Assessing the carbon footprint of shutting down 2G and 3G networks and migrating their services to 4G/5G

Executive Summary

Mobile Network Technical Experts Committee

September 2023

FOREWARD

The Technical Expert Committee on Mobile Networks was set by Arcep in 2018. Made up of technical experts working over a long-term horizon, the Committee may provide an independent technical recommendation/insight enabling to share views and to build up a sectoral consensus on any technical topic relating to mobile networks and technologies. Chaired by Catherine Mancini from NOKIA, the secretariat and management of the Committee are provided by Arcep.

Committee's published studies

Title of the study	Publication date
Committee's report on technical coexistence issues in 3,4 - 3,8 GHz band	05/2019
Energy assessment of 4G vs 5G deployment	01/2022
Assessing the carbon footprint of shutting down 2G and 3G networks and migrating their services to 4G/5G	09/2023

Assessing the carbon impact of shutting down 2G and 3G networks and migrating their services to 4G/5G

Technical Experts Committee on Mobile Networks

Executive Summary

The current level of 4G coverage – which is poised to equal that of 2G and 3G[1] – combined with the steady growth of the number of 4G-compatible devices in circulation raises the question of how necessary it is to maintain 2G and 3G networks across the country. Moreover, the growing demand for mobile data driven chiefly by 4G and 5G may justify having frequency resources currently allocated to 2G and 3G networks being reused by more recent and more spectrum-efficient 4G/5G technologies.

For any operator, the decision to shut down 2G-3G technologies is a strategic one that involves multiple considerations such as operational constraints, technical considerations, market strategy, skills maintenance, etc. Three mobile network operators in France have already provided information about their planned 2G-3G network shutdowns[2]. This is part of a global shift towards more modern and more efficient technologies, which are better suited to mobile network customers' current and future behaviours. The Global Mobile Suppliers Association (GSA) identified 142 operators[3] that had announced the forthcoming or already completed shutdown of their 2G and/or 3G networks. Environmental concerns also factor in to these decisions. And the topic has now become a matter of public debate.

The Mobile Technical Experts Committees, which Arcep created in October 2018, began conducting technical work to assess the carbon impact of shutting down 2G-3G networks in France and migrating their services over to 4G/5G. The Committee members include experts representing mobile network operators, equipment suppliers, along with participants from academia and French National Frequency Agency, ANFR. It is chaired by Catherine Mancini, and Arcep assumes its secretarial duties. This study is the deliverable of that work. Aimed at public actors in particular, it seeks to provide qualitative and quantitative input on the environmental issues surrounding 2G-3G network shutdowns, such as climate change. This document provides a summary of the approach taken to the study along with its main findings. A fuller account can be found in the detailed memorandum on the report and in the FAQ document.

All feedback on this report is welcome, and can be sent by e-mail to: ComiteExpertsMobile@arcep.fr

---

[1] https://monreseaumobile.arcep.fr/

[2] The three mobile operators' shutdown announcements at the time of writing: (Orange) https://reseaux.orange-business.com/articles/arret-2g-et-3g/, (SFR) https://actus.sfr.fr/tech/news/bientot-la-fin-de-la-2g-et-3g-202201260005.html and (Bouygues Telecom) https://www.bouyguestelecom-entreprises.fr/bblog/arret-programme-des-technologies-2g-et-3g-4-questions-pour-tout-comprendre/#:~:text=S'inscrivant%20dans%20ce%20mouvement,ans%20plus%20tard%2C%20fin%202029

[3] https://gsacom.com/paper/2G/3G-switch-off-october-2022-summary/

2G and 3G networks today are used primarily for voice and machine-to-machine (M2M) services on the Internet of Things (IoT) (see Glossary), which is making less and less use of these technologies and switching to 4G/5G, as testified to by Experts Committee members regarding their own networks.

In the medium term, operators' 900 MHz band frequencies will remain switched on to relay this small stream of 2G-3G traffic and will account for around 17% of networks' power consumption.

- From an energy-efficiency standpoint, it is preferable to switch over completely to 4G/5G.
- From a carbon footprint standpoint, the migration to 4G/5G raises the question of the need to replace certain devices that are only 2G-3G compatible (some smartphones, features phones (basic phones) and connected objects that are part of the Internet of Things (M2M/IoT) earlier than planned.

