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

Frequently Asked Questions (FAQ)

Mobile Network Technical Experts Committee

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1 The study assumes the shutdown of both 2G and 3G technologies, however, the extinction of one technology and then the other is a priori what is planned (cf. operator announcements). What is the reason for such a choice?

This study is based on a comparison of two scenarios: one where 2G and 3G are kept, and another where the two technologies are migrated to 4G/5G. Even if the announcements that have been made thus far stipulate that 2G and 3G will be shut down successively, the two shutdowns will take place only a few years apart. Studying the shutdown of just one or the other technology would only complicate the exercise, and would only apply to a timeframe of a few years. This study therefore seeks to examine the effects over a long period of time, which is why it is more relevant to look at a 2G and 3G shutdown scenario.

2 The study explicitly examines (radio access) base stations. But what about the other parts of a mobile network, such as the core network, backhaul, or radio network controllers for which no calculations are made in this study?

The study is based on a comparative analysis of a scenario of keeping 2G-3G and one where these two technologies have been migrated to 4G/5G. The aim is therefore to assess the difference in impact between the two scenarios, rather than the impact of each scenario. Hence, processes where input/output data can be excluded if they are identical in the two product systems.

This is why a quantitative assessment of the backhaul network and cell sites (excluding base stations) was not performed.

2G/3G radio network controllers (BSC, RNC)[1], the core network, have a small energy footprint compared to the access network, which is why a quantitative assessment of them was not performed.

[1] Radio network controllers account for a few percent according to estimates from a Committee member who is an operator.

3 The study analyses the weight that 2G and 3G networks represent for a generic operator; although 2G/3G RAN Sharing between several operators does exist at some sites. Having a single operator shut down 2G-3G does not necessarily mean shutting down 2G-3G technologies at the site it if continues to be used by the other operators. Have you assessed the impact of sharing in your scenario?

The study does not take sharing into account; it is a simplifying assumption.

In fact, as the study evaluates a ratio (the evaluation is made in relative terms), sharing applies to the 900MHz 2G-3G band as well as to other frequency bands and technologies, so the order of magnitude of the result remains valid.

4 Will 2G and 3G networks' relative footprint not evolve between now and 2025/2030, when the shutdown occurs?

The Committee began by estimating the footprint of 2G and 3G networks to date to determine whether it would be worthwhile to conduct a more in-depth study. As this footprint proved not inconsiderable (see Annex A of the detailed study), it was decided to conduct a more detailed analysis based on a comparison of two scenarios (see in particular the answer to the first two questions in this FAQ, the main detailed study, and its Annex B on this topic).

The comparison of the two scenarios takes proper consideration of the reduced 2G-3G traffic on Migration Day (M-Day), and so of the "weight" of 2G-3G in a more distant future.

5 Considering the time-related aspect and the networks' shutdown, is it not more apposite to present 2G and 3G networks' footprint in absolute terms?

As indicated in the previous question, the Committee assessed 2G and 3G networks' footprint to date, to determine the value of a more in-depth study. To this end, 2G and 3G networks' relative share is a more easily obtainable piece of information and sufficient to meet this objective.

As part of the in-depth study based on the comparison of the two scenarios, the 4G/5G scenario gains compared to the 2G-3G scenario were assessed in absolute terms on the network portion for one year, while a relative value was also given.

The network analysis revealed that the migration of 2G-3G technologies to 4G/5G technologies enables continual and steady energy savings compared to the scenario of keeping 2G-3G technologies on the benchmark mobile operator's network, starting on M-Day. These energy savings between the analysed scenarios also translate continual and steady decrease in carbon footprint, from Migration Day onwards.

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

The study also assessed the time needed in number of months from M-Day for the two considered switchover dates to reach a point of equilibrium between continual and steady network savings and the carbon cost of devices that are not 4G/5G-compatible on M-Day.

6 As the deadline for 2G-3G network shutdowns draws nearer, traffic on these networks will be increasingly light. Will this decrease in traffic have an impact on 2G and 3G networks' energy consumption? In particular, under your assumption of base stations accounting for 30% of the load.

The Committee performed a macroscopic assessment of 2G-3G networks' energy consumption footprint relative to all of the networks combined, which revealed that 2G-3G networks' consumption represented a substantial share of the electricity consumed by mobile networks in France. The study then showed that 2G-3G traffic shrinks between now and Migration Day, and so bolstering the value of analysing the replacement of 2G-3G technologies with 4G/5G.

