Utilities, including the energy sector, is an industry which is actively working towards a significant impact on avoided emissions.[170] Given this, spectrum policy could have a noticeable role on climate change by having a specific approach for the energy sector.

The energy sector has been changing in the UK for over a decade, moving from large fossil fuel power stations to more localised renewable sources like wind and solar, with energy generation being distributed more regionally and locally than large scale national generation. These developments and the increasing importance of enhanced visibility and control of the distribution networks to monitor and balance supply, coupled with an increasing market demand, has led to a greater emphasis on the need for critical network assets in utility networks. There are thus increased data volumes at all stages of the chain: in energy generation, in transmission, in distribution, in market operations, and at the end user. The priority for the sector is to be able to meet the increasing demand at lowest cost through enhanced operational telecommunications control capability to address the UK government's net-zero agenda.

In order to face the different challenges, the sector needs telecommunications capability designed to carry larger volumes of data traffic, with much greater levels of enhanced and near real-time monitoring and control throughout the network, as well as with low interference risks and designed in resilience (so that visibility and control of the network is not lost). The current operational telecommunications systems will not address the dynamic system capability of the future and hence presents challenges for the energy sector.

- Solutions providing suitably reliable and resilient remote connectivity are limited, have long delivery timeframes and high costs.
- Radio spectrum is a scarce resource, but dedicated spectrum access is fundamental to enhanced operational capability.
- PSTN will be turned off by 2025 in the UK, and 2G and 3G networks are also being shut down.

To tackle these challenges, the sector raises the importance of private mobile networks, to provide:

[168] For more details, see: https://www.ecmwf.int/sites/default/files/elibrary/2019/19163-why-we-need-protect-weather-prediction-radio-frequency-interference.pdf
[169] For more details, see: https://www.ofcom.org.uk/__data/assets/pdf_file/0024/203829/100-ghz-statement.pdf
[170] GSMA , The Enablement Effect, 2019. Available at: https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf

- reliable and resilient telecom networks (to tackle storm, flood, as well as possible network congestion);
- secure dedicated operational control capability to enable a high level of cybersecurity;
- scalability; for instance, Western Power Distribution has conducted a trial in 410-430 MHz with 10 substations, from grid supply point to distribution substations, and it underlines the importance of scalability to cover its 200,000 substations and its 8 million customers; and
- future-proof solutions, enabling systems upgrades and avoiding the technology risk of refresh cycles associated with Public Networks.

Trials based on LTE spectrum specifically dedicated for utilities have been conducted in many countries, including Ireland, USA, Poland,[171] Spain,[172] Germany,[173] Portugal, and Russia. In Saudi Arabia, the forthcoming auction[174] by CITC in the 410-430 and 450-470 MHz bands will enable utilities to bid. In the Republic of Ireland, the positive impact of smart grids[175] on climate change has been recognised, and the allocation of utility spectrum in the 400 MHz band in 2019 is enabling ESB (Electricity Supply Board) Ireland networks to procure a dedicated 'Smart Grid' operational capability to support enhanced low carbon technologies (such as solar panels, wind generation, heat pumps, and electric vehicles) to be deployed. Private mobile networks are suitable for all types of utilities operating in the same geographic area (electricity, gas, water). Appendix D of this document provides more detail on the critical role of smart grids, as well as a description of the Irish case study.

3.6.4 Public and private networks

The previous sub-sections have described the necessity to protect sciences services (earth and weather observation and forecast) and the energy sector by identifying and enabling access to suitable spectrum for these services.

ETNO and GSMA underline that "*reserved frequencies to provide services related in one way or another to the fight against climate change, should be evaluated against the value on alternative uses of the frequencies they request, and against the possibility of using public networks that could fulfil the same purpose at a potentially lower environmental cost,*" explaining that "*these services could range from private networks for use by verticals to digitise their supply chain and be more energy efficient, to frequencies for satellite services that monitor climate change and its impact.*"

More generally, ETNO supports the reference to service and technological neutrality to guide any upcoming measures to be broad enough for ensuring legal certainty and flexibility for operator, on the basis that "*providing services in public mobile networks, instead of dedicated networks, supports energy efficiency in operation and manufacturing.*"

The EBU argues for the need for adequate spectrum for 5G private networks dedicated to content production. These can help to reduce carbon footprint by enabling distributed, remote, or automated production workflows which may reduce the need for the physical presence of the production staff on location, consequently reducing the need to travel.[176]

[171] Poland, 2019: 450-470MHz awarded for private utility networks
[172] Spain, 2020: 2.3GHz for private utility LTE network
[173] Germany, 2021: 450-470MHz awarded for private utility networks
[174] Autumn 2021
[175] "Smart grids within the energy sector utilise mobile communications technology to help monitor and regulate electricity demand and transmission, to improve coordination and distribution efficiency. Additionally, small-scale renewable electricity generators are able to participate in the wider market by using M2M connections, increasing the amount of green and local energy in the national grid.", The enablement effect, GSMA, The Carbon Trust
[176] EBU, Response to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.

It is crucial, therefore, as previously noted, that the potential beneficial environmental impact of network slicing is balanced against any reduction in reliability or resilience.

3.7 Conclusions

The literature review has shown that there is an existing research gap on the issue of the role of spectrum policy on combating climate change. There is a clear need for further research, particularly quantitative research on this issue. If there is a consensus on the importance of the subject, each organisation defends its own interests, and it appears critical to be able to quantify the positive and negative impacts raised in the different positions. Another caveat is that the published sources mostly cover each industry's views, but the whole value chain is not represented in those positions (vendors, user representative association).

Because there is a lack of targeted studies and no quantitative analysis published that could support the propositions made by the different organisations mentioned above (GSMA,[177] ITU, ETNO,[178] RSPG, EBU,[179] and BNE[180]), the following section attempts to take a broader view on what other propositions could be relevant for spectrum policy to combat climate change and to assess each of these propositions. Against this, overly harsh constraints may for example have a negative impact on price for the final user, which may again lead to a reduction in demand. Another example would be that limiting user choice may lead to the demise of some technical solutions. This type of necessary balanced approach has been taken in the following section, that discusses the pros and cons of different options, including those promoted by the GSMA in its response to the RSPG consultation.

[177] GSMA, Response to Draft RSPG Opinion on RSPP,March 2021.
[178] ETNO, Comments to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[179] EBU, Response to Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.
[180] BNE, Response to the Questionnaire of the Sub-group on Role of RSP to Help Combat Climate Change, January 2021.

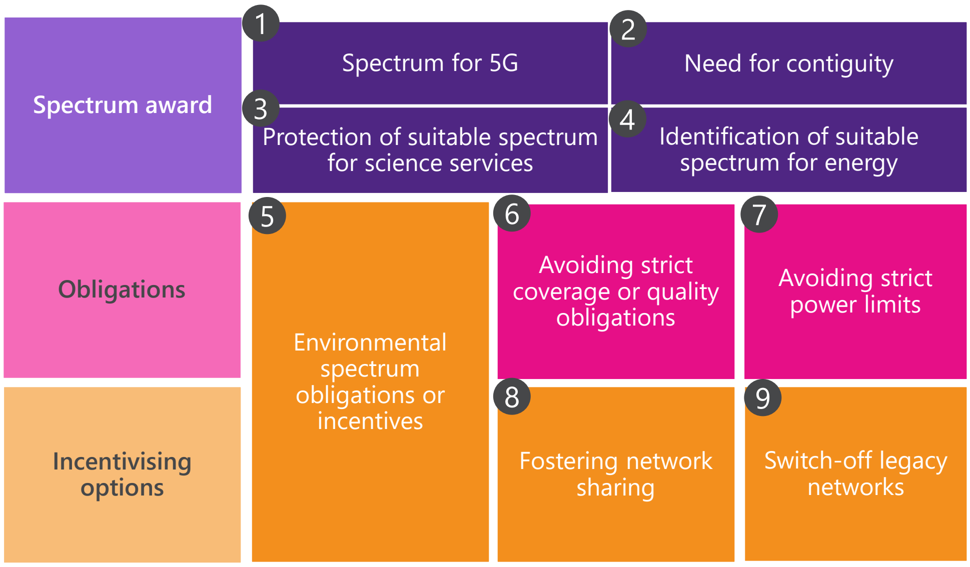
4 Spectrum policy options and their contribution to averting climate change

Based on our literature review, the conversations we have had with different stakeholders, and our knowledge of the industry, this section presents several potential radio spectrum policy actions to contribute to tackling climate change. This section also provides an assessment of each of these actions, including the level of positive and negative impacts on the environment, the potential timescale to be implemented or the cost.

Spectrum policy actions considered

Figure 4.1 below shows a number of different policy options which could potentially play a positive role in averting climate change. These have been formulated from research done during our literature review, and include (but are not limited to) the options proposed by GSMA in response to the RSPG's consultation seeking comments on the Radio Spectrum Policy Programme (RSPP).[181]

Figure 4.1: Spectrum policy options to combat climate change



Source: Plum analysis

As illustrated above, the options have been grouped under three categories: spectrum award, obligations, and incentivising options. As well as these individual policy options, we must first consider how these may be included in regulatory policy, in terms of the ability of the regulator to take account of environmental concerns.

Evaluation Framework

Each potential policy has been examined across the following criteria:

- impact on environment (at the network level, for supply chain actors, and at the end user level);

[181] RSPG, Public Consultation on the Draft RSPG Opinion on a Radio Spectrum Policy Programme, 15 Feb 2021- 26 March 2021. Available at: https://rspg-spectrum.eu/public-consultations/

- timescale and regulatory approach;
- cost implications;
- impact on other telecommunications services; and
- impact on other sectors.

For each of these criteria, arguments in favour and against have been discussed, in order to develop a balanced understanding of the environmental impact of each option. We highlight various factors for each option which we think should be considered to gauge a net potential environmental impact. Considering both the potential positive and negative environmental impact helps provide key insights on which areas to target when framing a policy on the subject.

The assessment below is based on a dialectical discussion. We assume the counterfactual to be the complete absence of the proposed option. However, in reality there can be multiple scenarios displaying different degrees of adoption both at the counterfactual and intervention level. As such, to estimate the net impact one would need to quantitatively assess each of these scenarios and draw conclusions based on those. However, this would require detailed time series and granular data (for different elements of the network and not just an aggregate ballpark on energy consumption of the different technology options, which is not readily available or easily accessible. As such, our focus in this assessment has been to undertake a two-way discussion on each of the options, supplemented by examples to provide an objective perspective on the options likely environmental impact, potential financial and opportunity costs to be incurred and likely corollary impact on other telecommunication services and sectors beyond ICT. Assessing the wide variety of criteria (and not restricting it to only environmental impact) will also ensure that the policy recommendations are thorough and practical.

Further to the difficulty in accessing data on energy consumption, the lack of publicly available research and data on the specific topic of the role of spectrum policy in climate change has also been a reason to adopt a discursive methodology.

4.1 Obligations of the regulator

Before considering how different spectrum policies may impact climate change, it is crucial for us to understand how any policies may be implemented. The responsibilities and duties of Ofcom are set out in the Communications Act 2003 (amended), and the relevant parts of that Act are included in Figure 4.2.

Figure 4.2: General duties of Ofcom as set out in S3 of the Communications Act 2003 (amended)

(1) It shall be the principal duty of OFCOM, in carrying out their functions—

> (a)to further the interests of citizens in relation to communications matters; and
>
> (b)to further the interests of consumers in relevant markets, where appropriate by promoting competition.

(2) The things which, by virtue of subsection (1), OFCOM are required to secure in the carrying out of their functions include, in particular, each of the following—

> (a) the optimal use for wireless telegraphy of the electro-magnetic spectrum;
>
> (b) the availability throughout the United Kingdom of a wide range of electronic communications services;
>
> (c) the availability throughout the United Kingdom of a wide range of television and radio services which (taken as a whole) are both of high quality and calculated to appeal to a variety of tastes and interests;

(d) the maintenance of a sufficient plurality of providers of different television and radio services;

(e) the application, in the case of all television and radio services, of standards that provide adequate protection to members of the public from the inclusion of offensive and harmful material in such services;

(f) the application, in the case of all television and radio services, of standards that provide adequate protection to members of the public and all other persons from both—

(i) unfair treatment in programmes included in such services; and

(ii) unwarranted infringements of privacy resulting from activities carried on for the purposes of such services.

(3) In performing their duties under subsection (1), OFCOM must have regard, in all cases, to—

(a) the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed; and

(b) any other principles appearing to OFCOM to represent the best regulatory practice.

(4) OFCOM must also have regard, in performing those duties, to such of the following as appear to them to be relevant in the circumstances—

(a) the desirability of promoting the fulfilment of the purposes of public service television broadcasting in the United Kingdom;

(b) the desirability of promoting competition in relevant markets;

(c) the desirability of promoting and facilitating the development and use of effective forms of self-regulation;

(d) the desirability of encouraging investment and innovation in relevant markets;

(e) the desirability of encouraging the availability and use of high speed data transfer services throughout the United Kingdom;

(ea) the desirability of ensuring the security and availability of public electronic communications networks and public electronic communications services;

(eb) the desirability of ensuring that relevant markets facilitate end-to-end connectivity in the interests of consumers in those markets;

(f) the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it;

(g) the need to secure that the application in the case of television and radio services of standards falling within subsection (2)(e) and (f) is in the manner that best guarantees an appropriate level of freedom of expression;

(h) the vulnerability of children and of others whose circumstances appear to OFCOM to put them in need of special protection;

(i) the needs of persons with disabilities, of the elderly and of those on low incomes;

(j) the desirability of preventing crime and disorder;

(k) the opinions of consumers in relevant markets and of members of the public generally;

(l) the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and in urban areas;

(m) the extent to which, in the circumstances of the case, the furthering or securing of the matters mentioned in subsections (1) and (2) is reasonably practicable.

(5) In performing their duty under this section of furthering the interests of consumers, OFCOM must have regard, in particular, to the interests of those consumers in respect of choice, price, QoS and value for money.

It is clear from this text that, while Ofcom is obliged to take account of a number of factors when setting policies, it has no obligation to consider environmental impact. Indeed, where environmental concerns may run contrary to competition or consumer welfare concerns, Ofcom is specifically prohibited from taking these into account.

Section 4 of the Communications Act 2003 provides some more detail on Ofcom's duties in respect of certain regulatory functions. In brief, these duties are:

- promoting competition;
- promote the interests of all members of the public in the UK;
- not favouring one technology or type of network over another;
- promoting network access and service interoperability;
- encouraging compliance with specific standards; and
- promoting connectivity and access to very high capacity networks.

Again, there is no specific environmental duty included here, and other than in the second requirement listed (where it can be argued that environmental concerns should be taken into account when looking at the interests of the public) Ofcom is not obliged to consider such arguments when making policy decisions – indeed, if they are contrary to other existing duties Ofcom must ignore them. Even if the environment is considered as part of the general public interest, there is no clarity on how it should be weighted and, as it is only one aspect of the public interest, it is likely that this may be deemed to be a conflict in Ofcom's considerations.

Despite it falling outside Ofcom's defined duties, climate change and other environmental concerns have been included in a number of impact assessments carried out in relation to its regulatory duties – for example, when considering planning consent for fixed links sites, and power limits on broadcasting sites. However, in all cases these concerns have not significantly influenced Ofcom's decisions. In 2011, Ofcom produced a report entitled Climate Change Adaption,[182] in which it identified areas in which climate change may impact on the regulations it needed to impose, but did not consider the impacts in the other direction.