The study shows that the breakeven point between networks' positive carbon impact and the negative carbon impact of these devices is reached in less than six months.

The study thus shows recurring reductions in carbon emissions from the first year after the 2G-3G shutdown. For the network and mobile devices, this reduction is achieved in under two months. When factoring in M2M/IoT as well, this reduction is achieved in under six months.

Different estimates indicate that 2G-3G networks account for a not insignificant share of mobile networks' power consumption, despite the steady decrease in the use being made of 2G-3G networks

In one initial approach to the problem, the study examined 2G-3G networks' share of mobile operator networks' total energy consumption, by conducting two complementary analyses that made it possible to obtain an estimated range and to pinpoint trends:

- A "generic" analysis that considered the profile of an average generic operator with an average (for all operators combined) distribution of cell sites;
- And a "specific" analysis based on primary data provided an operator who is a Committee member.

To situate the assessment in a more realistic shutdown timeframe, for both analyses the weight of 2G and 3G networks is evaluated both currently and up to 2025, incorporating deployments planned up to then.

Based on the information available to Arcep, we have seen a reduction in voice and data traffic on 2G and 3G networks over the past several years, and 2G and 3G currently use 900 MHz[4] band frequencies almost exclusively, whereas the other frequency bands assigned to operators are being used for 4G and 5G (700, 800, 1800, 2100, 2600, 3500 MHz).

The different estimates made through the two above-mentioned analyses (generic and specific) constitute different items of evidence indicating that 2G and 3G networks account for a not insignificant share of mobile networks' power consumption. 2G and 3G networks' currently represent

[4] This is confirmed by (French National frequency agency) ANFR figures (https://www.anfr.fr/gestion-des-frequences-sites/lobservatoire/) indicating that operators reuse a substantial portion of their 2100MHz band spectrum for 3G to 4G (number of cell sites in service factoring in network sharing: in September 2022, there were 33,033 2100MHz UMTS sites and 3,556 1800MHz GSM sites; in January 2023, there were 27,290 2100MHz UMTS sites and 3,060 1800MHz GSM sites; in July 2023, 13,824 2100MHz UMTS sites and 2,278 1800MHz GSM sites).

between 21% and 33% of all network base stations, a figure that could stand at around 17% by 2025 depending on the assumptions considered.

Far from being insignificant, this share of energy consumption raises the question of what savings could be expected from shutting down these networks and migrating to 4G/5G technologies. The migration in question consists of having services using 2G-3G technologies – chiefly voice and M2M – carried instead by 4G/5G.

This migration was examined in terms of carbon impact through a comparative analysis that is detailed below. This examination does not constitute an assessment of the carbon impact of refarming the 900MHz band used for 2G-3G to 4G/5G.

A comparative analysis concludes that shutting down 2G-3G networks and migrating their services to 4G/5G would have a positive carbon impact

Shutting down 2G-3G networks goes hand in hand with migrating the services using these technologies to 4G/5G networks: this essentially involves voice and M2M services. Evaluating the impact of this migration consists of quantifying the associated energy and material impact – i.e. the carbon impact across the networks' and devices' lifecyle.

Methodological guidelines

The methodology used in the study is based on a differentiated assessment of a reference scenario and a migration scenario for a mobile network in Metropolitan France:

- Reference scenario: voice and M2M services using a so-called benchmark 2G and 3G mobile network.
- Migration scenario: the same voice and M2M services, using a 4G/5G mobile network for which all of the benchmark 2G and 3G network's equipment has been upgraded to 4G/5G on the day of migration (M-day).

All of the equipment considered in the study belongs to the Information and Communications Technologies (ICT) sector as defined by Recommendation ITU-T L.1450.

The scenarios are compared for a period of one year starting on M-Day.

Then, as explained in the findings, the study also evaluates the amount of time, in number of months, from M-Day required to reach the breakeven point for the two scopes of study being considered and detailed below, between the networks' steady and ongoing energy savings and the carbon cost of devices that are non 4G/5G-compatible on M-Day.

This comparative analysis is conducted across the entire lifecycle of the different elements that make up the product system[5]; its scope includes the network equipment and devices that are part of the ICT sector as defined by Recommendation ITU-T L.1450 **[1]**. The study includes the following items in this initial scope: data centres (service platform), network equipment (base stations, mobile backhaul, radio network controllers and core network) and telephone equipment (feature phones and non-VoLTE smartphones) which make up the scope of reference.