7 What is the origin of the assumption that base stations account for 30% of the load? Would it not be useful to distinguish between the load weighing on 2G-3G networks and the one weighing on 4G networks?

The assumption of base stations accounting for 30% of the load was considered from a macroscopic perspective for the first part of the study, to determine whether a more detailed approach would be worthwhile. This value of 30% assumes a base station operating at an average load, which seems reasonable according to operators as members of the Committee. The second part of the study narrows furthermore this assumption.

8 Does the distribution of the base stations' configuration at the various cell sites not alter the relative weight of 2G-3G networks?

The fleet of 2G and 3G cell sites is made up of sites of different generations, with a variety of configurations. First, understanding that the entire fleet of sites is equipped with the previous generation of technology makes it possible to define the upper limit of 2G and 3G networks' footprint. Second, understanding that the entire fleet of sites is equipped with a more recent generation of technology makes it possible to define the lower limit of 2G and 3G networks' footprint. As a result, by bookending the calculation with these two configurations, the resulting information creates the ability to assess the relative weight of 2G and 3G networks to date and in the near future. The energy consumption values for 2G-3G base stations of different generations are based on laboratory measurements carried out by an equipment manufacturer who is a member of the Committee.

For the detailed study of a comparison of the two scenarios starting on M-Day, when 2G-3G services are switched over to 4G/5G under the migration scenario, all of the 2G-3G and 4G/5G base stations' hardware is considered new generation since Migration Day is farther off, with a time lapse of six years between the announced end of 2G-3G and the migration itself. A sensitivity study of these base stations' electricity consumption values comes to complete the analysis, to factor in possible disparities in the different new generation hardware.

9 The study posits that 2G and in 3G (such as voice and M2M) services delivered over the 900 MHz band would be delivered over the 900 MHz band in 4G and 5G. Is a scenario where the 900 MHz band (currently carrying 2G and 3G services) would be switched off, or where current 2G and 3G would be moved over to other bands possible?

The study examined the case whereby 2G-3G services being relayed over the 900 MHz band would be relayed in 4G/5G using another target band (e.g. 700 MHz), without (in the case of the study) prejudice to the future of the 900 MHz band. A shutdown of the 900 MHz band could therefore theoretically be envisaged, and would change nothing in terms of the assessment's results and conclusions. This would, however, mean making sub-optimal use of the operator's spectrum and not making full use of the available resources to meet the growing demand for mobile traffic. The 900 MHz band is particularly attractive to operators as it is a low-end band with a long range and good indoor performance. Operators' low-end spectrum is relatively weak in areas that are or will be overloaded in this band. It is therefore typically far more interesting from an investment, as well as an environmental, standpoint to reuse this frequency with already deployed and 4G-compatible equipment, rather than to add capacity by deploying a new frequency or by adding cell sites to increase network density in the area. It should be noted that the study did not model carbon savings.

10 What is the reason for the choice to consider only voice and M2M services on 2G and 3G networks? I.e. why ignore data (notably on 3G) and texting (SMS) services?

Mobile data services on 2G-3G networks remain marginal. 2G-3G mobile data traffic represents less than 4% (based on Arcep's Market Observatory data) of total mobile data traffic today, a figure that will be even lower on Migration Day, the study's starting date for comparing the two scenarios.

11 Why did you assume in the study that all radio equipment would be ready for 4G/5G by the migration date?

As indicated in the detailed analysis, even if the study does not assume a precise date for Tm, this date being relatively far for operational reasons, all of the reference operator's 900 MHz base stations will have been upgraded by this date to support 4G and 5G technologies, due to the obsolescence of older equipment and its replacement.

12 The shutdown of 2G and 3G technologies will have an impact on devices, both consumer and M2M. All of the 2G-3G devices in use on M-Day will need to be replaced. This impact will depend on the M-Day set in the study (as with the impact on network equipment). Would it not have been preferable to conduct these studies on two different migration dates to assess these impacts?

The study does not establish an assumption about Migration Day itself, but does consider a lapse of six years between Announcement Day (the date when the benchmark/generic operator announced the shutdown of 2G-3G technologies) and Migration Day (the date of the migration to 4G/5G)[2]. Every mobile operator, who is a Committee member, deemed this lapse realistic, and the Committee agreed that a sensitivity study on this parameter was not necessary.