The narrowness of Ofcom's duties has been recognised by the NIC (National Infrastructure Commission), which reported in 2019[183] that regulators including Ofcom, Ofgem and Ofwat needed to have duties relating to environmental issues clarified in their regulatory system, in order to ensure that the UK government could meet its net zero targets.

> **“The government has committed the UK to net zero by 2050, but if regulators aren't equipped with a new duty to specifically reach this target, then it is simply unattainable. The regulatory system must adapt to meet the demands of the future – and the great challenge we face to bring down emissions and build resilience against increasingly frequent extreme weather.”**

The NIC recommended that Ofcom, Ofgem and Ofwat should have new duties to "*promote the achievement of net zero by 2050 and improve resilience*". It is clear that such a recommendation is needed if Ofcom is to be able to act on the issues raised in this report.

[182] For more details, see: https://www.ofcom.org.uk/__data/assets/pdf_file/0031/56947/climate-change-adaptation.pdf
[183] For more details, see: https://nic.org.uk/news/utility-regulators-must-have-new-powers-if-uk-is-to-tackle-climate-change/

4.2 Spectrum for 5G

There are three key ways in which spectrum awarded for use by 5G networks will have an impact on climate change effects:

- awarding sufficient spectrum will allow for 5G networks to be most efficient;
- low-frequency spectrum will allow for lower power consumption; and
- the use of 5G allows for better industrial efficiency through increased productivity, analysis, and digitisation.

These three impacts are examined in turn below.

Increased network efficiency with sufficient spectrum

Ensuring that there is sufficient spectrum available to 5G networks will have two key impacts on efficiency: first, it will ensure that there is less need for additional sites, and second it will ensure that the network is able to offer the best possible QoS.

Deployment of more radio spectrum instead of additional physical sites to increase network capacity would have a positive environmental impact since it would require less production of equipment, a lower deployment footprint, and lower power requirements (with fewer sites needing air conditioning, computing power, and so on). Physical network infrastructure deployment would involve construction activities like digging of land and possibly even felling of trees (depending upon the topography); these could result in environmental impacts like dust pollution, noise pollution, particulate matter accumulation, soil erosion and ground water contamination.

However, it is important to note here that physical mobile network sites do play a very important role in expanding the coverage and the capacity of the network to ensure good QoS for consumers. The deployment of physical infrastructure provides the benefit of greater certainty of reliable communications in rural, low demand geographic areas due to potentially reduced signal attenuation loss.

Reducing the number of base stations can have a significant impact on reducing the energy consumption and resultant emissions of the network. However, reducing the number of base stations may require a greater power use for transmission so that the coverage area can remain the same. Further studies would need to be undertaken to understand how these power needs would compare.

As well as the impact from network deployment, lower equipment requirements also implies potentially less resource consumption and resultant emissions in the backward linkages of the supply chain – manufacturing, processing, and transportation. However, this could be offset due to increased production of the end user devices. Increasing data consumption and purchase of end user devices can have a significant rebound effect on any reductions in the carbon emissions at the network level. According to ITU-T study group 5, L.1470 study[184] and GESI[185] end-user devices account for approximately 50 per cent of the total carbon footprint of the ICT sector.

[184] ITU-T, L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement, 2020. Available at: https://www.itu.int/rec/T-REC-L.1470-202001-I/en
[185] GeSI, SMARTer 2030, 2015. Available at: https://smarter2030.gesi.org/downloads/Full_report.pdf

As well as this impact on the number of base stations, 5G technology is known to be more efficient in terms of energy consumption in comparison to earlier mobile technologies (2G, 3G and 4G).[186]

Ericsson notes that if 5G is deployed in the similar way as previous mobile generations to support data traffic, then the energy consumption is expected to increase. As such, it proposes what it refers to as 'Breaking the Curve' which could enable the operator networks to support the growth in traffic with efficient energy use. The approach is based on activating energy-saving software, building 5G with precision and operating site infrastructure intelligently.[187]

Further any positive environmental impact of 5G would also depend upon the associated network architecture. For example, 5G Non-Standalone (NSA) might produce less emissions in comparison to 5G Standalone (SA) as the latter would likely require installation of new network equipment and the former can also function on the existing LTE infrastructure; however NSA requires an LTE network to underpin it and this network itself may be less energy efficient. Technology options like network virtualisation, dynamic spectrum sharing, and network slicing have a potential to increase the 5G network efficiency which could reduce the emissions. Therefore, to accurately assess any positive impact of the 5G technology at the network level, information about the 5G network design and architecture is critical – not least because there are multiple options that the operators can choose from. For example, according to a survey report by Mobile World, network virtualisation is ranked the lowest on energy consumption for the mobile networks. 5G NR and growth of IoT also figured in the lowest four amongst a list of ten.[188] Also, ITU-T study group 5 is working on a study looking into the role of technologies like AI and other emerging technologies to save the energy of the 5G base stations.[189]

At the end user level, 5G services may lead to consumption of high volumes of data which would translate into overall higher energy consumption and possibly even offset any emissions reduction at the network level. Bieser et al highlight this risk of consumption of more data or the rebound effect and 5G counteracting its abatement potential. The Mobile World survey ranks the growth in mobile Internet data traffic as the biggest reason for increasing the energy consumption of the mobile networks.[190] Open Signal reports that 5G users currently consume up to 2.7 times more data than 4G users.[191] This may suggest that with increasing 5G adoption, data consumption may rise and the resulting emissions would increase. Even if use of 5G does not itself cause people to use more data, there is a steady increase in demand for services and 5G technologies enable this growth.

Finally, at the retail level, there is an expectation of an increase in the production of 5G supported smart phones. According to Cisco's Internet report (2018-2023), 5G devices and connections will account for over 10 per cent of global mobile devices and connections by 2023. This implies that by 2023, about 1.4 billion of the total global mobile devices (about 13.1 billion) would be 5G capable.[192]

This option focuses on 5G, but sufficient spectrum as a whole for all technologies, including backhaul, would enable increased network efficiency.

[186] Information Age, 5G networks found to be up to 90 per cent more energy efficient than 4G, 2020. Available at: https://www.information-age.com/5g-networks-found-90-more-energy-efficient-than-4g-123492972/#:~:text=2%20December%202020-,5G%20networks%20found%20to%20be%20up%20to,more%20energy%20efficient%20than%204G&text=11%20different%20pre%2Ddefined%20traffic,traffic%20capacity%20than%20legacy%20technologies.

[187] Ericsson, How to break the energy curve, 2021. Available at: https://www.ericsson.com/en/about-us/sustainability-and-corporate-responsibility/environment/product-energy-performance

[188] Mobile World Live, How sustainable are our mobile networks. Available at: https://www.mobileworldlive.com/survey-report-how-sustainable-are-our-mobile-networks

[189] ITU, Smart energy saving of 5G base stations: Based on AI and other emerging technologies to forecast and optimize the management of 5G wireless network energy consumption, 2021. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14762

[190] Mobile World Live, How sustainable are our mobile networks. Available at: https://www.mobileworldlive.com/survey-report-how-sustainable-are-our-mobile-networks

[191] Open Signal, 5G users on average consume up to 2.7x more mobile data compared to 4G users, 2020. Available at: https://www.opensignal.com/2020/10/21/5g-users-on-average-consume-up-to-27x-more-mobile-data-compared-to-4g-users

[192] Cisco, Annual Internet Report (2018–2023) White Paper, 2020. Available at: https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

Reduction in power consumption with sub-1 GHz spectrum

Radio waves in the sub-1 GHz spectrum have better propagation characteristics and therefore can travel larger distances. As such mobile services deployed on sub-1 GHz spectrum have the potential for greater coverage. This could reduce the number of physical sites to be installed to provide coverage, reducing the reliance on physical infrastructure. This could result in potential reduction of network equipment installation, in turn reducing the energy consumption and emissions. However, the Ultra High Frequencies (UHF) bands have limited bandwidth and cannot support high-capacity data applications.

It is important to note that UHF spectrum antennas are low gain so this limits achievable coverage. Also, active antenna systems, which might be more energy efficient because of better spectral efficiency, improved coverage, and bandwidth, cannot be installed on UHF spectrum. However, active antenna demands significantly more power to make them work which could offset any energy savings. On balance there is little difference between link budgets of the sub-1 GHz bands and some of the higher frequency bands.[193]

The likely use case for the assignment of more UHF spectrum for mobile would be increasing network coverage. For example, the 700 MHz band is being used in many countries to expand 5G coverage in rural areas and can also be used to improve indoor coverage. Better indoor coverage would also be required for certain IoT and Ultra Reliable Low Latency Communications (URLLC) applications.

In the UK, in response to Ofcom's consultation ahead of the 5G auction, BT/EE claimed that low "*frequency spectrum would be crucial for providing 5G services, in particular eMBB (enhanced mobile broadband), service continuity in moving vehicles, IoT services and URLLC*." It argued that the difference in good quality indoor coverage would be even more obvious as 5G mobile services were introduced, as customers would increasingly demand seamless connectivity using data intensive services indoors and deep indoors.[194]

Improving coverage through sub-1 GHz spectrum is likely to have a positive environmental effect because it reduces the need for network expansion by deployment of physical sites. Further, it might also reduce the need for deploying multiple small cells to improve 5G coverage in urban areas, which could also reduce overall emissions. While small cells are likely to be energy efficient and some can even be powered in a sustainable way (for example, using solar or wind energy), the emissions from their production process is a matter of concern. However, small cells will largely be used to provide high levels of capacity – in New York city alone it is estimated that at least 3,135,200 small cells would be deployed to support 5G services [195] – and so it is uncertain that 700 MHz spectrum would have a significant impact on this demand.

Accordingly, there is likely to be little impact on the production of network equipment and resultant emissions by the assignment of the UHF band as the same equipment could be utilised for other sub-mmWave bands. Most base stations can now support multiple bands and technologies.

From the point of view of the end user, provision of mobile services on the UHF spectrum could increase network coverage, which may lead to more people opting for mobile broadband services. According to a study conducted by the ITU for 145 countries for the time-period (2008-2019), a 1 per cent increase in 4G coverage can increase Mobile Broadband (MBB) penetration by approximately 0.1 per cent.[196] This increase in mobile broadband penetration would increase the demand for more end user devices and consume more data, in turn

[193] Link budget is referred to as the net power gains and losses that a communication signal experiences in a telecommunication system. For example, from the transmitter, through a communication medium such as radio waves, cable, waveguide, or optical fibre, to the receiver.
[194] Ofcom, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 2020. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/192413/statement-award-700mhz-3.6-3.8ghz-spectrum.pdf
[195] Curran Claire, What Will 5G Mean for the Environment?, 2020.Available at: https://jsis.washington.edu/news/what-will-5g-mean-for-the-environment/
[196] ITU, The impact of policies, regulation, and institutions on ICT sector performance, 2021. Available at: https://www.itu.int/pub/D-PREF-EF.ICT_SECT_PERF-2021

increasing emissions. However, in common with the power use of base stations, lower frequency spectrum can require a lower power draw for end user devices.

5G as significant enabler of climate beneficial analysis

Through industry-specific use cases such as flexible work, smart grid, automated driving, and precision farming, 5G is capable of inducing a large enablement effect. According to a paper by Bieser et al, use of 5G to deliver these use cases can avoid between 0.1 to 2.1 Mt CO2e/year by 2030.[197] However, many of these high-speed applications and use cases that 5G promises can also be provided through a fixed or private network. RSPG notes that wired technologies (optical fibre, cable etc.) are likely more energy efficient than wireless technologies like 5G.[198]

According to a report by O2, 5G could mitigate 269 megatons of CO_2 emissions through to 2035. The report notes that most of the benefit is likely to come from utilities and the home energy sector, where it is expected that 5G could mitigate 181 megatons of CO_2 within a 15-year timeframe. As per the report, smart heating could reduce domestic energy use by 20 per cent. The report also claims that 5G could make the transport sector 45 per cent more energy efficient through connected autonomous vehicles and 'smart' rail systems. The report also predicts relatively smaller emission reductions from the manufacturing and healthcare sectors with increasing automation and digitisation.[199] [200]

5G services could also be used to provide dedicated networks for certain applications. These may be more energy efficient in theory as enough capacity would be available to provide high bandwidth applications than deploying additional base stations to enhance capacity as in the case of multi-service mobile networks. However, it should be noted that altering this network design would potentially require manufacturing and installation of new network equipment, which also has an environmental cost. Having dedicated networks for different use cases might actually lead to network duplication and increase energy emissions.

For 5G to operate there would be a need for production of 5G specific network equipment, especially for 5G standalone services, which would increase the emissions. For example, network equipment for the operators and also devices like IoT sensors, drones or robots for enablement use cases. According to GSA September 2021 data, 5G modules (modules that allow machines – robots, drones, home automation) to connect to the network) comprise 13.8 per cent of the announced 5G devices (third highest). The largest share of 5G devices comes from the end user level (also discussed below) - mobile phones (48.2 per cent) followed by FWA CPE (17.9 per cent).[201]

As for the above options, to assess the net positive or negative environmental impact of 5G at the network level, the supply chain actors and end user impact needs to be looked at together. 5G also adds another potential dimension of enablement, so along with 5G's environmental impact within the ICT sector, its catalysing impact on other sectors must be assessed as well to see the full picture. It is important to note that the enablement impact from 5G is expected to be different for each use case (because of significant difference in the service or product offering of each), which might also differ across regions depending upon the energy mix or the efficiency of the technology deployed. This would make it important to assess the use cases individually.

[197] University of Zurich, EMPA, Next generation mobile networks Problem or opportunity for climate protection?, October 2020. Available at: https://plus.empa.ch/images/5G%20climate%20protection_University%20of%20Zurich_Empa.pdf

[198] RSPG, The role of radio spectrum policy to help combat climate change, June 2021. Available at: https://rspg-spectrum.eu/wp-content/uploads/2021/06/RSPG21-026final_RSPG_Report_on_Climate_Change.pdf

[199] Edie, O2: 5G will play 'huge role' in decarbonising energy, transport, and manufacturing, 2020. Available at: https://www.edie.net/news/8/O2--5G-will-play--huge-role--in-decarbonising-energy--transport-and-manufacturing/

[200] O2 reveals vision for a greener, connected future: 5G to play key role in building a greener economy, 2020. Available at: https://news.o2.co.uk/press-release/o2-reveals-vision-for-a-greener-connected-future-5g-to-play-key-role-in-building-a-greener-economy/

[201] GSA, 5G ecosystem report, September 2021.

4.2.1 Time scale and regulatory approach

The timescale required to utilise spectrum to increase network capacity would be expected to be less than that of deploying additional physical sites. In addition to installation of base stations, time would also be required to obtain the necessary Rights of Way (RoW) clearances. For example, in the UK Ofcom have framed an 'Electronic Communications Code – Code of Practice', with the intention to guide the operators and the landowners on a range of network infrastructure build-related issues. The code addresses installation of physical infrastructure on land, buildings, rooftops, in a tunnel, or on a lamppost. The code states that when a suitable location has been identified for the installation, the operator would need to obtain the necessary consents in accordance with the regulations of the Local Planning Authority.[202] This suggests that the operators are likely to take relatively more time in rolling out services if they need to deploy additional physical infrastructure due to insufficient spectrum. Alternatively, they could use another band which might not be optimal in terms of energy consumption, if a band with similar propagation characteristics is not available.