[5] Only the equipment's end-of-life stage is left out due to a lack of data and the only minor part that this stage plays in the overall outcome.

An extended scope was also defined to include the connected objects used for communications between machines (M2M/IoT).

The Experts Committee took a three-step approach to selecting the objects concerned:

- First, a list was drawn up of connected objects likely to use 2G-3G technologies;
- Second, this list was submitted for examination to the Technical Experts Committee on Measuring the environmental impact of Digital[6] which gave its opinion on whether to include each category of object in the ICT sector, according to its interpretation of Recommendation ITU-T L.1450;
- Third, the extended scope was defined based on this opinion.

This selection of connected IoT objects using only 2G-3G technologies includes, notably, intercoms, mobile PoS terminals and smart meters.

The two scopes (reference scope and extended scope) are illustrated below:

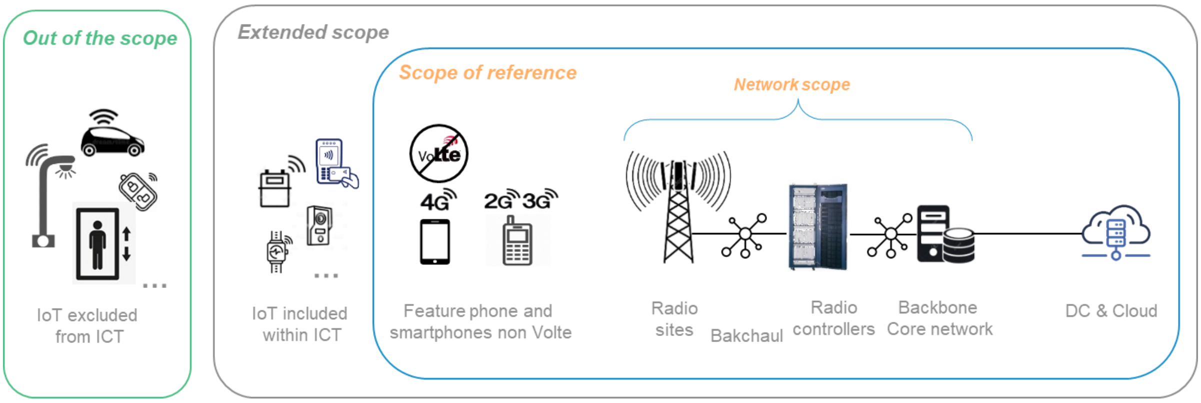


Figure 1 - Illustration of the two scopes (reference and extended scopes) used for the study

To conduct this comparative analysis, the study aligned itself with the ITU L.1410 methodological guidelines **[2]** specifying the approach to performing a Life Cycle Assessment (LCA) of two product systems (in this case two ICT services).

The functional diagram for comparing the reference and migrations scenarios, the allocation rules for isolating voice/M2M services' share in the case of shared use of 4G/5G base station equipment with other services (data services), analysis of the quality of the impact data (power consumption, embodied carbon) and activity data (hardware inventory and the fleet's rate of growth, traffic volume and load curve, etc.) used in the evaluation for each product category and listed in the detailed memorandum.

Based on the comparative functional diagram, the following table summarises the identified differences between the reference scenario and the migration scenario, which are evaluated as part of the comparative analysis.

[6] The Technical Experts Committee on Measuring the environmental impact of Digital was created by ARCEP and ADEME in 2020. Chaired by Catherine Mancini, Committee members include industry players, academics and digital and environmental think tanks. The Committee issues fully independent opinions on technical issues surrounding the digital environmental footprint.