[2] N.B. the three mobile operators' shutdown announcements as of this 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.

13 In a study published in 2020, produced on behalf of the FFT[3], it was stated that 2G consumes 37 kWh/Gb, 3G: 2.9 kWh/Gb, 4G: 0.6 kWh/Gb, and 5G: 0.06 kWh/Gb. Are these figures provided by the FFT compatible with the figures obtained in this study?

The figures calculated in this study were obtained by reasoning based on 2G-3G services migrating over to 4G/5G; it is not easy to compare with energy consumed per Gb of traffic. We nevertheless find the same trend as in this study, namely that relaying traffic in 2G and 3G is less energy-efficient than in 4G and 5G.

14 An alternative to a total shutdown of both 2G and 3G technologies could consist of keeping a single 2G-3G network in the country. Do you think that such an alternative could reduce the carbon footprint significantly compared to a shutdown?

In order to assess the environmental impact of maintaining a single 2G-3G network, and using a similar methodological approach already described in the detailed note, we can, for example, compare the following 2 scenarios, one with 3 networks migrated to 4G/5G and one network maintained on 2G-3G, and the other where all four networks have been migrated to 4G/5G at a date called Tm4. The comparison is made from the Tm4 date for the same services, i.e. voice and M2M services that used 2G-3G before the different migrations.

A comparative analysis is developed in the Appendix of this document. In this example, given that it is difficult to predict the exact behaviour of the various users of the 3 networks who will migrate to 4G/5G and whose terminals (smartphones, feature phones, IoT) do not support a network without 2G-3G, two cases have been considered for the scenario with the single 2G-3G network:

(1) All these users decide to stay on the networks that will migrate to 4G/5G, and their various terminals must be migrated to 4G/5G.
(2) All these users decide to migrate to the single 2G-3G network and keep their terminals.

In the first case, the existence of the single network leads to the same conclusions as the reference scenario in the detailed note.

In the second case, the single network makes it possible to avoid 4 x Ic ("Ic": Carbon Impact) at date Tm4, which multiplies by 4 the break-even points identified in the reference scenario of the detailed note (considering the fact that the consumption of the single 2G-3G network is very similar to the consumption of a network carrying the traffic of only one operator). Furthermore, beyond the breakeven point, the 2G-3G network has a negative carbon impact equivalent to almost all its electricity consumption.

This analysis does not prejudge how long this single 2G-3G network could be maintained. For operational and industrial reasons, the 2G-3G network cannot be maintained indefinitely. In addition, the announcement to the market that a 2G-3G network would be maintained could have induced purchases of 2G/3G objects after the various dates (Ta) of 2G-3G shutdown announcements, which would not have occurred if all networks had stopped 2G-3G. All these purchases of 2G-3G end-user devices would then generate an additional carbon impact[4] on the shutdown of the maintained 2G-3G network, in addition to the equivalent power consumption of

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[3] https://www.fftelecoms.org/app/uploads/2020/12/20201215-FFT-Etude-Economie-des-Telecoms-2020-vSynthese.pdf

[4] To be determined by depreciation calculation at the date of 2G-3G network shutdown, based on the lifetime of the various items and when they were purchased.

this network during its existence. **The carbon impact "Ic" avoided at date Tm4 cannot therefore be taken in its entirety.**

In conclusion, the alternative of maintaining a 2G-3G network would increase both energy consumption and environmental impact compared with the scenario where the four 2G-3G networks would be migrated to 4G/5G.

Furthermore, maintaining a single 2G-3G network across the country raises a number of issues, not only in terms of technical and operational feasibility and QoS for users, but also regulatory (particularly if it were to run counter to the principle of technological neutrality) and environmental concerns.

Indeed, for operational reasons for operators and industrial reasons for suppliers, it would seem unrealistic to maintain a 2G-3G network in France indefinitely, especially as 2G-3G networks will be disappearing one after the other worldwide and in Europe[5]: should it be decided to maintain such a 2G-3G network for a long time, its operator(s) and network equipment and terminal supplier(s) would be faced with rising costs and a scarcity of expertise in these technologies.

Finally, from a technical point of view, this 2G-3G network would run counter to the proper use of frequencies, since it would monopolize spectrum for inefficient use.

15 The study's extended scope does not incorporate certain devices that use 2G-3G technology (such as remote alarm systems, the eCall modules in cars, lifts, etc.). Why were they not factored into the upper limit of the impact?