As such, it is important that sufficient spectrum in the desired bands is available to the operators. However, the process of identifying suitable spectrum and planning its release and award can take significant time. The process can take several years and can take significantly longer than installing new physical infrastructure.

It should also be noted here that currently spectrum allocation decisions across different services (mobile, broadcasting and satellite services) are based on technical, social, and economic considerations. However, it might also be useful to consider the environmental angle when harmonising spectrum use across the services particularly where the services might be substitutes for each other.

The provision of 5G services has high dependence on the availability of optimal amounts of spectrum in the appropriate bands. 700 MHz, 3.5 GHz and mmWave bands have emerged as the preferred 5G bands across the world. UK had assigned part of the C-band (3410-3580 MHz) to mobile in April 2018. In the March 2021 spectrum assignment in the UK, a total of 200 MHz of bandwidth in the 700 MHz and 3.5 GHz bands was assigned. 80 MHz was assigned in the 700 MHz – two, 30 MHz blocks of paired spectrum (703-733 MHz and 758-788 MHz), and a 'centre gap' of 20 MHz at 738-758 MHz. 120 MHz of contiguous spectrum was assigned in 3.5 GHz – 3680 and 3800 MHz. mmWave frequencies are yet to be assigned in the UK for mobile services,[203] although the frequencies 24.25 – 26.5 GHz have been made available for shared use but only for low power indoor licences, essentially for the verticals.[204] As discussed in the previous option, there are potential environmental benefits from assigning sub-1 GHz spectrum because of its higher coverage and potentially low need for base stations to improve coverage, especially in the rural areas. On the other hand, while the 3.5 GHz does not have the coverage advantages of the sub-1 GHz bands, it has significant capacity advantages which also reduces the need for installation of more base stations and thus could induce a positive environmental effect. For example, GSMA April 2021 report notes that decreasing the 3.5 GHz channel size from 100 MHz to 60 MHz would increase the need for cell sites by 64 per cent. As such, the report emphasises that wider channels lower network density.[205]

For countries like the UK which have already assigned the 5G spectrum and rolled out services, this should not be considered final. As demand increases over the coming years it is likely there will be calls for more spectrum to be assigned for 5G, given its economic and environmental enabling potential for the country. In other regions there have been moves to award parts of the 4.8 GHz and 2.3 GHz bands to 5G operators, and discussions at WRC-23 and WRC-27 may identify additional spectrum for international harmonisation.

[202] Ofcom, Electronic Communications Code: Code of Practice, 2017. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0025/108790/ECC-Code-of-Practice.pdf
[203] Ofcom, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 2021. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0019/192412/information-memorandum-award-700mhz-3.6-3.8ghz-spectrum.pdf
[204] Ofcom, Shared access licences, 2019. Available at: https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/shared-access
[205] GSMAI, 3.5 GHz in the 5G Era, 2021. Available at: https://www.gsma.com/spectrum/wp-content/uploads/2021/04/3.5-GHz-for-5G.pdf

The UK's 5G spectrum strategy highlights the potential role of spectrum management in managing environmental concerns through enabling other industries to reduce their environmental impact through smart utilities management, asset monitoring and climate monitoring. As such the strategy specifically focuses on supporting wireless innovation, promoting spectrum sharing, licensing to fit local and national services.[206] However, to achieve this vision, a lot of work would need to be done, beginning with a discussion with the industry stakeholders to chart out a clear spectrum roadmap, followed by necessary spectrum clearance before any formal assignment. This could take a number of years.

4.2.2 Cost implications

Installing less network equipment might mean a lower financial cost for the operators – both Capex and Opex for purchasing and maintaining the network equipment thereafter. However, it could also have a significant opportunity cost - either financial, socio-economic, or environmental - if the spectrum resource is also demanded by other services like broadcasting and satellite services.

5G installation is likely to inflict a financial cost on the operators because of the need for installing new network equipment for providing 5G services, especially for 5G standalone services. As for the environmental impact, the actual cost the operator bears to deploy 5G would also depend upon its preference for 5G network design and architecture, because of varied options to choose from. For example, if deployed using OpenRAN based network design which provides the operators with a flexibility to source different parts of the network from different equipment providers, the installation might be more affordable because of increased competition.[207]

4.2.3 Impact on other services

Spectrum is a scarce resource and all telecommunication services (mobile, broadcasting, satellite services) use it to provide their respective services to the consumers. As such providing spectrum to the mobile sector could be at the cost of other services, as the same spectrum can be desired by more than one service.

Amongst many examples, consider the case of mobile and satellite communications in the 28 GHz band. At WRC-19, a total of 17.25 GHz of spectrum was identified for IMT services in the high-frequency range above 24 GHz (mm-wave spectrum). The 28 GHz band (27.5-29.5 GHz) is part of the Ka-band (17.7-21.2 and 27.5-31 GHz) which is allocated for fixed satellite services (FSS). 28 GHz is not among the identified IMT bands, and only a small number of countries have assigned (or partially assigned) this band for IMT.

In most countries, the assignment of mmWave spectrum has been in the adjacent 26 GHz band, which is fully harmonised on global basis for IMT.

Next-generation high-throughput satellite (HTS) systems are capable of delivering gigabit connectivity and the 28 GHz band is a key enabler to achieving this, especially as the Ku-band (11-14 GHz range) is increasingly congested. If IMT services are deployed in the 28 GHz band, potential interference between satellite earth stations and IMT receivers (base stations and terminals) is likely to occur unless coexistence measures, such as geographic separation, are in place. Moreover, HTS services are expected to be deployed ubiquitously and on the move through earth stations in motion (ESIM), and in such a situation co-channel uses of HTS services and IMT in 28 GHz is not feasible.[208]

[206] Ofcom, Supporting the UK's wireless future: Our spectrum management strategy for the 2020s, 2020. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0027/208773/spectrum-strategy-consultation.pdf

[207] LightReading, FCC acknowledges open RAN is cheaper, albeit with reservations, 2021. Available at: https://www.lightreading.com/open-ran/fcc-acknowledges-open-ran-is-cheaper-albeit-with-reservations/d/d-id/771467

[208] It should be noted that satellite already shares the 28 GHz band with fixed links which are used in many cases for mobile backhaul. Therefore there is an additional reason why this would not be possible in the UK.

In the case of the C-band in the UK, 3.6-3.8 GHz has been allocated to mobile on a primary basis, while 3.8-4.2 GHz has been allocated to it on a secondary basis with a primary allocation to Fixed and Fixed satellite services. The latter could play a critical role to provide emergency communication especially in case of a climate catastrophe.

The Ultra High Frequency (UHF) band spectrum between 470 MHz and 694 MHz has been historically allocated to television broadcasting, with secondary users of Programme Making and Special Events (PMSE) equipment in the white spaces created by the need for non-overlapping transmissions (and a small reservation for use by radio astronomy). However, with increasing demand for mobile services, the mobile sector is demanding spectrum allocation in this band on a co-primary basis in ITU-Region 1. While access to mobile broadband on UHF spectrum might play a critical role in rolling out high-quality connections in rural areas, keeping in mind the high demand for mobile broadband, it should also be noted that there has been a rather slow decline in the use of television broadcasting.[209] Some Region 1 countries also have greater reliance on DTT - for example, DTT is one of the most popular methods of accessing television in the UK.[210]

Further to the competing claims from the broadcasting industry for the UHF spectrum as discussed above, Public Protection and Disaster Relief (PPDR) services could also be impacted by the mobile assignments in the UHF band. PPDR services can play a critical role in disaster management (including climate disasters like floods, hurricanes or forest fires).[211]

WRC-19 recognised that some countries in Region 1 have identified certain parts of the frequency ranges 694-791 MHz and 790-862 MHz for broadband PPDR deployment. WRC-19 further encouraged governments to consider 380-470 MHz (Region 1) and 406.1-430 MHz, 440-470 MHz, and 4940-4990 MHz (Region 3) for PPDR deployment as well.[212]

For example, in the UK, multiple frequency ranges within the UHF band i.e., between 300 MHz and 3 GHz are being used for emergency services (including 400 and 700 MHz bands amongst others.)[213]

4.2.4 Impact on other sectors

Better mobile services can improve the productivity of various sectors through improved connectivity, better communication, and management. This in turn can have a positive impact on the economic growth of the country. For example, a study by Analysys Mason on a 5G Action Plan for Europe concluded that the largest economic benefit in terms of GDP contribution would be from smart factories, smart agriculture and 5G FWA in sub-urban and rural areas. [214] In addition, according to a report by Vodafone, 5G could result in total productivity benefits of £158 billion in the UK between 2020-2030.[215]

Further, mobile broadband connectivity can result in significant consumer welfare across multiple sectors, especially in the rural economy, through mechanisms like increased access to inputs, access to capital markets, improvement in labour market outcomes, and positive wage effects. For example, Dorset council launched the 5GRural Dorset project, partly funded by the DCMS. The objective of the project is to see how reliable 5G

[209] Plum, The Future use of UHF in ITU Region 1, 2021. Available at: https://plumconsulting.co.uk/the-future-use-of-uhf-in-itu-region-1/
[210] DCMS, Consultation on the renewal of Digital Terrestrial Television (DTT) multiplex licences expiring in 2022 and 2026. Available at: https://www.gov.uk/government/consultations/consultation-on-the-renewal-of-digital-terrestrial-television-dtt-multiplex-licences-expiring-in-2022-and-2026/consultation-on-the-renewal-of-digital-terrestrial-television-dtt-multiplex-licences-expiring-in-2022-and-2026
[211] ITU, Emergency Radiocommunications, 2021. Available at: https://www.itu.int/en/ITU-R/information/Pages/emergency.aspx
[212] WRC, World Radiocommunication Conference 2019. Available at: https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.14-2019-PDF-E.pdf
[213] Ofcom, Frequencies for emergency services in the UK, 2020. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0021/103296/fat-emergency-services.pdf
[214] Analysys Mason,5G action plan review for Europe: final report, 2020. Available at: https://www.qualcomm.com/media/documents/files/5g-action-plan-review-for-europe.pdf
[215] Vodafone, How 5G can boost productivity across the UK, 2020. Available at: https://newscentre.vodafone.co.uk/app/uploads/2020/06/Vodafone-5G-Report-final.pdf

connectivity can boost agricultural productivity, rural business applications, industrial applications, and coastal cliff monitoring.[216]

Nokia undertook a study on BMW Remote Services in the urban underground parking structures in Aalborg, Denmark, and open rural areas with poor LTE coverage in southern Germany. This study assessed the functioning of the remote services like locking and unlocking the doors, sounding the horn, climate control, activating the headlights or sending navigation destinations in advance and passenger entertainment applications like music streaming, using LTE eMTC and NB-IoT technologies on the 800 MHz band. The results revealed that a minimum of 60 – 70 per cent of the total indoor underground parking locations can be served from an outdoor macro-LTE 800 MHz cell while full eMTC or NB-IoT radio coverage can be provided in rural areas. Given the locations studied, higher frequency spectrum was significantly less useful. [217]

4.3 The need for contiguity

When assigning spectrum between services and between operators, regulators must take account of previous use and existing band plans. Where part of a band has already been assigned, this can lead to spectrum users being awarded several smaller lots. This is particularly true for some historic mobile awards, or for broadcast licences.

While these non-contiguous blocks can be used, it is often significantly less efficient in terms of both cost and environmental impact. Given this, providing contiguous spectrum blocks could induce a positive environmental impact – for example, on mobile networks, reducing the need for carrier aggregation (which typically consumes more energy), or on broadcasting networks reducing the need for multiple multiplex equipment.

However, as demonstrated in papers such as that by Weidang et al[218], there is considerable scope for minimising inefficiencies associated with non-contiguous spectrum. In particular, in terms of the emissions from deploying any new equipment for carrier aggregation, the impact might be low as aggregation could be handled at the level of software, rather than requiring installation of new equipment, especially when the bands being considered are already in use.

Even if mobile networks supported by contiguous spectrum might be more energy efficient, it might not be easy to reduce the fragmentation in the spectrum assignments at the first place. For example, in the UK mobile assignments in the C-band are fragmented between the upper frequency range (3.4-3.6 GHz) and (3.6-3.8 GHz). Realigning spectrum holdings to provide all operators with a single contiguous block will require extensive coordination, and some blocks may be considered more valuable than others. In its 2019 report on defragmentation of the C-band[219], Ofcom considers whether spectrum trading may allow for the market to resolve this issue, but it is unclear whether there would be a sufficient incentive for operators to work together and agree to a solution.

There is also an impact on power consumption by end-user devices. An ECC report from 2018[220], notes that devices consume more power if facilitating communication through non-contiguous spectrum blocks in comparison to contiguous spectrum blocks. This is because contiguous spectrum achieves higher trunking efficiency, since many pieces of user-equipment might not support carrier aggregation – therefore, the power consumption of user equipment may increase significantly where carrier aggregation is used. A paper by Bazzo

[216] 5G Rural Dorset, 2021. Available at: https://5gruraldorset.org/
[217] GSA, Nokia, Automotive services enabled with LTE evolution for IoT.
[218] Gao Weidong et al, Energy efficient power allocation strategy for 5G carrier aggregation scenario, 2017. Available at : https://jwcn-eurasipjournals.springeropen.com/articles/10.1186/s13638-017-0924-1
[219] Ofcom, Defragmentation of spectrum holdings in the 3.4-3.8 GHz band, 2019. Available at : https://www.ofcom.org.uk/__data/assets/pdf_file/0011/152102/consultation-defragmentation-spectrum-holdings.pdf
[220] ECC, Guidance on defragmentation of the frequency band 3400-3800 MHz, 2018. Available at: https://docdb.cept.org/download/3a143dbe-7cbc/ECCRep287.pdf

et al suggests a 13 per cent increase in UE power consumption while transferring data over 10+10 MHz carrier aggregation, rather than a 20 MHz single carrier, in LTE-A systems.[221]

4.3.1 Timescale and regulatory approach

Any delays in the assignment of contiguous spectrum are likely to be from legacy service clearances, interference issues and competing spectrum claims from other services. Where spectrum is currently fragmented, Ofcom will need to work with all existing users to ensure that there is an agreed outcome and roadmap to meet this, and Ofcom will need to consider the incentives that users have to rearrange their spectrum holdings.

4.3.2 Cost implications

Contiguous spectrum assignment might not significantly reduce operators' financial costs as there might not be any reduction in network equipment as discussed above – if carrier aggregation is currently carried out by software, there will only be a potential licencing fee to be considered. There may be a small decrease in the operating costs of energy consumption. Further, if existing fragmentation has been overcome through hardware solutions, any move to contiguous spectrum will lead to this hardware being made obsolete ahead of its economic and environmental lifespan – with additional, new, equipment being required.

Decreases in costs are more likely to be experienced by end users as a consequence of a significant reduction in power use.

4.3.3 Impact on other services

Provision of contiguous spectrum would require there to be a coordinated effort to clear existing use and reallocate spectrum. It is possible the existing holdings may be used for verticals, FWA, or fixed links if an operator is making use of a geographic compartmentalisation of spectrum use; these services will need to be moved to the new spectrum holdings where possible.

Moving to contiguous spectrum would have a minimal impact on other sectors, as this policy would not change the amount of spectrum required for a service, only the way it is distributed between users.

4.4 Protection of suitable spectrum for science services

'Science services' include space research and radio astronomy, but, as noted above, the only services relevant in the present context are those related to meteorology and Earth sensing.