Table 1 –Differences between the reference and the migration scenario

Product category	Equipment	Identified differences	Observations (exclusions, allocations etc.)
Data centres	IoT/M2M service platform	Same platform: No evaluation required	
	IMS servers (for voice and SMS over LTE)	Only utilisation stage needs to be examined	Impact disregarded[7]
Networks	Core network	Core network circuit in the case of the reference scenario with a configuration that could be kept in the reference scenario[7]	Impact disregarded [7]
	Backbone Network	Same network: No evaluation required	
	2G/3G RNC	Hardware removed in the case of a migration. Only utilisation stage needs to be examined	Impact disregarded (in keeping with the cut-off rules[7])
	Aggregation/backhaul network	Same network and same volume of traffic: No evaluation required	
	900 MHz cell sites (excl. base stations)	Same components: No evaluation required	
	900 MHz base stations	Production stage to be examined for the migration scenario if new hardware deployed on M-Day. Utilisation stage to be examined.	It is supposed that installed network equipment is 4G/5G-ready (no new hardware needed) Allocation rule needed to consider voice/M2M services' share of the carbon footprint during 900 MHz band base stations' 4G/5G utilisation stage
Mobile phones	Non-VOLTE smartphones	Production stage to be examined following the earlier-than-planned replacement of non-VoLTE-compatible smartphones under the migration scenario.	Factoring in the remaining share of smartphone's life when amortising its embodied carbon footprint. Factoring in the case of refurbished smartphones.
	Feature phones	Production stage to be examined following the earlier-than-planned replacement of feature phones with VoLTE-compatible phones under the migration scenario.	Factoring in the remaining share of the feature phone's life, when amortising its embodied carbon footprint.
Connected objects	2G/3G cellular IoT	Production stage to be examined following the earlier-than-planned replacement of 2G/3G-only cellular IoT modules with 4G/5G-compatible IoT modules under the migration scenario.	Factoring in the remaining share of IoT terminal's life, when amortising its embodied carbon footprint. Only the connected object's connectivity module (modem) is considered in the evaluation.

Main assumptions: Average generic operator, installed base of device

The following assumptions are made when defining the reference mobile operator and network:

- The number of 900 MHz-band base stations is the average number of 2G-3G networks' 900 MHz-band base stations in Metropolitan France extrapolated on M-Day (Migration Day);
- An operator regularly upgrades their 900 MHz-band base stations such that on Migration Day all of the network equipment is already 4G/5G-ready, with a coverage level similar to 3G;

[7] See the detailed memorandum

- There is very little M2M traffic, and it is voice services that shape 2G and 3G traffic. The volume of voice traffic is identical for both scenarios (reference and migration). This traffic is evaluated based on known voice traffic at the end of 2021 (average of four operators in Metropolitan France) and a percentage of this traffic (10%) remaining on 2G-3G on M-Day.

The following assumptions are made regarding telephones from the benchmark (reference) operator's fleet:

- The study differentiates how feature phones and smartphones are treated because of the difference in their respective carbon footprint, and in their numbers of rate of growth between the day the operator announced the shutdown of 2G-3G technologies (A-Day) and the day of the actual migration (M-Day).
- To model the inventory of non-VoLTE smartphones up to the day of shutdown, the study starts with a current inventory of smartphones (announcement or A-Day[8]), and the breakdown (percentage) by the age of the different devices in the benchmark operator's network that were not LTE compatible when the announcement was made. To extrapolate the number of devices just before M-Day, the study calculates the percentage of devices remaining in the network after x years. These percentages are solely dependent on the life cycle of the smartphone whose maximum life is considered to be equal to eight years, which significantly longer than the average observed lifespan (estimated at 2.5 years**[3]**).
- The same approach to modelling is used to calculate the number of feature phones in the benchmark operator's fleet on migration day, with the supposition that all of the feature phones are non-VoLTE-compatible and have a longer maximum life span (10 years).
- The two models for smartphones and feature phones are supported by the data on the evolution of annual sales of these devices.
- Every new mobile phone is Voice over LTE-compatible on announcement day.
- The lapse between the two dates (A-Day and M-Day) is considered to be 6 years.

The following assumptions are made regarding the connected objects (IoT) in the benchmark operator's fleet:

- The approach taken to determining the number of connected objects using the benchmark operator's network when it is shut down is analogous to the one used for mobile phones. To fully consider the diversity of IoT objects affected by the shutdown, the modelling approach is further refined by factoring in three distribution curves for the objects remaining in the network after x years, corresponding to the three types of IoT object in the ICT sector according to their longevity: objects with a maximum life of 20 years (e.g. intercoms), objects with a maximum life of 15 years (e.g. smart meters), and objects with a maximum life of 10 years (e.g. mobile POS terminals).
- Similar to the case of mobile phones, the model makes the additional assumption on the sale of objects that were not compatible with 2G-3G technologies prior to the shutdown announcement date.