Although a substantial number of connected objects that use 2G-3G technology would be affected by the migration, it is not necessarily right to include every object systematically in the study. The devices considered for the purposes of the study are those that are part of the defined scope of ICT, as detailed by the current version of Recommendation ITU-T L.1450. Moreover, the Recommendation cautions against including all connected objects (such as cars and refrigerators) in the ICT category, as it would render the definition of ICT meaningless, and create a risk of double counting with other sectors (e.g. the transport and mobility sector in the case of connected cars). This is why the Committee's choice when defining the study's extended scope focused on including only a selection of IoT objects, based on the Recommendation and informed by an opinion from the Arcep/ADEME Experts committee on Measuring the environmental impact of Digital Technologies.

In conclusion, having not been considered by Recommendation ITU-T L.1450 as part of ICT, certain IoT objects (such as remote alarm systems, the eCall modules in cars, lifts, etc.), regardless of their numbers, are not considered in the study.

16 Why did the study not consider the option of a sleep mode for 2G-3G network equipment as a possibility for saving energy during the transition phase, until the networks' actual shutdown?

In the case that interests us for the purpose of examining 2G-3G as of M-Day, only an RRU with the 900 MHz frequency band, with a minimum configuration (a single 2G TRX; a single 3G carrier frequency) per sector will carry all of the services (voice, IoT) for devices that are only compatible with 2G-3G technologies (and not 4G/5G).

[5] https://onomondo.com/blog/2g-3g-sunset/

Different sleep functions for 2G-3G are based on disabling cells, disabling TRX for 2G, disabling 3G carrier frequencies, or activating sleep mode for all RRU based on different criteria such as load. These sleep functions are not compatible with the 2G-3G scenario studied.

Only some more specific 2G-3G sleep functions appear to be useable in the case studied in the memorandum, but energy savings seem too meagre to be considered in the basic case being studied[6].

17

In what way does the study factor in the impact that the shutdown will have on the devices (telephones and connected objects) served by mobile virtual network operators (MVNOs) given their specific positioning and not inconsiderable market share (of around 10% considering all technologies)?

The study assumed that the MVNO pool is connected to their host network operators. In light of the shutdown timetable announcements made by French operators that host these MVNOs, and considering the leeway until the actual date of the shutdown, this assumption is considered reasonable.

18

Why did you only consider the connectivity module when calculating the carbon footprint of 2G-3G connected objects as part of the expanded benchmark scope, and not the object in its entirety? And how do you justify your choice of the value employed in the study concerning these objects' embedded carbon footprint?

As indicated in the detailed memorandum, the study considers devices as being part of the ICT sector, referring to Recommendation ITU-T L. 1450. This Recommendation is not explicit and prescriptive when it comes to the scope of calculating the impact of IoT; this is due, first, to the diversity of the objects' composition profiles and, second, to the difficulty in setting a clear division between the relative share of connectivity and other functions/modules embedded in the object. As result, to assess the objects' embedded carbon footprint, the study proposes confining itself to the footprint generated by connectivity: this share includes the modem and all of the other elements that support the object's connectivity function (e.g. antennas, SIM cards, etc.). Although it supposes an *a priori* restricted scope, this choice is consistent with the characterisation of ICT (whose main principal is connectivity) and creates the ability to limit uncertainties caused by the lack of data for characterising the object in its entirety.

The study retained a value of the embedded carbon footprint based on the publication by T. Pirson and D. Bol[7] (2021), because of the transparency of the modelling and the underlying data, further supplemented by an exchange with T. Pirson. Note that, to the Committee's knowledge, little data on IoT's carbon footprint is available. To summarise, the choice of value retained in the study appears to align with the Committee's approach of seeking to minimize uncertainties over the data used as much as possible, while striving for transparency.

[6] A few percent according to a supplier Committee member, and less than 10% according to an operator who is also a member of the Committee. We can also note that the sensitivity study conducted on base stations' consumption values takes these variations in consumption levels very extensively into account.

[7] "Assessing the embodied carbon footprint of IoT edge devices with a bottom-up life-cycle approach," 2021, Thibault Pirson and David Bol.