The most vulnerable application in this category is the passive EESS, which makes use of radiometer sensors on satellites operating in specific spectrum bands dictated by the emission and absorption spectra of particular molecules. These cannot, therefore, be substituted by other bands.

The data gathered by these satellites, which include the Sentinel-series satellites of the ESA/EU 'Copernicus' programme as well as those operated by Meteorological agencies, are vital for both day-to-day weather forecasting and for understanding climate trends. Any disruption of the sensors is liable, therefore, to reduce the

[221] Bazzo J J et al , UE current consumption on carrier aggregation in LTE-A systems, 2020. Available at: https://ieeexplore.ieee.org/document/9289502

accuracy of information needed to ameliorate the immediate impact of severe weather events and to reduce the accuracy of climate models.

While satellite-borne passive sensors are uniquely vulnerable because of their high sensitivity and their view of wide areas of the Earth's surface, other important meteorological sensors have also been disrupted by interference. Weather radars, used to produce the rain maps essential for short-range forecasting, operate at 5.6 GHz, in spectrum shared with Wi-Fi. When the allocation to Wi-Fi was made, the use of Dynamic Frequency Selection (DFS) was mandated[222], but interference continues to be an issue, due partly to failings in the DFS algorithm but also due to the widespread use of non-compliant equipment. The sensitivity of radar receivers means that radars operating in other bands are also vulnerable[223] to interference from unwanted and spurious emissions from a wide range of radio services.

National and international regulators already devote considerable effort to the protection of these services at every level, from technical studies in the ITU-R to on-site tracking of specific interference cases. Such work is constrained both by budgetary issues and by strategic considerations.

A recent example of the latter was seen in the protracted studies leading up to the WRC-19 concerning potential interference to satellite sensors operating at 24 GHz from new 5G systems operating at 26 GHz. As is generally the case with such agreements, the resulting compromise satisfied neither party, but is a useful reminder of the policy trade-offs that need to be made.

In this case the risk of long-term degraded sensor accuracy needed to be weighed against the additional short-term costs that would be incurred by the operators of 26 GHz 5G services, which might be limited in bandwidth, or require more costly hardware to limit emissions. As in many such cases, the greatest uncertainty in the modelling comes from the assumptions that need to be made about market growth and hence the density of deployment.

The importance of making appropriate decisions is particularly evident when considering the deployment of unlicensed devices. In this regard it is relevant to note that Ofcom's initial framework for the release of spectrum above 100 GHz, (currently used by space sensors) imposes a requirement for licencing so that should unforeseen issues of interference arise, the situation could, in principle, be rectified.

We consider that one of the most direct ways in which spectrum policy decisions could have an impact on climate change would be to continually re-assess the protection given to these scientific uses of spectrum and, where necessary, to re-balance regulation to prioritise such protection.

4.5 Identification of suitable spectrum for energy

As in the case for science services, the energy sector appears to be a key driver for combating climate change through the development of green energies. The sector is also fundamental for the operation of other verticals (the energy sector provides inputs to industry, transport, agriculture, etc.). The mission-critical role of this sector is illustrated by the social and economic impact of energy network breakdowns when they happen, and the heavily regulated penalties it must pay in case of breakdowns.

As explained in previous sections, innovation has led to the development of green energies, and the increased procurement of renewable electricity is expected to drive down carbon footprint of ICT[224]. This would ideally

[222] ETSI standard EN 301 893
[223] M. Vaccarono and Al , Survey on electromagnetic interference in weather radars in Northwestern Italy, 2019.Available at: ., https://www.mdpi.com/2076-3298/6/12/126
[224] For more details, see: https://www.carbontrust.com/news-and-events/news/updated-calculation-released-on-the-carbon-impact-of-online-video-streaming

require local production of energy through decentralised networks, and this will require monitoring and control across all the smart grid network.

The energy sector claims it requires dedicated spectrum, as it does not want to have to rely on commercial networks because it needs to ensure:

- Availability and continuous QoS and not be dependent on networks run by MNOs;
- Longevity of its networks (the perspective of 6G/7G opens the possibility of having to change the equipment); and
- Cybersecurity.

Understanding the need for dedicated spectrum by the energy sector requires a different perspective as spectrum allocation to this sector does not lead to direct revenue generation, as is the case for spectrum awarded to the MNOs. Nevertheless, spectrum is a strategic asset for the energy sector, as it enables and facilitates its core activities which are directly related to climate issues.

The biggest challenge is identifying suitable spectrum the location of the monitoring and control points are spread across the country, some in remote rural areas, and ideally spectrum below 1 GHz is needed to support the range of deployments (e.g. the need for long link lengths). In the UK it is likely that incumbents will need to be migrated to other frequencies and solutions to release spectrum. For example, the UHF1 (410 – 450 MHz) and UHF2 (450 – 470 MHz) bands are used extensively for a wide range of parties, including Ministry of Defence (MOD), Emergency Services (ES) and Business Radio (BR) users[225].

In many countries, this policy option has already been implemented (Ireland, USA, Poland, Spain, Germany, Portugal, and Russia) or is planned (Saudi Arabia, Spain)..

4.6 Environmental spectrum obligations and incentives

Environmental obligations could be of multiple forms – emissions reduction targets, sustainable sourcing of network equipment (including eco-design of network) and sustainable disposing of network equipment. While obligations could compel the operators to reduce emissions, spectrum policy incentives such as reduced spectrum fees could facilitate a speedy realisation of these obligations as some of these are likely to incur additional financial costs for the operators.

However, spectrum fee reductions could come with the risk of distorting the optimal allocation of inputs and reduce productive efficiency. To remediate this potential drawback, the award would need to be designed in a manner that it is able to strike a right balance between the criteria of technical know-how, socio economic benefit, financial capacity, and environmental considerations.

Determining the nature of the targets can be challenge as well. For example, being too prescriptive can deter innovation and being too flexible could create confusion and potentially increase compliance costs of the operators. However, in light of the multiple interdependencies and complexity of the topic, it might be better for the regulator to give independence to the operators in defining their specific targets under overarching guidelines.

In terms of carbon reduction targets, ITU-T Study Group 5 has provided detailed methodologies and carbon emissions reduction trajectories for the mobile networks in their study – L.1470 (2020) amongst other ICT sub-

[225] Ofcom, Strategic Review of UHF band 1 and band 2, 2017. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0017/102185/Statement-on-strategic-review-of-UHF-Band-1-and-Band-2.pdf

sectors like fixed networks and data centres, for the years 2020, 2025 and 2030. Science Based Target initiative (SBTi[226]) has also developed a methodology for MNOs to set emissions targets. One difference between the ITU and the SBTi approach is that the former includes the emissions from the electricity supply and grid losses while the latter does not. From this perspective the ITU methodology is closer to a life-cycle assessment than SBTi.[227] Although, neither ITU or SBTi look at the Scope 3 emissions of the networks i.e., those from the supply chain actors such as the equipment providers.

It is important to note here that we have not come across any examples of regulators in any countries implementing environmental obligations in our research.

As discussed in Section 2.4, MNOs and broadcasters in the UK have already set or are in the process of setting reduction targets, mostly in line with SBTi methodology. As pointed to above, the methodologies from both the ITU and the SBTi might still not be holistic enough to capture the net impact and this is something that the regulator would need to consider when incentivising the industry to set its targets.

From the point of view of end users, if the operators have to incur heavy financial costs to comply with the environmental obligations, then consumers could experience an increase in the price of services. Also, in a scenario where the productive efficiency of the operators is a not optimal due to environmental obligations, service quality might suffer.

Incentivising operators to use green sources of energy

An incentive from the regulator to use green sources of energy would provide the operators with an opportunity to reduce their Scope 2 emissions – that is, indirect emissions from the generation of electricity that an operator purchases. This could have an immense environmental benefit as there are limits to only focussing on Scope 1 emissions reduction.[228]

In many options above (such as the deployment of 5G networks or switching off legacy networks) we highlight the significance of energy efficiency to reduce the overall energy consumption. However, we also note in the discussion above that any energy efficiency gains at the network level could be offset by rebounds at the user end.

There could be challenges related to the availability of green sources of electricity and access to it. However, in the UK renewable sources of electricity have shown some promise. As of first quarter of 2021, 11 per cent of energy and 43.1 per cent of electricity in the UK was generated from renewable sources.[229] as discussed in section 2.4, many operators in the UK have been shifting to renewable sources of energy. For example, both Vodafone and Three (3) claim to be using 100 per cent renewable energy across different parts of their supply chain (for example, data centres, network, and retail stores). [230,231]

The regulator should encourage these developments in the industry and incentivise the operators to continue their transition to renewable sources of electricity, for example through spectrum fee reduction incentives.

[226] For more details, see: https://sciencebasedtargets.org/about-us

[227] ITU-T, L.1470: Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement, 2020. Available at: https://www.itu.int/rec/T-REC-L.1470-202001-I/en

[228] Compare your Footprint, What is the Difference Between Scope 1, 2 and 3 Emissions?, 2018 Available at: https://compareyourfootprint.com/difference-scope-1-2-3-emissions/

[229] Department of Business Energy and Industrial Strategy, UK Energy in brief, 2021. Available at : https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1016822/UK_Energy_in_Brief_2021.pdf

[230] Vodafone UK News Centre,Vodafone commits to 'net zero' carbon emissions by 2040, 2020. Available at : https://newscentre.vodafone.co.uk/news/group-net-zero-carbon-emissions-by-2040/

[231] EE, Our Environment 2021. Available at : https://ee.co.uk/our-company/corporate-responsibility/being-responsible/the-environment

In situations where renewable grid electricity is not available, operators could also consider off-grid electricity generation options, though they might not be easily scalable. There could also be challenges to get council or the respective body's clearance in building an off-grid electricity generation site. For example, in the EU Vodafone states that it has invested €65m during the year 2020 on on-site renewable projects and energy efficiency.[232]

It is also important to note here that while green electricity might have made some progress in the UK, its share in the overall energy mix of the UK is still low compared to oil and gas.[233] The latter feed into the heating systems in the UK, which are largely dependent on oil and gas.[234] Generally, network equipment operates over a wide temperature range but some equipment would need heating, which would increase emissions as this is likely to be dependent on non-renewable sources of energy. In such a scenario, where there are limited options available at least in the immediate short term, operators are likely to focus on energy efficiency options and greening electricity to the extent possible.

It is possible that end users might experience an increase in cost of services, as renewable sources of electricity might be expensive in comparison to fossil fuel-based alternatives. However, a recent report by the Department for Business, Energy and Industrial Strategy (BEIS) suggests that electricity generated from renewables sources of electricity such as wind and solar might actually be 30-50 per cent cheaper than previously thought. The estimates suggest that by 2025 the electricity generated from onshore wind or solar could cost half that of gas generated power by 2025. Improvements in green energy technology over time would play a role in this.[235]

Sustainable network equipment (eco-design)

Eco-design network equipment essentially refers to equipment designed to have a lower carbon footprint. It could include aspects such as materials efficiency, longevity, repairability, and upgradability/modularity.[236] Deployment of eco-design network equipment is likely to reduce network-level emissions, however it could be a challenge for the operators to source such equipment as the market for this equipment is not expected to be mature in the near future. Sourcing eco-design network equipment is highly related to Scope 3 emissions of the operators (i.e., related to their supply chain actors) as it deals with greening of the equipment sourced from the vendors. As such, this could play a significant role in greening the overall ICT supply chain beyond the operators.

From a spectrum policy perspective, it is crucial that the needs of eco-design equipment are taken into account when formulating band plans and spectrum awards. It is possible that such equipment will require defined combinations of spectrum, or certain block sizes.

Demand for eco-design based network equipment would require for the equipment vendors to increase research and development and production of such equipment. The current research shows that the topic of eco-equipment is still at the initial conception stage where organisations like the ITU-T study group 5[237] and industry organisations like the NGMN alliance[238], are developing methodologies for the industry (more targeted on equipment vendors in this case) to adopt and manufacture sustainable equipment.

[232] Vodafone UK News Centre, Vodafone's European network 100 per cent powered by electricity from renewable sources, 2021. Available at: https://newscentre.vodafone.co.uk/press-release/vodafones-european-network-100-powered-by-electricity-from-renewable-sources/
[233] BEIS, UK Energy in Brief, 2020. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904503/UK_Energy_in_Brief_2020.pdf
[234] EDF, UK Gas Boiler Ban – Everything You Need to Know. Available at: https://www.edfenergy.com/heating/advice/uk-boiler-ban
[235] Carbon Brief, 2Wind and solar are 30-50 per cent cheaper than thought, admits UK government, 2020. Available at: https://www.carbonbrief.org/wind-and-solar-are-30-50-cheaper-than-thought-admits-uk-government
[236] Next Generation Mobile Networks (NGMN), Green Future Networks, Network Equipment Eco-Design and End to End Service Footprint, 2021. Available at: https://www.ngmn.org/wp-content/uploads/210719-NGMN_Green-future-Networks_Eco-design-v1.0.pdf
[237] See ITU-T study group 5 studies L.1060, L.1100, L.1101, L.1102. Available at: https://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5
[238] NGMN, Green Future Networks
Equipment Eco-Design and End to End Service Footprint, 2019. Available at: https://www.ngmn.org/wp-content/uploads/210719-NGMN_Green-future-Networks_Eco-design-v1.0.pdf

Requirements for battery back-up

From a reliability and security perspective, operators are required to ensure that networks are resilient to power failures, meaning that large battery backup systems are included in the costs of any base station. Such batteries are, by their nature, environmentally costly, with significant use of rare minerals and a high environmental cost of production. Any reduction in the obligation for these batteries to be installed would have a positive impact on the environment; regulators may wish to consider making this an obligation only on certain base stations, or reducing the time period that the battery back-up must last for.

4.6.1 Timescale and regulatory approach

In terms of environmental obligations, it is important for the regulator to have in place a set of guidelines or an overarching framework on which the operators could base their individual specific targets. Providing some flexibility to the operators would be important to ensure compliance and not deter innovation. Also, the regulator would need to ensure that allocative efficiency is not compromised in incorporating environmental considerations.

To achieve this, a detailed study would need to be done looking at the current emissions of the operators in the UK, potentially even considering the emissions from the supply chain actors and end users to develop a complete understanding. Further, reduction targets would need to be aligned to UK's national carbon budgets or reduction targets, which in turn are aligned to the global reduction targets (for example as per the Paris Treaty). These would be UK's net zero emissions commitment by 2050[239] and sixth carbon budget (2033-2037) target of 965 million tonnes of carbon dioxide equivalent ($MtCO_2e$).[240] Conducting these studies can take a significant amount of time.

Further, it would be critical for the operators to set up a process for energy consumption reporting and monitoring metrics before considering any specific environmental obligations. This would provide the regulator with a greater insight on the issue and help in formulating more targeted obligations. This is discussed further in Section 6.

The regulator would also need to think about the content of the environmental obligations i.e., whether to restrict it to carbon emission targets, or have obligations related to sourcing and disposal of the equipment as well. However, while the emission targets could include the potential emissions from the life cycle of the equipment (rather than having separate obligations for equipment's sourcing and disposal), it should be expected that incorporating supply chain emissions within the reduction targets might be difficult to do (because of multiple actors in the chain). As such it might be easier to have separate obligation on network equipment sourcing and disposal.