Particular attention was given to assessing the quality of the impact and activity data used in the study. A data quality analysis is substantiated in the technical appendices of the detailed memorandum.

[8] Given that three of the four national operators have already made announcements about shutting down their 2G/3G networks.

The different data and assumptions considered, as well as the technical developments of the computational approaches used to estimate the inventory of the different product categories (network, phones and IoT), are set out in the detailed memorandum.

Results of the evaluation

The results must provide the ability to evaluate the benefit, from a GHG emissions standpoint, of migrating 2G-3G to 4G/5G technologies for the scope of reference and the extended scope.

The network analysis shows that migrating 2G-3G technologies to 4G/5G technologies enables continuous and steady energy savings compared to keeping 2G/3G technologies in the benchmark mobile operator's network starting on M-Day.

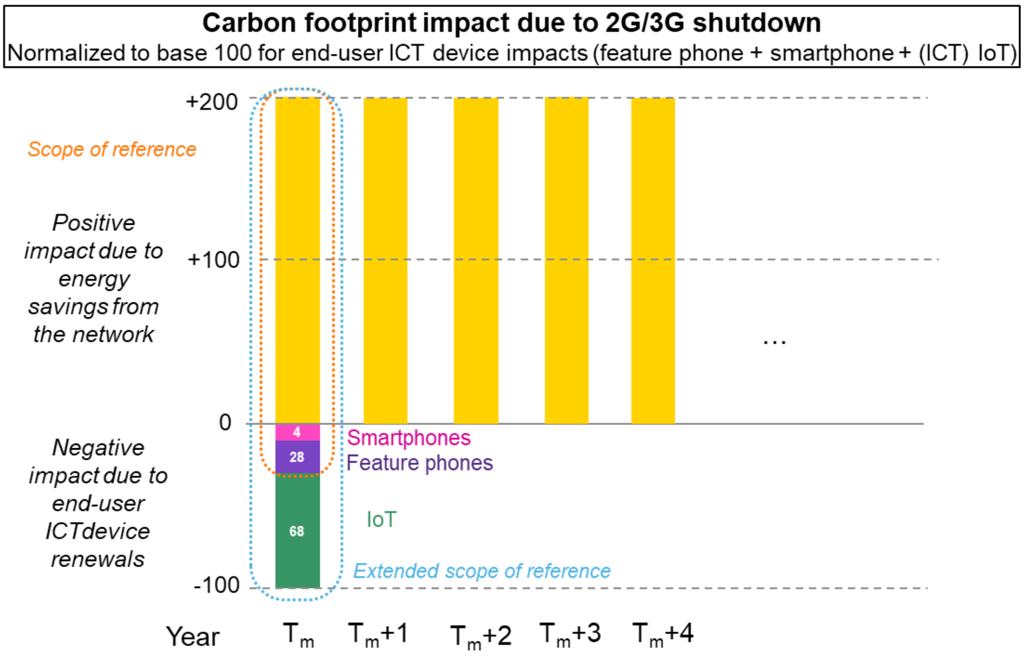
This energy savings between the analysed scenarios represents virtually the entirety[9] of the benchmark 2G-3G network's electricity consumption on M-Day, which corresponds as well to a continuous and regular reduction in the carbon footprint from M-Day onwards.

Note that these energy savings for the networks are due essentially to the fact that very little traffic is being relayed over 2G-3G on M-Day (<1% of the 900 MHz frequencies' capacity) and the volume of IoT traffic is insignificant.

But this migration has a carbon impact on M-Day for mobile devices (reference scope) and IoT devices (extended ICT scope) that are not 4G/5G-compatible.

The study assesses the number of months from M-Day needed to reach the breakeven point for both of the scopes considered, between the continuous and steady energy savings and the carbon cost of devices that are not 4G/5G-compatible on M-Day.

[9] See Chapter on: "Findings and conclusions" of the detailed memorandum showing that migrating services using 2G/3G to 4G/5G enables a 99.44% energy saving for the 2G/3G network on M-Day.



** This illustration assumes a constant electricity grid emission factor over time, however this does not change the fact that gains in network electricity consumption are constant and persist over time beyond Tm*

Extended scope of reference: break-even point after less than 6 months

For the reference scope (network + mobile devices), the breakeven point is reached in less than two months.

For the extended scope that includes IoT, the breakeven point is reached in less than six months.