On the shift to renewable sources of electricity, while some operators are making progress in shifting to renewable sources of electricity, an industry-wide shift across the entire supply chain would take time. This would depend upon the access to renewable sources of energy (for example for heating) and the pace with which the renewable energy sector grows.

To expedite the shift the regulator could provide financial support to the operators through spectrum fee reduction incentives. These would need to be balanced against the technical, socio-economic and financial parameters of the spectrum award. The regulator could also speed this shift by incorporating the move to renewable sources of electricity as one of environmental obligations (non-prescriptive but guidelines-based as

[239] UK government, UK becomes first major economy to pass net zero emissions law, 2019. Available at: https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law
[240] UK government, Setting of the sixth carbon budget (2033-2037), 2021. Available at: https://www.gov.uk/guidance/carbon-budgets#setting-of-the-sixth-carbon-budget-2033-2037

discussed in the previous option). However, the compliance rate is likely to improve if coupled with a financial incentive.

In terms of the use of eco-design equipment, as the market is in very early stages the essential step for the regulator would be to conduct a stakeholder consultation exercise to understand the developments in this area, the key issues and challenges. The consultation could then be used to formulate some high-level guidelines encouraging the industry (both the operators and vendors) to produce and adopt such equipment. All of these steps are likely to materialise in a much larger timeframe.

4.6.2 Cost implications

The cost of complying with environmental obligations would depend on their scope – whether they are focusing on network-level emission reduction targets, life cycle reduction targets, additional obligations related to the sourcing and disposal of equipment, and the nature (prescriptive or flexible) of the obligations. It is possible that some of the incentives offered may reduce the cost of network deployments, but this would depend on the policies chosen.

4.6.3 Impact on other telecommunications services

Environmental obligations and incentives would have a mixed impact, depending upon how the operators choose to reduce their emissions. For example, 5G would require the operators to have additional radio spectrum, which could be a matter of concern for other telecommunications services. However, the mobile sector adopting environmental obligations would set the right example for the other sectors..

4.7 Avoiding imposing strict coverage or quality obligations

In the UK, as of March 2020, government entered into an agreement with the UK MNOs and announced a grant funding for them to deliver the 'Shared Rural Network'. As per the terms of the agreement, each MNO has committed to providing good quality data and voice coverage to 88 per cent of the UK landmass by 30 June 2024, and 90 per cent by 30 June 2026. The obligations are subject to certain conditions such as provision of funding for elements of the programme.[241]

Not having such coverage or quality obligations could give the operators the liberty to deploy only in the regions with high Return on Investment (RoI). This would mean reduced deployment in less profitable rural regions and reduction in overall energy consumption and resultant emissions. However, there is a possibility this could result in the loss of consumer welfare through the digital divide between the urban and the rural areas. Market competition in developed countries such as the UK has meant that such a loss of consumer welfare has not occurred, but instead operators are able to optimise their investments from a cost and environmental point of view, when not constrained by regulatory obligations. Further, the lack of deployment in the rural areas is likely to have only a marginal environmental impact. Mobile broadband connectivity in the rural areas can actually induce the enablement effect through use cases such as telemedicine, working from home, and e-learning, which can reduce the need for frequent travel, in turn having a positive impact on emissions reduction.

Given this, there is an important balance to be struck between imposing obligations for social benefit and taking account of environmental cost. In the UK the current regulatory measures, of incentivising sharing and reducing costs of rural coverage through targeted subsidies and funding, are likely to lead to a preferred outcome where duplicate networks are minimised but coverage and service quality is maintained.

[241] Ofcom, Mobile Coverage obligations, 2021. Available at: https://www.ofcom.org.uk/spectrum/information/cellular-coverage

4.7.1 Cost implications

Not having coverage or quality obligations can decrease the cost of network deployment. However, given the social value of coverage and the government's focus, it is important for high levels of coverage to be achieved. As mentioned above, government has come up with various measures and schemes to ease the financial pressures of the operators to deploy in rural areas, including the Shared Rural Network, which offsets the cost of environmental improvements while maintaining coverage.

4.7.2 Impact on other telecommunications services

Directly, coverage and service quality obligations might not have an impact on other telecommunications services, as this does not relate to acquiring additional spectrum in competition with other services, but instead involves installing network infrastructure in rural areas to utilise already-assigned spectrum. However, the requirement to fulfil these obligations might lead to MNOs demanding more spectrum, which might in turn affect other services.

4.7.3 Impact on other sectors

Coverage and quality obligations could induce potential productivity effects across other sectors. For example, according to a previous report by Plum, the economic benefits of digital infrastructure in the rural areas in the UK could be around £17 billion over 10 years (2020-2030).[242]

4.8 Avoiding imposing strict power limits

Increasing potential power limits of the base stations can allow for the utilisation of the same mobile site for deploying multiple spectrum bands and multiple mobile technologies. This has the potential to reduce network duplication and therefore be more energy efficient, in turn reducing emissions. Further, allowing high transmitter powers from the base station could increase the base stations' coverage, which could imply deployment of fewer sites and result in energy savings and induce a positive environmental effect.

However, higher power limits can increase interference potential and higher EMF emissions could have health concerns. The EMF emission limits in the UK are in line with the Non-Ionizing Radiation Protection (ICNIRP)[243] guidelines, and the interference power limits[244]. As such these limits are harmonised to international standards which are developed after rigorous deliberations between varied stakeholders and thus should not pose a concern to the operators.

Further, increasing power limits would imply that the base stations could now consume more energy to reach the higher level of power which can counteract any positive environmental benefit from any reduction in the base station deployment. This means to find the net change in emissions one would need to consider the potential reduction in network density alongside the increase in the energy consumption of the base stations after increasing the power limits.

[242] Tech UK, Unlocking value with rural broadband: a policy rethink, 2020. Available at: https://plumconsulting.co.uk/5g_the_rural_opportunity/
[243] Ofcom, Guidance on EMF compliance and Enforcement, 2021. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0025/214459/guidance-emf-compliance-enforcement.pdf
[244] Current National Frequency bands and National Interfaces for Mobile use. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0016/100276/Annex-5-Current-National-Frequency-bands-and-National-Interfaces-for-Mobile-use.pdf

4.8.1 Impact on other telecommunications services

Interference power limits can ensure reduced interference between the telecommunications services (especially the ones co-existing in a frequency band) helping to ensure good quality of telecommunications services to consumers.

4.9 Incentivising network sharing

Network sharing can include both physical infrastructure sharing and spectrum sharing. It can be further classified as passive and active sharing, where the former includes network elements such as masts, sites, and cabinets, amongst others, and active sharing involves active elements in the radio access network such as antennas and radio network controllers. Spectrum sharing is also a part of active sharing.[245]

Both active and passive infrastructure sharing (excluding spectrum sharing) can result in deployment of less physical infrastructure and reduce network duplication, which is likely to reduce energy consumption and resulting emissions. This can already be seen in the UK with extensive infrastructure sharing within MBNL and CTIL. Spectrum sharing would also reduce emissions as it would imply network equipment sharing, which would mean reduced equipment deployment resulting in energy conservation and reduced emissions[246]. Spectrum sharing can lead to more efficient spectrum use among the MNOs and may reduce the need for more sites.

The amount of environmental benefit from network sharing would depend upon which part of the network the operators share. Sharing of energy dependent elements like sites, masts, antenna, and radio network controllers, to cite a few is likely to have a larger environmental benefit when compared to sharing elements like cabinets, site compounds etc. which are not energy dependent. Further, the architecture of the sharing network would also determine the amount of potential energy savings. For example, MOCN (Multi Operator Core Network) sharing (which includes the sharing not only of all radio access network elements (such as radio equipment, antenna, masts, site compounds and backhaul) but also of spectrum) is likely to have a marginally higher reduction in emissions when compared to RAN sharing (which excludes spectrum). Further, GWCN (Gateway Core Network), which involves sharing of both the access and the core network, has the potential to deliver an even larger environmental impact.

However, network sharing in some cases could also affect the quality of service of the host network if the existing network capacity is not able to support the additional traffic. In such a scenario, additional sites might be needed to increase the capacity or more spectrum, would need to be deployed. Both will lead to potential additional emissions, although likely to be less than a scenario of network duplication.

From the point of view of end users, network sharing can impact service quality. However, this would depend upon the type of sharing arrangement. In the case of an acquisition or a merger where both the entities combine their infrastructure, the network capacity might not be constrained. However, in case of sharing arrangements like network hosting, where the infrastructure assets are contributed only by the host network, service quality could be affected. Depending on the agreement between the two operators, the impact is likely to be greater for the virtual operators than the host network, since the former will often have access to a smaller share of the host's network capacity. For example, according to a 2018 report by the Android Authority, MVNO networks' download speeds were 23 per cent worse in comparison to the host network.[247]

[245] BEREC, BEREC Report on infrastructure sharing, 2018. Available at: https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8164-berec-report-on-infrastructure-sharing

[246] This is likely to be a rather second-order effect, however, as the overall emitted power will remain largely constant.

[247] Android Authority, Report: Average MVNO service significantly worse than service with main carrier, 2018. For more details, see: https://www.androidauthority.com/mvno-service-comparison-917354/

4.9.1 Timescale and regulatory approach

The speed at which changes can be made would depend upon the existing policy framework: if there is an obligatory network access policy regulation in place in the concerned country, any environmental benefits could be felt relatively quickly. This would not only be important to facilitate network sharing but ensure effective competition in the market. In the UK, the Communications (Access to Infrastructure) Regulations 2016 provide the guidelines for telecommunications and utilities to share physical infrastructure. In 2020, DCMS released a policy paper seeking stakeholder opinion to further improve infrastructure sharing in the UK.[248]

In terms of spectrum sharing, while the UK has an existing policy framework, this is more about spectrum sharing via local licensing and not sharing between the MNOs. The latter is likely to reduce network duplication to induce positive environmental impacts. The former, on the other hand, has a potential to induce positive enablement effect through various verticals as discussed under the 5G section. The UK currently allows a shared access licence in four mobile spectrum bands – 1800 MHz (1781.7 to 1785 MHz paired with 1876.7 to 1880 MHz), 2300 MHz (2390 to 2400 MHz), 3800 to 4200 MHz and 24.25 to 26.5 GHz. While this is a useful beginning, spectrum sharing between the MNOs could be expanded as it has the potential to have significant environmental benefits through more efficient use of the spectrum and reduced equipment rollout.[249]

In addition to the environmental benefits, network sharing can facilitate competition by allowing new entrants. However, in some cases it may reduce competitive pressure in the market and raise the risks of a collusive outcome, which might affect prices and service quality. These are the factors which Ofcom would need to carefully consider while framing its network sharing policy for the MNOs.

The switch-off of legacy services can occur over long periods of time. In the UK, an industry report has recommended for the 2G services to be switched off sometime in the 2030s. This is because elderly and rural population still use the voice and text being provided on 2G network, the M2M applications (such as smart meters) are deployed on the 2G network and the emergency eCall system (which connects vehicles to national emergency services in the event of an airbag deployment) uses 2G services. Specifically on smart meters, the smart meter rollout programme in the UK is expected to be completed by 2025 and it relies on the 2G/3G networks for communications. The smart meters are expected to have a life span of 15 years, which means that 2G connectivity in the UK might be needed until 2039.[250]

While legacy network switch off can be economically advantageous for the operators because of potential new sources of revenue and the possible environmental benefit that could be accrued, it can take time for the regulator to implement it because of other social or legacy dependency (as in the case of smart meters) concerns. This suggests that Ofcom would need to balance all these parameters when making a decision on service switch off.

4.9.2 Cost implications

As network sharing will reduce network duplication it will also save some financial costs for the operators. However, this is not a straightforward calculation, as increased traffic over certain equipment may mean larger power requirements or additional capacity.

[248] DCMS,Review of the Access to Infrastructure Regulations - call for evidence, 2020. Available at: https://www.gov.uk/government/publications/review-of-the-access-to-infrastructure-regulations-call-for-evidence/review-of-the-access-to-infrastructure-regulations-call-for-evidence

[249] Ofcom, Shared access licences, 2019. Available at: https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/shared-access

[250] Real Wireless, The Potential Impact of Switching off 2G in the UK, 2019. Available at: https://www.real-wireless.com/the-potential-impact-of-switching-off-2g-in-the-uk/

4.10 Switching off legacy networks

There are a large number of legacy spectrum users in all areas, including fixed links, business radio networks, and broadcast systems. In most cases newer technologies exist that can reduce power consumption or other environmental impacts; it would therefore be ideal for this legacy equipment to be replaced. However, it is not realistic to expect all spectrum users to invest in this way. Instead, policy should focus on large network users.

Mobile networks

The latest mobile technologies are expected to be more energy efficient than older mobile technologies. For example, in case of mobile networks a joint study between Telefonica and Nokia, which focussed on the power consumption of the RAN, found that 5G networks can be up to 90 per cent more energy efficient per traffic unit.[251]

However, as described in the option for 5G adoption above, deployment of any new mobile technology involves manufacturing additional network equipment which in turn is likely to increase emissions. Further, the method used to dispose of old equipment is critical. Incineration and landfill are likely to have higher emissions in comparison to a more circular economy-based methods like reuse/recycle/repair. According to a UN report, e-waste now is the fastest growing domestic waste stream.[252] As of 2019, UK was the second highest e-waste producing country per capita, after Norway.[253]

TV and radio broadcasting

As indicated by the existing research, the bulk of energy consumption and carbon emissions come from the consumer end in the form of TV sets, set-top boxes, radio receivers, and smart speakers.[254] To the extent that spectrum policy can directly impact on the means of distribution of TV and radio broadcast services, there will also be a significant downstream impact on consumption of broadcast TV and radio services, particularly in the context of switching off legacy networks or technologies. However, the implications of such a move in terms of its environmental, economic and other wider public policy impacts can be complex and will need further study.

From the broadcast TV perspective, historic developments of broadcast technologies means that TV viewership is spread over multiple platforms in the UK – DTT, cable, satellite, and IP delivery. In general platform operators should have the commercial incentives to adopt the most advanced technologies and switch off legacy networks in order to optimise energy consumption as these lead to reduced energy costs. In practice however, there could be market and regulatory factors which may hinder such moves, for example a transition from Digital Video Broadcasting Terrestrial (DVB-T) to DVB-T2.[255] Broadcast TV platforms, particularly those carrying public service broadcasting (PSB) are subject to strict quality and coverage requirements to ensure near-universal coverage.[256]

Similarly, broadcast radio services in the UK today are still distributed over analogue (FM/AM) and digital platforms (DAB, DTT and IP). The recent BBC radio study found the most energy intensive platform (in terms of mean energy per device-hour) was DTT followed by AM, with the distribution accounting for the majority of the

[251] ISP review, 5G Mobile Networks up to 90 per cent More Energy Efficient Than 4G, 2020. Available at: https://www.ispreview.co.uk/index.php/2020/12/5g-mobile-networks-up-to-90-more-energy-efficient-than-4g.html

[252] AA, Global e-waste surges 21 per cent in 5 years, 2020. Available at: https://www.aa.com.tr/en/environment/global-e-waste-surges-21-in-5-years-un-report/1897694

[253] Edie, In charts: How big is the UK's waste mountain - and what are we recycling?, 2019 Available at: https://www.edie.net/library/In-charts--How-big-is-the-UK-s-waste-mountain---and-what-are-we-recycling-/7046#:~:text=According%20to%20the%20body's%20Global,capita%20was%20the%20global%20average.