The energy savings observed on the network are repeated each year, whereas the impact of devices is counted only once. As the breakeven point is reached rapidly, the longer the period being considered, the greater the savings.

The base case analysed thus shows a real benefit in terms of carbon footprint from migrating 2G-3G to 4G/5G, as much for the reference scope as the extended scope.

Sensitivity study

To estimate the sensitivity of certain variables, the assessment is completed by a sensitivity analysis of the following parameters: embodied carbon impact of mobile phones and IoT connected objects; the unitary power consumption of network equipment; the breakdown profile of smartphones and feature phones remaining on the network; smartphone and IoT sales profile; the number of smartphones, feature phones and IoT objects remaining on the network on announcement day; the ratio of VoLTE-compatible feature phones before announcement day; the maximum load of 4G/5G base stations for all services combined. These different sensitivity cases are analysed separately (never combined) to be able to obtain as objective an assessment as possible of each parameter's significance in the sensitivity study.

The sensitivity analysis reveals the following:

- **Smartphones:** smartphones' absolute impact in this study is negligeable given the small percentage of non-VoLTE-compatible smartphones on the network shutdown date, and the age of these devices. Variations of the percentage of non-VoLTE-compatible smartphones have little influence on the results in terms of absolute carbon impact.

- **Feature phones/mobile phones' total impact/reference scope:** an operator that had a larger number of feature phones (4 million instead of 2 million) on that date could take between one and two years to see a comparable or possibly smaller impact.
- **IoT/ extended ICT scope:**
    - The number of IoT objects considered influences the results. An overestimate of the number of IoT objects (5.5 million) gives a breakeven point of around six months.
    - The examined case wherein the sale of IoT objects continues after the announcement of a 2G-3G shutdown gives a breakeven point of seven months. This is undoubtedly an important point that underscores how vital it is for the entire ecosystem to take a forward-looking view, to limit these sales.
- **Other cases examined for their impact on the two breakeven points:**
    - A sensitivity study was conducted on base stations' consumption data, which demonstrated an insignificant impact of 2G-3G base stations' consumption parameters.
    - A sensitivity study on the network portion shows that the examined parameters (multiplying 2G-3G voice traffic on M-Day eightfold, cutting the maximum 4G/5G load in half) have very little influence on the results. This is due to the fact that very little traffic is being relayed by 2G-3G networks on M-Day.
    - By increasing, respectively, the embodied carbon values for feature phones and IoT by 25%, we delay the breakeven points compared to the base case, but still maintain a value of less than two months for the reference scope, and less than six months for the extended scope.

Depending on the cases analysed, the sensitivity study therefore reveals insignificant impacts compared to the base case, or a certain influence with a later breakeven point equal to seven months in the case of the extended scope. It confirms the conclusion that the migration would be beneficial in terms of a reduced carbon footprint.

Conclusions

This study relating the Committee's work provides qualitative and especially quantitative clarification of the carbon impact issue arising from the opportunity to shut down 2G-3G networks and migrate their services to 4G/5G networks, based on a life cycle assessment and for a scope of impact that goes beyond just the networks. By sharing this study, the Experts Committee is seeking to contribute – under the current circumstances and based on well-defined assumptions – to a better understanding of the carbon impact of shutting down 2G-3G networks. This study lays out the following:

- Beyond the scope of the networks themselves and a strictly energy-related analysis, the study sought to obtain the full measure of the impact through an LCA of the carbon footprint, factoring in the possible obsolescence of the network's hardware elements and potentially some ICT devices.
- The choice of IoT equipment that belong to ICT is based on the ITU definition of the ICT sector and Recommendation, even if it may be legitimate to question the rationale behind the inclusion/exclusion of certain IoT devices in the ICT sector, and the need to define harmonised allocation rules – questions that were raised during the work of the Technical Experts Committee on measuring the digital environmental footprint **[4]**.
- Methodological anchoring of the technical standards for measuring ICT's environmental and energy footprint: this study is based on the recognised methodological recommendations on this matter, notably those of the International Telecommunication Union (ITU) **[1][2][5]** and the European Telecommunications Standards Institute (ETSI) **[6]**. This aligns with the

Recommendation from the Arcep/ADEME Experts Committee on measuring the digital environmental footprint **[4]**.

- A rigorous analysis of the quality of the data, despite the difficulties encountered in collecting them.