[254] Schien et al. (2020) and Fletcher and Chandaria (2020).

[255] For more details, see: https://plumconsulting.co.uk/2318/

[256] For more details, see: https://www.ofcom.org.uk/consultations-and-statements/category-2/broadcast-tv-technical-codes

AM platform's energy consumption. From the environmental perspective, it would appear there is a case for switching off legacy analogue radio broadcast transmission. On the other hand, there are also other policy considerations that need to be taken into account as reflected in the government's July 2020 decision on the analogue radio licence renewals.[257]

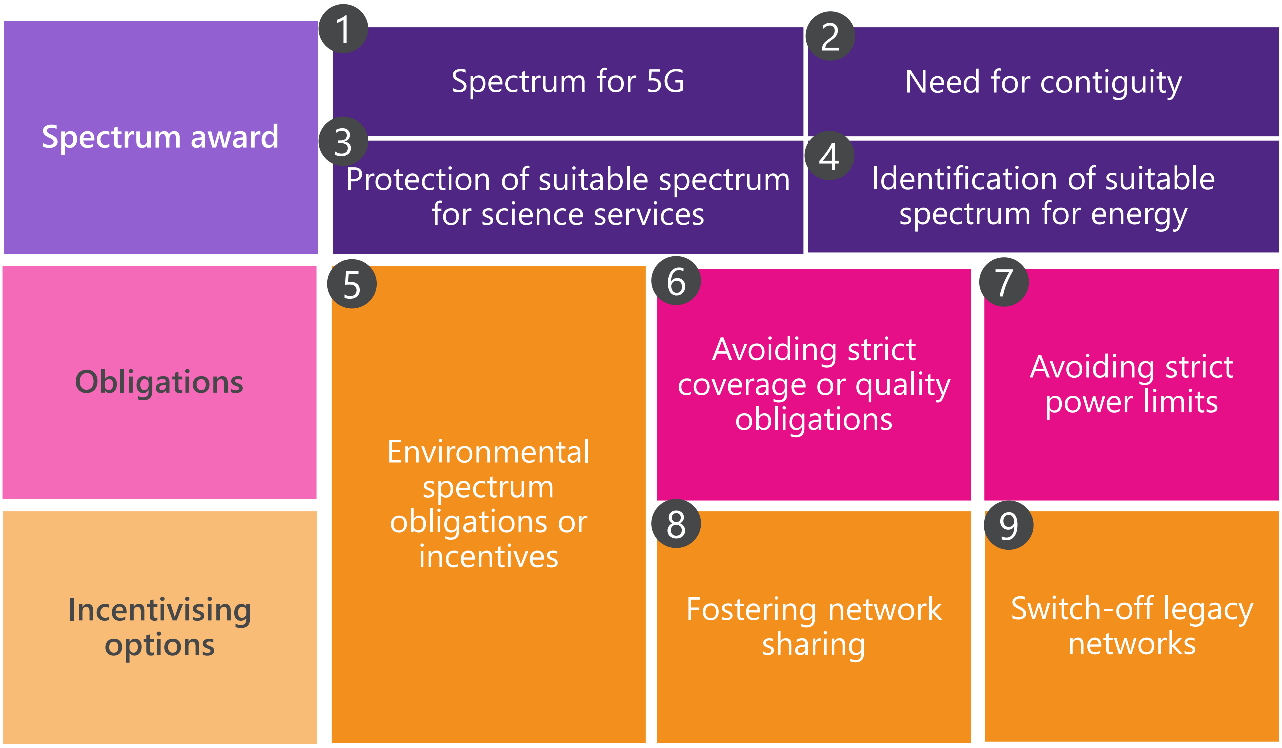
[257] In July 2020 it was announced by the government that analogue commercial radio licences which are due to expire from 2022 would be renewed for a further 10 years. It was noted the analogue radio accounted for around 40 per cent of radio listening and remain an important platform for the next few years. The continuation of analogue radio till end of the decade and beyond would help provide long-term security for local stations to plan and develop services for the move to digital. https://www.gov.uk/government/consultations/consultation-on-the-renewal-of-analogue-commercial-radio-licences/outcome/further-renewal-of-analogue-commercial-radio-licences-consultation-response

5 Comparative assessment of spectrum policy options

5.1 Methodology

As mentioned in the previous section, the options in the figure below have been formulated from our on current literature and our discussions with industry stakeholders.

Figure 5.1: Spectrum policy options to combat climate change



Source: Plum analysis

These options have been grouped under three categories: spectrum award, obligations, and incentivising options. In the previous section we have discussed the potential scale of these impacts, and the speed at which they may be felt. In order to develop clear recommendations on how policy should be prioritised, it is necessary to rank these policy options.

Given the lack of quantitative data on all these options, our ranking focusses on two criteria:

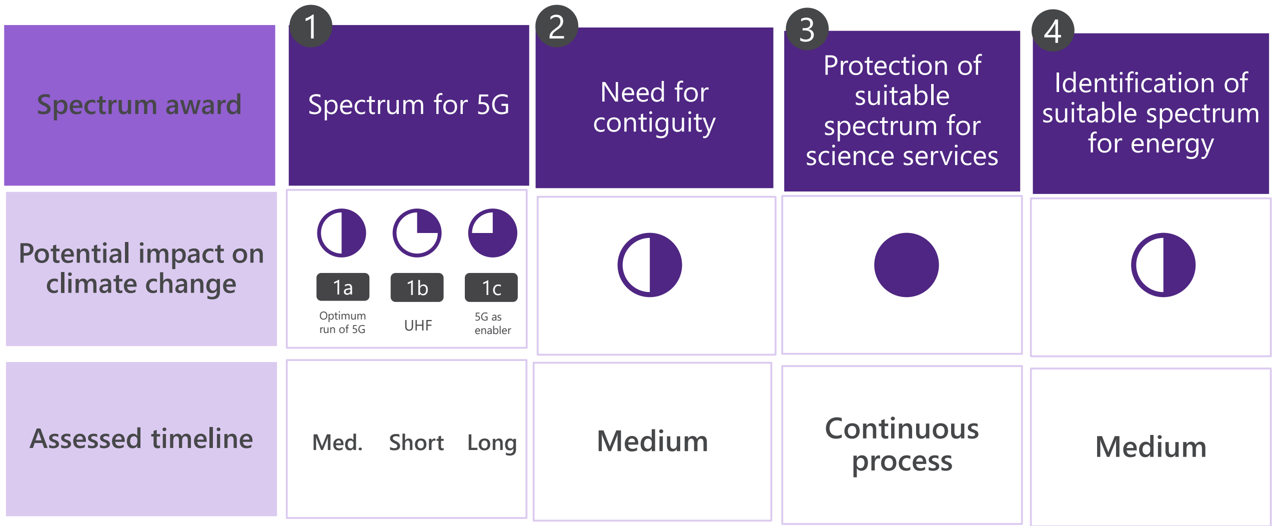
- Potential impact on environment at country level (also based on the extent of the implementation, whether it would affect a large or a small area); and
- Timescale (as assessed to implement the policy option and see its impact).

Based on the discussion described in Section 4, a qualitative discussion-based assessment has been agreed for each option. One caveat must be raised here: the net impact of each option is difficult to assess because of the lack of quantitative data and because the impact would be based on multidimensional models and numerous interactions. In each category, the potential impact on the environment has been assessed for each option compared relative to the others, and has been rated as low, medium, high or very high. The timeline has been rated as short-term, medium-term, or long-term, as well as continuous process for one of the options.

5.2 Spectrum award options

Option number 3 has been considered as having the biggest potential impact due to the critical mission of science services regarding the climate, followed by 5G as an enabler for IoT and by the identification of spectrum for the energy sector.

Figure 5.2: Spectrum award policy options



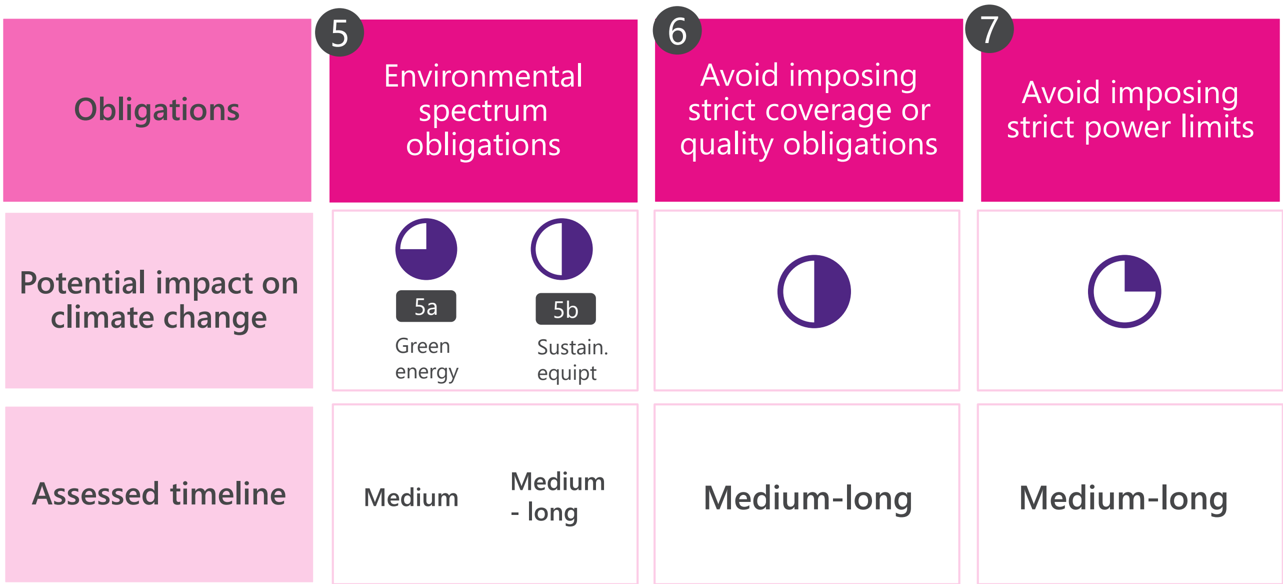
Source: Plum analysis

For Policy option number 1, we have considered the three aspects of policy – amount of spectrum, availability of UHF spectrum, and use of 5G by IoT – as separate issues. Of these, the long-term impact of having comprehensive IoT technologies is likely to have the largest impact.

5.3 Obligations options

Policy option number 5 is split between obligations and incentives as there are a number of ways it could be implemented. Within this policy option, as discussed in Section 4, we have considered the impact of green energy sources and sustainable equipment. Requiring stakeholders to use green energy (option number 5a) would have the highest impact in this category and could be achieved in the shortest timeframe. On the other end of the scale, a policy choice to avoid strict power limits has been considered as having a low potential impact, as it does not look to be a significant barrier on the UK market.

Figure 5.3: Obligations options

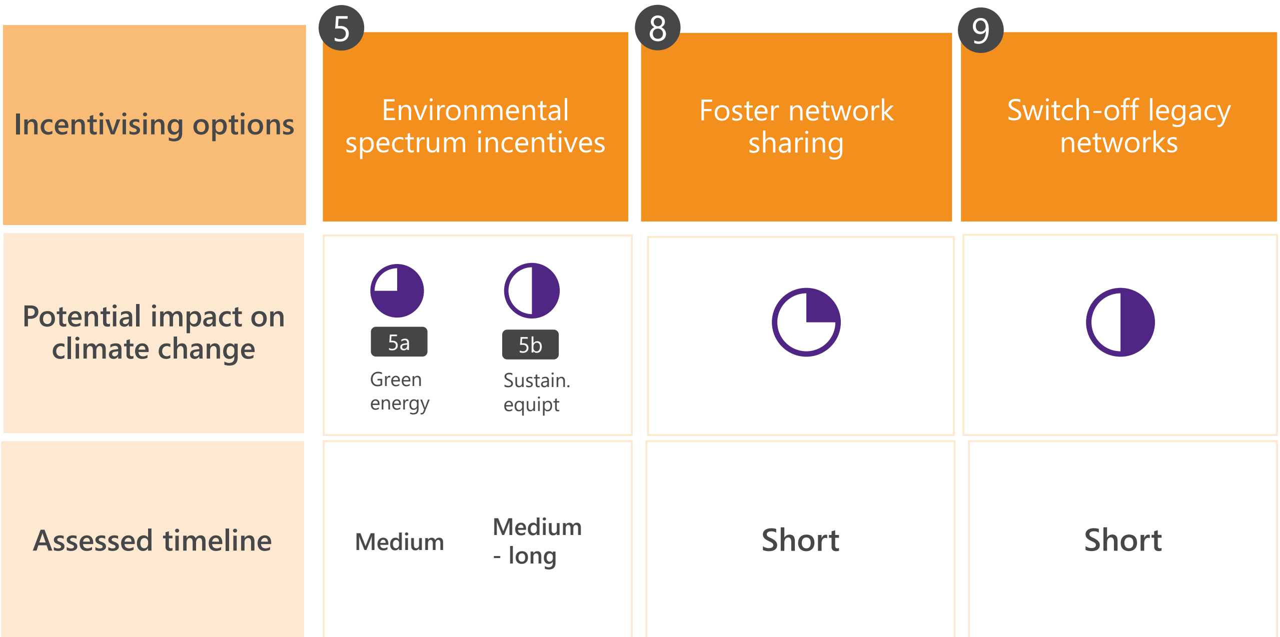


Source: Plum analysis

5.4 Incentivising policy options

Incentivising market players in using green energy (option number 5) is predicted to have the highest impact in this category. Overall, there seems to be a relatively low potential impact on climate change of these incentivising polices, although switching off legacy networks may have a noticeable impact in a relatively short timeframe.

Figure 5.4: Incentivising options

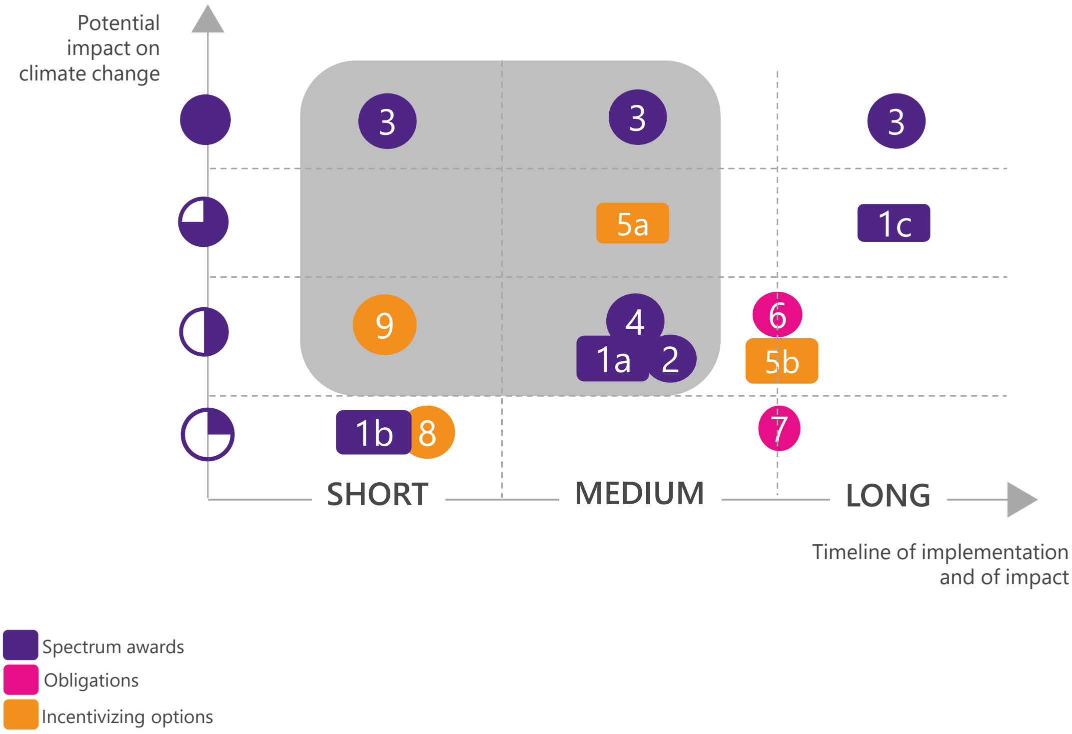


Source: Plum analysis

5.5 Ranking spectrum policy options to combat climate change

The options set out above have been placed on a diagram (Figure 5.5). From this it is clear to see those policy options which may lead to noticeable impacts in a reasonable timeframe.