Note that the purpose of this study is not to obtain an absolute figure of the carbon impact of shutting down 2G-3G, but rather to assess whether the migration is worthwhile from a carbon footprint standpoint. In other words, this study does not seek to replace a detailed report that an operator would produce about its own network, but rather to assess the carbon-related benefit of such a migration. Moreover, as the role of an LCA is to be able to identify the levers for minimising a piece of equipment's or a system's environmental footprint, this assessment is also meant to draw attention to the particular points of vigilance, to avoid diminishing the carbon reductions achieved by shutting down 2G-3G. For instance, it is important that device resellers stop selling 2G-3G devices and instead promote VoLTE-compatible feature phones. The entire ecosystem needs to work together to pave the way for a 2G-3G shutdown, which would include stopping the sale of non 4G-compatible IoT objects and paying particular attention to proper communication with the public and businesses.

Glossary

- **Life cycle assessment (LCA):** Compilation and evaluation of the inputs, the outputs and the potential environmental impacts of a product system over the course of its life cycle[10].
- **Embodied carbon (or energy):** All of the carbon emissions other than those produced during the equipment's utilisation stage[11].
- **Feature phone:** a basic mobile phone that keeps the shape factor of previous generations of mobile phones, typically with a keypad, a small non-touch LCD screen, a microphone, a camera in the back and GPS services. They are called feature phones to distinguish them from smartphones. Feature phones provide the ability to make phone calls, exchange text messages and use certain basic mobile applications: calendar, calculator, multimedia apps and a basic mobile web browser[12].
- **Internet of Things (IoT):** Objects that become internet compatible (IoT devices) typically interact via integrated systems, a form of communication network, and a combination of leading edge computing and Cloud Computing. The data produced by the devices connected to the IoT are often (but not solely) used to create new applications for end users[12].
- **Machine to Machine (M2M):** The technologies used by machines to be able to "talk" to each other, with no direct human involvement. In the study, IoT and M2M are treated indistinctively.

[10] ISO 14040:2006: Environmental Management — Life cycle assessment — Principles and framework: https://www.iso.org/obp/ui/#iso:std:iso:14040:ed-2:v1:en

[11] GHG Protocol ICT Guidance: https://www.gesi.org/research/ict-sector-guidance-built-on-the-ghg-protocol-product-life-cycle-accounting-and-reporting-standard

- **Smartphone:** A mobile phone that performs many of the functions of a computer, and which typically has a touchscreen interface, can access the internet over Wi-Fi and mobile networks, a GPS connection and an operating system (OS) capable of running downloaded applications[12].
- **Information and Communications Technologies (ICT):** The sectors of economic activity that contribute to the viewing, processing, storage and transmission of information by electronic means[13].
- **VoLTE:** Voice over the LTE (4G network): A voice calling service relayed over IP via the LTE (4G) mobile access network[14].

References

[1] Recommendation ITU-T L.1450 "Methodologies for the assessment of the environmental impact of the information and communication technology sector" (09/2018)

[2] Part II ("Comparative analysis between ICT and reference product system (Baseline scenario); framework and guidance") of Recommendation ITU-T L.1410 "Methodologies for environmental lifecycle assessments of information and communication technology goods, networks and services" (12/2014)

[3] E. Lees Perasso *et al.* "Evaluation environnementale des équipements et infrastructures numériques en France"

https://www.arcep.fr/uploads/tx_gspublication/etude-numerique-environnement-ademe-arcep-volet02_janv2022.pdf

[4] https://www.arcep.fr/la-regulation/grands-dossiers-thematiques-transverses/lempreinte-environnementale-du-numerique/mesure-impact-environnemental-numerique.html

[5] Recommendation L.1390 (08/2022) Energy saving technologies and best practices for 5G radio access network (RAN) equipment.

[6] ETSI ES 202 706-1 v.1.6.1 Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power consumption – static measurement method.

[12] E. Lees Perasso *et al.* "Evaluation environnementale des équipements et infrastructures numériques en France", https://www.arcep.fr/uploads/tx_gspublication/etude-numerique-environnement-ademe-arcep-volet02_janv2022.pdf

[13] OECD definition: https://www.oecd.org/digital/ieconomy/2771153.pdf

[14] Source: GSMA – https://www.gsma.com/futurenetworks/volte-2-2/