Figure 5.5: Ranking options



Source: Plum analysis

Options with short-term and medium-term timelines, combined with at least medium impact on climate change, are considered to be the highest priority – represented by the grey square in the chart. These help to form our recommendations, as set out in the next section.

6 Key recommendations for spectrum policy to tackle climate change

This section presents our recommendations. These recommendations have been based on the research conducted to assess different spectrum policy options that would potentially contribute to address climate change issues. They aim at being reasonable and feasible approaches, as well as preferably short-term to medium-term.

Recommendations from Section 6.3 to Section 6.8 are our initial spectrum policy recommendations. But before any policy decisions are made, a full regulatory impact assessment is needed.

6.1 The regulator must have environmental impact responsibilities

We have described in Section 4.1 how the role of Ofcom, as regulator in the UK, is defined strictly in terms of its obligations and duties. Currently there is no requirement, or indeed, allowance for Ofcom to take account of environmental impact during its regulatory procedures. This is common with a large number of regulators around the world.

In June 2020, the French regulator Arcep launched an open consultation called "*achieving digital sustainability*" and invited all market stakeholders to contribute to it, acknowledging that the ICT sector "*must join the low-carbon strategy [of government] without having to give up business and innovation opportunities*" and that "*everyone must be responsible for achieving low-carbon technologies*" including "*public policymakers*" and "*the regulator*" [258]. The consultation resulted in the publication of a report in December 2020 with 11 recommendations (see Appendix E of this document for detailed recommendations).

A legislative proposal was recently introduced[259] to give power to Arcep regarding climate issues, particularly by enabling Arcep to establish an environmental barometer of digital market players. This is in line with the environmental strategy of government whose first axis is to "*measure, to get to know in order to act better*"[260]. Arcep's objective is to make environmental issues a new chapter of regulation, working in sync with France's Environment and Energy Management Agency (ADEME). According to our research, Arcep is the most advanced ICT regulator on the issue of climate change (at the international level, it is worth noting that BEREC has started tackling the issue too).

This is consistent with the recommendations of the NIC in the UK, which has recommended:

> **"Ofcom, Ofgem and Ofwat should have new duties to promote the achievement of net zero by 2050 and improve resilience."**

In its spectrum management strategy for 2020, Ofcom notes: "*Environmental concerns will continue to change how people and businesses behave, and the economy, as the UK moves towards its 2050 greenhouse gas net zero target. There will likely be increasing focus on low-power communications services to reduce overall energy consumption. Manufacturers will look to make equipment more durable and recyclable. Spectrum will become more important in enabling other industries to reduce their environmental impact such as through asset*

[258] Arcep, Press release, 15 December 2020. Available at: https://en.arcep.fr/news/press-releases/view/n/the-environment-151220.html
[259] Numerama, article in French, 21 September 2021. Available at: https://www.numerama.com/tech/741090-le-gendarme-des-telecoms-aura-peut-etre-son-sifflet-pour-reguler-leffet-du-numerique-sur-le-climat.html
[260] French Ministry of Ecological Transition, 1 October 2021. Available at: https://www.ecologie.gouv.fr/feuille-route-numerique-et-environnement

monitoring, smart utilities management or climate monitoring. Climate changes could also result in changes to how signals propagate, affecting the risk of interference between spectrum users."[261]

Our research has shown that each category of stakeholders logically represents its own interests and approaches the climate issue from its own prism. A more systematic approach is needed for a broader view that will enable the ICT sector to tackle the climate issue.

Spectrum policy options discussed in this report and those recommended below would be applicable depending on the role of Ofcom in climate issues. Like most of telecommunications regulatory bodies, Ofcom currently does not have any specific responsibility related to climate change. Extending Ofcom's scope of activities to climate change and environmental impact would foster the national industry's momentum towards monitoring climate change.

6.2 A measurement and monitoring regime is required to help with regulation

As stated in Section 2.3 of the report, there is a lack of transparent and harmonised data on the net environmental footprint of the ICT sector. BEREC raises the "*lack of common methodology between studies as well as challenges around data availability*" on that matter[262]. Some private initiatives have been launched (Section 2.4) but on an aggregate national basis, there is a gap that may prevent monitoring of progress.

This recommendation directly relates to the first one. Collecting data from stakeholders and building relevant indicators will:

- Help with assessing and monitoring progress made by the industry on the climate subject;
- Encourage emulation between market players; and
- Enable detailed modelling to be able to compare the impact of different spectrum policies.

This data collection should be done by a public authority - the telecommunication regulator appears as the most relevant one to be able to do so – and made publicly available.

6.3 Science services spectrum must be protected

The critical role of weather forecasting, climate monitoring and earth observation makes it important to ensure that science services' spectrum is being protected.

This spectrum policy option has been applied so far and does not require any specific deeper research. Nevertheless, the key position of science services – as it has been detailed in Sections 3 and 4 of the report – makes the need for continued protection of the frequencies used for atmospheric sensing and meteorological services very important to tackle climate change issues.

[261] OFCOM, Supporting the UK's wireless future, December 2020. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0027/208773/spectrum-strategy-consultation.pdf
[262] BEREC, Summary report on BEREC sustainability, March 2021, available at: https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/9883-summary-report-on-berec-sustainability-eng-workshops-sustainability-within-the-digital-sector-what-is-the-role-of-berec

6.4 Spectrum users should be compelled to use green sources of energy

Regulatory guidelines (binding or non-binding) for stakeholders on shifting to renewable sources of energy could be an option the regulator might consider. A detailed assessment would consider for instance the current energy mix of the operators, access to renewable options, scalability of off-grid options and associated construction clearances, financial implications, and potential timeline. Where operators are already using green energy sources, there may be no need for regulatory intervention.

This recommendation relates to our second recommendation ("*A measurement and monitoring regime is required to help with regulation*"), as the first step to the assessment would be to ask operators to report their energy-related metrics. This recommendation also relates to recommendation number 6 ("*Suitable spectrum for energy should be identified*"), as it relies on the development of green energy and the efficiency of the energy sector.

6.5 Legacy networks should be switched off when feasible

Because the latest mobile technologies are expected to be more energy efficient than older technologies, the closure of legacy networks has been considered as a position option to combat climate change, and has started in many countries, including the UK. On the other side, deployment of any new technology involves manufacturing of additional network equipment which in turn is likely to increase emissions. Further, the related data consumption increase has the potential to offset any positive environmental benefit at the network level by shifting to more advanced mobile technologies like 5G.

Further studies would need to be undertaken to understand and monitor the switch-off of legacy networks in the different telecommunications sectors.

6.6 Suitable spectrum for energy should be identified

As it is the case for science services, the energy sector appears to be a key driver for combating climate change through the development of green energies, as well as it is the vertical sector needed to operate all other verticals. The mission-critical role of this sector is illustrated by the heavily regulated penalties it must pay in case of breakdowns. Therefore, we would recommend spectrum policymakers consider a specific approach for the energy sector to enable it to tackle the different challenges it faces.

This approach does not necessarily mean reserving specific spectrum for the energy sector. It may be more efficient for this industry to use part of the mobile networks through spectrum and network slicing, providing that this provides suitable reliability and resilience.

Although we know that Ofcom has been working on this topic and has investigated what is being done in other countries, we would recommend accelerating the process and studying counterfactual of a national energy sector with dependency on commercial networks and their evolution (4G to 5G to 6G).

6.7 Sufficient spectrum should be provided to keep the number of mobile sites low

Deployment of more radio spectrum instead of additional physical sites to increase network capacity would have a positive environmental impact since it would require less production of equipment, a lower deployment footprint, and lower power requirements (with fewer sites needing air conditioning, computation power, and so on). Reportedly, 60 per cent-80 per cent of the entire mobile network energy consumption is due to base stations.[263] This suggests that reducing the number of base stations can have a significant impact on reducing the energy consumption and resultant emissions of the network. However, reducing the number of base stations may require a greater power use for transmission so that the coverage area can remain the same.

Further studies would need to be undertaken to understand how these power needs would compare.

6.8 Spectrum should be awarded in contiguous blocks

When assigning spectrum between services and between operators, regulators must take account of previous use and the existing band plans. Where part of a band has already been assigned, this can lead to spectrum users being awarded several smaller lots. While these non-contiguous blocks can be used, it is often significantly less efficient in terms of both cost and environmental impact. However, there is considerable scope for minimising inefficiencies associated with non-contiguous spectrum. Moreover, even if mobile networks supported by contiguous spectrum might be more energy efficient, it might not be easy to reduce the fragmentation in the spectrum assignments.

Ofcom is considering whether spectrum trading may allow for the market to resolve this issue, but it is unclear whether there would be a sufficient incentive for operators to work together and agree to a solution.

[263] Nalapatla S.R. and Mamidala, S.R.., Literature review on Energy Efficiency of Base Stations and Improving Energy Efficiency of a network through Cognitive Radio, 2012, Available at: http://www.diva-portal.org/smash/get/diva2:831382/FULLTEXT01.pdf

Appendix A ITU complementary studies on circular economy

This appendix presents a list of some other relevant studies by ITU-T SG5 on promoting circular economy in the ICT sector.

- The ITU L.1031 (Guideline for achieving the e-waste targets of the Connect 2030 Agenda, 2020) describes an approach to achieve the e-waste targets as set in the Connect 2030 Agenda. These steps include guidelines on approaches to design e-waste prevention and reduction programmes, developing an e-waste inventory, amongst others. The intent of the recommendation is to catalyse the achievement of Target 3.2 of the Connect 2030 Agenda i.e., to achieve the target of 30 per cent global e-waste recycling and raise the percentage of countries with e-waste legislation to 50 per cent[264].

- The ITU L.1023 (Assessment method for circular scoring, 2020) provides an assessment method for circularity scoring of ICT goods based on circular product design which would be determined by factors like product durability, ability to recycle, repair, reuse.[265]

- The ITU L.1022 (Circular economy: Definitions and concepts for material efficiency for information and communication technology, 2019) – provides the guidelines for circular economy parameters, metrics, and indicators for ICT.[266]

- The ITU L.1000-L.1007 (studies on universal power adapter, 2016-2019): these studies emphasise on the avoidance of duplication of raw material and waste in the production of power adapters for various different uses, as such reducing excess energy consumption.[267]

- The ITU L.1021 (Extended producer responsibility – Guidelines for sustainable e-waste management, 2018): establishes guidelines and recommendations for the development of extended producer responsibility (EPR) polices for sustainable e-waste management.[268]

- The ITU L.1030 (E-waste management framework for countries, 2018): provides different steps that countries could adopt so as to put in place an e-waste management system. These include: compiling an inventory of e-waste, ensuring availability of public funds to promote cooperation among ministries and enforcement agencies and defining incentives for adequate collection, amongst other steps.[269]

- The ITU L.1010 (Green battery solutions for mobile phones and other hand-held information and communication technology devices, 2014): Recommendation defines a minimum set of parameters (based on eco-design principles) which are necessary to identify green battery solutions. These could be considered by developers/manufacturers to reduce the future environmental impact of battery use. Green batteries reduce the global resource consumption, extend the lifetime of handsets.[270]

[264] ITU, Guideline for achieving the e-waste targets of the Connect 2030 Agenda, 2020. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14572
[265] ITU, Assessment method for circular scoring, 2020. Available at: https://www.itu.int/rec/T-REC-L.1023-202009-I
[266] ITU, Circular economy: Definitions and concepts for material efficiency for information and communication technology, 2019. https://www.itu.int/rec/T-REC-L.1022-201910-I
[267] ITU-T, Recommendations under Study Group 5 responsibility L Series 1000-1007, 2016-2019. Available at: https://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5
[268] ITU, Extended producer responsibility - Guidelines for sustainable e-waste management, 2018. Available at: https://www.itu.int/rec/T-REC-L.1021-201804-I
[269] ITU, E-waste management framework for countries, 2018. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13577
[270] ITU, Green battery solutions for mobile phones and other hand-held information and communication technology devices, 2014. Available at: https://www.itu.int/rec/T-REC-L.1010-201402-I

- The ITU L.1060 (General principles for the green supply chain management of information and communication technology manufacturing industry)[271] This Recommendation notes the definition of a Green Supply Chain as the '*effective use of resources and energy along the supply chain in each link and intersection*' and outlines the GSC requirements for ICT products. The objectives require the development of policies in areas including the control of raw materials to ensure environmentally friendly derivation, green logistics, minimising energy used in transport and after-sales services, including recycling.

[271] ITU, General principles for the green supply chain management of information and communication technology manufacturing industry, 2021. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14717

Appendix B GeSI – Assessing GHG emissions from ICT goods and services[272]

GeSI has published a practical methodology to calculate the GHG emissions from ICT goods and services. The report can be downloaded here: https://www.gesi.org/research/ict-sector-guidance-built-on-the-ghg-protocol-product-life-cycle-accounting-and-reporting-standard

The report[273] provides the guidance for calculating the carbon emissions of ICT sector products and services, with an emphasis on the latter. The methodology for the guidance is based on GHG Protocol Product Standard[274]. This guidance is different to ITU L.1470 and GeSI's 2020 report (summarised above) providing guidelines for calculating ICT sector emissions, both of which do not look at the services and in products only look at user devices. Another difference is that this guidance does not provide any reduction trajectories or targets as such but also methodology of how to calculate the emissions and enablement potential of certain ICT goods and services.

The guidelines were developed by a 15 person steering committee and a working group of over 50 members representing ICT companies, government, NGOs, industry analysts, standards development organisations and academic institutions. The stakeholder advisory group consisted of more than 350 participants from over 45 countries.

The categorisation of the products and services is based on the Product Standard which defines both goods and services as products. In this guidance products include both networks and software as ICT services. The different services and products that the report looks and as they name it include:

- Telecommunications Network Services: Includes all technology telecom networks. For example – mobile, fixed, satellite, private and submarine networks;
- Desktop Managed Services (DMS): includes computing facilities, usually in a corporate environment. For example: equipment like desktops, laptops, printers, local area network (LAN), wide area network (WAN), supporting human services (like help desk). The guidelines note that DMS account for a large part of ICT outsourcing market and a major portion of the ICT emissions.
- Cloud and Centre services: Refers to cloud and data centre service providers;
- Hardware: for example, wireless router, Universal Mobile Telecommunication system (UMTS) base transceiver station (BTS);
- Software: for example, operating systems, applications, and virtualisation;
- Transport substitution: Provides an approach to study the ICT's role in reducing carbon emissions through teleconferencing and telecommuting.

[272] GeSI, ICT sector guidance built on GHG Protocol Product Life Cycle Accounting and Reporting Standard, 2017. Available at: https://gesi.org/public/research/ict-sector-guidance-built-on-the-ghg-protocol-product-life-cycle-accounting-and-reporting-standard
[273] Ibid.
[274] Greenhouse Gas Protocol, 2011, Product Life Cycle Accounting and Reporting Standard. Available at: https://ghgprotocol.org/sites/default/files/standards/Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf

Overall, the methodology compares the baseline or the business-as-usual scenario with the ICT-enabled scenario to calculate (if any) benefit from the ICT-enabled solution in reducing the GHG emissions. This includes calculating the emissions in three categories:

- ICT product emissions: life cycle emissions of the ICT solution (potential causing enablement effect);
- Enabling effects: avoided emissions because of not conducting certain resource extensive activities because of the ICT solution; and
- Rebound effects: any increase in emissions because of higher use of the ICT solution compared to the baseline scenario.

Appendix C ITU guidelines to ICT sector emissions

The ITU study L.1470 (2020)[275] estimates the GHG emission reduction trajectories for the global ICT sector and sub-sectors for the years 2020, 2025 and 2030, using 2015 base line emissions. Supplement to L.1470 (2020)[276] specially looks in detail into the reduction trajectories of sub-sectors like mobile networks, fixed networks, and data centres. The recommended trajectories are in line with the 1.5°C objective target emissions as described in the IPCC report[277] and use the methodology of a previous ITU-T study L.1450[278] and Science-based Targets (SBT) initiative. The methodology deployed in L.1470 used two approaches referred to two as Perspective A and B respectively in the study. Former is based on a life cycle-based carbon footprint of the ICT sector while the latter is not, specially it does not account for the emissions related to the electricity supply (ES) chain and grid losses associated with the use of electricity in the ICT sector. [279] Figure 1 below lays out the emission targets for different years by sub-sector for both Perspective A and Perspective B.

Figure C.1: ICT sector trajectories (CO_2e) (Mt)

ICT sub-sectors	2015	2020	2025	2030
Perspective A (including electricity grid losses)				
Mobile networks	115	109	92	70
Fixed networks	67	59	42	27
Data networks	141	127	104	79
User devices	401	379	284	207
Enterprise networks	16	14	8	5
Total	**740**	**687**	**530**	**388**
Perspective B (including electricity grid losses)				
Mobile networks	98	94	79	59
Fixed networks	55	49	35	22
Data networks	116	104	84	60
User devices	335	317	241	174
Enterprise networks	13	12	6	4
Total	**617**	**576**	**445**	**319**

Source: ITU-T L.1470

We can see from Figure C.1 above that user devices as a sub-sector emit the highest share of emissions, followed by data centres, mobile networks, fixed networks and lastly the enterprise networks. As expected, the

[275] ITU, Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement, 2020. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14084
[276] ITU, Guidance to operators of mobile networks, fixed networks and data centres on setting 1.5°C aligned targets compliant with Recommendation ITU-T L.1470, 2020. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14318
[277] IPCC, Global warming of 1.5°C, 2019. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf
[278] ITU, Methodologies for the assessment of the environmental impact of the information and communication technology sector, 2018. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13581
[279] ITU, Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement, 2020.

figure also shows us that Perspective A emissions (that account for electricity grid losses are higher than Perspective B, that don't.

Most recently, ITU is working on L.1471 that would aim to provide guidance on setting net zero targets and strategies.[280]

In addition to sub-sector level guidelines, study L.1460 focuses bottom up i.e., in reducing the emissions per device in line with The Connect 2020 global initiative that aims to decrease the GHG emissions per device by 30 per cent, compared to the baseline year (yet to be defined). Examples, of potential actions for stakeholders suggested in the study are[281]:

- Improving the energy efficiency of the ICT goods, networks, and services through activities such as developing free cooling for the operation of data centres, consolidation, and virtualization of servers, applying power saving features, equipment sharing between operators, developing energy efficient of software;

- Enhancing the circularity of the sector with activities like promoting the eco-design of ICT goods, networks and services and their associated packaging, enhancing the reuse, reassembly, and recycling of products;

- Increasing the usage of renewable energy including on-site off-grid generation of energy by the sector members (where possible); and

- Actions to increase knowledge and awareness among the ICT sector and society at large on GHG emissions and circular economy stakes of the ICT sector.

[280] ITU, Study L.1471 Guidance and criteria for ICT organisations on setting Net Zero targets and strategies, September 2021. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=14720
[281] ITU, Connect 2020 greenhouse gases emissions – Guidelines, 2020. Available at: https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=13582

Appendix D Approach to the energy sector

This Appendix provides complementary information on the energy sector. Its first section provides an explanation on the role of smart grids in energy supply, the second part describes the case of Ireland, which has specific spectrum access to the energy sector.

D.1 The changing energy supply dynamic and the critical role of 'smart grid'

In common with other developed economies around the globe, the UK has a largely 'dumb' energy network – especially with regards to lack of intelligence and visibility towards the periphery of the networks. In the 20th century it was perfectly adequate to use static design criteria for the majority of the network – building infrastructure for a highly predictable, unidirectional peak energy flow. The evolving energy network of the future will make these previous design assumptions comparatively useless when needing to accommodate real time dynamic monitoring and control of fixed energy infrastructure assets.

In order to have reliable, cost effective, low cost zero carbon energy networks. it is anticipated that 'big data' analytics, AI and machine learning will play a major role in ensuring the dynamic control of a massive amount of energy sector plant. However, a prerequisite for this to happen is the need for highly reliable, cybersecure connectivity between all of the active devices in the network. Without this connectivity (including resilience to power blackouts) there can be no meaningful transition towards a full smart grid and in turn the decarbonisation of the energy sector cannot be fully achieved.

The most cost-effective manner to reliably connect a large number of smart devices is via wireless means, which requires the allocation of a dedicated piece of radio spectrum.

- Smart Grid is the key enabler for a decarbonised energy sector. Without the smart grid a decarbonised energy sector becomes (i) less reliable (ii) more expensive (iii) more reliable on 'brute force' network reinforcements.
- In turn, connectivity is the key enabler for the smart grid. Without robust reliable connectivity to millions of embedded devices there can be no real-time monitoring and control of devices and energy sector decarbonisation will be severely restricted.
- The connectivity which is required for the smart grid can be most cost effectively delivered using wireless means. Hence, a dedicated radio spectrum award facilitated by appropriate radio spectrum policy is crucial to achieving the decarbonisation targets of the UK.
- Whilst other wireless technologies besides LTE have been considered, none of them offers the ecosystem and vendor support which is required by the energy utilities.

D.2 The approach adopted by ComReg in Ireland to enable spectrum access

It is worth reflecting on the basis for the spectrum award in the Republic of Ireland with extracts[282] from the consultation process which resulted in the award reproduced below for ease of reference.

[282] ComReg, Further consultation on the release of the 410-415.5 / 420-425.5MHz sub-band, February 2018. Available at: https://www.comreg.ie/publication/further-consultation-on-the-release-of-the-410-415-5-420-425-5-mhz-sub-band/

3.27 Smart Grids are a key component of government efforts to meet demand for increased energy requirements in a cost effective and secure way while reducing the environmental impact of consumption and associated carbon emissions. Different functions of the Smart Grid could provide substantial reductions in energy use and carbon emissions by using new technology and making renewable energy and efficiency programs more affordable and potentially more accessible.

3.28 In particular, greater integration of renewable energy into electricity and gas grids is key to lowering the environmental impacts of generation and meeting climate change targets. For example:

- The ITU has outlined how Smart Grids can help to mitigate climate change by building more controllable and efficient energy systems;
- The United Nations (UN) has outlined that the demands of climate change requires the development of a Smart Grid which is founded upon communications networks that can deliver centralised real time monitoring and control, eventually across the entire power distribution domain.

3.29 A number of seminal international and national studies have estimated the potential carbon reductions arising from the use of Smart Grids:

- The Electrical Power Research Institute (EPRI) has estimated that Smart Grid enabled electrical distribution could reduce electrical energy consumption by 5 per cent to 10 per cent and carbon dioxide emissions by 13 per cent to 25 per cent;
- A smart electrical power grid could decrease annual electric energy use and utility sector carbon emissions by at least 12 per cent by 2030; and
- The Sustainable Energy Authority of Ireland estimates that by 2050, Smart Grids will see an accumulated reduction in energy related CO_2 emissions of 250 million tonnes.

3.30 At a European Level, the European Commission has been encouraging the use of Smart Grids in order to encourage more efficient energy generation and consumption. For example, under the Electricity Directive:

- "Member States should encourage the modernisation of distribution networks, such as through the introduction of smart grids, which should be built in such a way that encourages decentralised generation and energy efficiency.
- "In order to promote energy efficiency, Member States or, where a Member State has so provided, the regulatory authority shall strongly recommend that electricity undertakings optimise the use of electricity, for example by providing energy management services, developing innovative pricing formulas, or introducing intelligent metering systems or smart grids, where appropriate.

3.31 The European Commission has an existing policy framework for climate and energy from 2020 to 2030 which proposes new targets and measures to make the EU's economy and energy system more competitive, secure and sustainable. It includes targets for reducing greenhouse gas emissions and increasing use of renewable energies noting that "*the EU and Member States will need to develop further their policy* *frameworks to facilitate the transformation of energy infrastructure with more cross-border interconnections, storage potential and smart grids to manage demand to ensure a secure energy supply in a system with higher shares of variable renewable energy*".

3.32 In that regard, at a national level the Department of Communications, Climate Action and Environment is currently developing a National Energy and Climate Plan (NECP) as one of the key provisions of the proposed Governance of the Energy Union Regulation. The plan, which is due to be submitted to the European Commission by the end of 2018, will include trajectories for renewable energy, energy efficiency, and national emissions, and measures required to achieve these trajectories. The plan must set out how Ireland is going to achieve targets on reducing carbon emissions and increasing renewable energy up to 2030. The then Minister for Communications, Climate Action and Environment, Denis Naughten T.D noted that this will be facilitated by existing work streams such as the National Development Plan (NDP). The NDP includes measures such as Smart Grid to transition to a low-carbon economy.

3.33 Such requirements are also broadly in line with State policy to encourage the provision of Smart Grid and other related technologies. For example:

- The Project Ireland 2040 National Planning Framework promotes a transition to a low carbon energy future which requires decisions around development and deployment of new technologies relating to areas such as wind, smart grids, electric vehicles, buildings, ocean energy and bio energy.

- It also commits to a roll-out of the National Smart Grid Plan enabling new connections, grid balancing, energy development and micro grid development.

- The Department of Communications, Climate Action and Environment National Mitigation Plan observes that smart operation of the power system at both transmission and distribution level and energy efficiency will enable maximisation of the existing grid.

- The National Development Plan 2018-2027 foresees the piloting of "*climate smart countryside*" projects to establish the feasibility of the home and farm becoming net exporters of electricity through the adaptation of smart metering, smart grids and small-scale renewable technologies, for example, solar, heat pumps and wind.

- The Sustainable Energy Authority of Ireland "*Smart Grid*" Roadmap to 2050 notes that Smart Grid can maximise our use of indigenous low carbon renewable energy resources which is central to ensuring Ireland meets its long-term target of a secure and low carbon future.

This strategic intervention by ComReg and the Irish government to acknowledge and facilitate spectrum access for Smart Grid developments to address climate change objectives has been informed by a thorough appraisal of the changing energy supply-demand context. This context is not unique to the Republic of Ireland but is playing out across Europe. The German regulator[283] has enabled spectrum access in the 450 MHz range to

[283] BNetza, 450MHz, 2020. Available at: https://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/450MHz/450MHz-node.html;jsessionid=F1446C4044B718A668BDC23941A861B8

facilitate the Energy Transition, whilst in the UK there is an ongoing study underway by Ofcom to consider the spectrum access needs of the UK Energy Utilities.

Appendix E Arcep's proposals to combine increasing use of digital tech and decreasing its environmental footprint[284]

This Appendix details the eleven proposals formulated by Arcep, the French regulator, to take concrete actions and combine an increasing use of digital technologies with a reduction of the sector's environmental footprint.

Strand 1: strengthen public policymakers' capacity to steer digital technologies' environmental footprint

- Entrust a public entity with the power to collect useful information from the entire digital ecosystem (content and application providers, operating system developers, device manufacturers and datacentre operators, in addition to electronic communications operators for which this type of mechanism already exists) to be able to obtain granular and reliable data that is crucial to assessing and monitoring the sector's environmental footprint, and the measures that have been implemented;
- As part of its initiatives with ADEME, participate in the creation of a common frame of reference for measurement: Improve measurement to better identify the issues, compile data to keep users informed and foster a virtuous dynamic in the sector.

Strand 2: incorporate environmental issues into Arcep's regulatory actions

For fixed access:

- Facilitate the transition from copper to fibre;
- Encourage network optimisation by promoting civil engineering infrastructure and fibre infrastructure last drop (access network) sharing schemes;
- Encourage initiatives designed to implement automatic sleep mechanisms in operators' boxes, at certain times of the day or when not being used for long stretches of time.

For mobile access:

- Achieve more detailed analysis of the positive and negative impact of switching off 2G and 3G networks, to lift potential barriers and ensure that the right incentives are put into place. European regulation on in-vehicle emergency calls (e-call) warrants in-depth examination, working in tandem with the government;
- Examine network performance indicators in 2021, to incorporate environmental issues in consumer choice parameters;

[284] Arcep, Press release, 15 December 2020. Available at: https://en.arcep.fr/news/press-releases/view/n/the-environment-151220.html

- Work with interested stakeholders to explore solutions for optimising mobile networks' medium and long-term environmental impact, focusing in priority on sharing issues and making the best possible use of frequencies;

- Develop, if appropriate, more detailed monitoring of operators' handset subsidy practices and their effects.

Strand 3: increase incentives for economic stakeholders, private and public sector stakeholders and consumers

- Work with interested stakeholders to draft Codes of conduct/charters to buttress green design, and which are capable of leading to the adoption of legally binding commitments, akin to electronic communications operators' regional digital development commitments, and commitments to cover the country's sparsely populated areas with electronic communications' networks (Art. L.33_13 of the French Postal and Electronic Communications Code (CPCE)). Notably:

  – content and application providers, particularly the largest, most influential ones (e.g. over best practices such as adapting content resolution to the device's screen, or limiting auto-play);

  – operating system developers, particularly the largest, most influential ones (e.g. over best practices such as maintaining older versions of their OS, or taking better account of obsolescence issues in updates);

  – datacentre operators (e.g. over best practices such as data centres' architecture, optimising cooling systems, or managing storage equipment…).

  Other proposals in line with this incentive-based approach are regularly put forth, such as introducing mechanisms designed to convey price signals that heavily affect content and application providers, e.g. regarding bandwidth use. This type of solution could be useful if codes of conduct fail and, in any event, warrant closer analysis.

  Compliance with codes of conduct must be monitored by a public entity with supervisory and, if applicable, sanctioning powers.

- Increase users' accountability and their ability to take action through a data-driven approach to regulation, fostering the emergence of tools for aiding consumers in making choices, and understanding their impact on the environment. Publish a "*Green Barometer*" to help showcase best practices from across the digital ecosystem.