Appendix in relation to Question #14

Case study of maintaining a single 2G/3G network

This appendix (referring to Question #14) examines the environmental impact of maintaining a single 2G-3G network versus a scenario where all available 2G-3G networks are switched off and their services migrated to 4G/5G. It should be noted that maintaining a single 2G-3G network could send a signal encouraging the purchase of new 2G-3G terminal equipment (phones and IoT) that is not 4G/5G compatible. This effect, which undermines the environmental impact of maintaining a 2G-3G network, is difficult to assess and has not been taken into account in this evaluation.

The analysis developed in this appendix ignores a number of considerations, notably the exact date from which the single maintained network would come into service, and the (necessarily limited) duration for which this network would be maintained. Not considering the inevitable extinction of this single 2G-3G network minimizes the carbon cost associated with this scenario. The analysis does not go into detail on the technical, economic or legal aspects of implementing such a single network.

Comparative scenario description

In order to assess the environmental impact of maintaining a single 2G-3G network, and using a similar methodological approach already described in the detailed note, we can, for example, compare the following two scenarios:

- **A reference scenario:** where all 4 2G-3G networks have migrated to 4G/5G by a date called Tm4.
- **A scenario with a single 2G/3G network:** where three 2G-3G networks have migrated to 4G/5G at a date called Tm4, while a single 2G-3G network is maintained.

The comparison is made from date Tm4 for the same services, i.e. voice and M2M services that used 2G-3G before the different migrations.

The difference between the two scenarios is the difference between the power consumption of the remaining voice and M2M services on the maintained 2G-3G network and the power consumption of a 4G/5G network for its voice and M2M services from its previously completed migration.

In the scenario where a single 2G/3G network is maintained, it is difficult to predict the exact behaviour of the various users of the 3 networks who will migrate to 4G/5G and whose terminals (smartphones, feature phones, IoT) do not support a network without 2G-3G.

In order to understand the behaviour of these users on the results of this case study, two variants of the scenario with a single 2G-3G network have been considered:

- **Case 1**: all these users decide to stay on the networks that will migrate to 4G/5G, and their various terminals must be migrated to 4G/5G; this is similar to the situation already analysed in the detailed note. So, in this variant, each network that has migrated to 4G/5G retains its 2G/3G traffic on its migrated network.
- **Case 2**: all these users decide to migrate to the single 2G-3G network and keep their terminals. In this case, the associated mobile traffic is transferred to the single network.

Mathematical development and assessment

In the following, the 2 scenarios and their variants are mathematically translated using the assumptions and notations used in the detailed note.

Reference scenario (where all 2G/3G networks have migrated to 4G/5G)

From date Tm4, 4G/5G networks collectively consume (4 x **A**) kWh where **A**, the daily consumption of a 4G/5G network having previously received 2G/3G traffic, is equal to: 24 * ($\mathbf{a_{45}}$ * **M** * MaxVoiceTraffic/$MaxVoiceCapacity_{45}$+ **K** * $\mathbf{b_{45}}$)***Nb_BS** ("$Consumption\text{-}BS_{45}$" in the detailed note multiplied by the number of base stations at date Tm).

These networks have a collective carbon impact equal to (4***Ic**) due to the replacement of terminals / IoT not supporting 4G/5G at date Tm.

Scenario with a single 2G-3G network (case 1)

From date Tm4, the three 4G/5G networks that previously carried 2G-3G traffic collectively consume (3 x **A**) kWh daily.

These networks have a collective carbon impact equal to (3***Ic**) due to the replacement of terminals / IoT not supporting 4G/5G at date Tm.

The remaining 2G-3G network consumes **B** kWh daily, with **B** equal to: 24 ($\mathbf{a_{23}}$ * **M** * MaxVoiceTraffic/$MaxVoiceCapacity_{23}$ + $\mathbf{b_{23}}$) ***Nb_BS** ("$Consumption\text{-}BS_{23}$" in the detailed note multiplied by the number of base stations at date Tm).

Ignoring the inevitable future switch-off of this 2G-3G network, there is no **Ic** impact.

The difference in daily power consumption between the scenario with a single network (case 1) and the reference scenario is equal to: (3 x **A** + **B**) - (4 x **A**) = **B - A**.

The difference in consumption between a 2G/3G network and a 4G/5G network having taken over voice traffic previously in 2G-3G ("**B - A**") while being associated with a replacement of terminals ("**Ic**") is the scenario of the main study. The same conclusions therefore apply, with the difference that the **Ic** avoided cannot be taken in its entirety, since there will be an **Ic'** (which may be greater than **Ic**) when the single 2G-3G network is inevitably phased out in the future.

Scenario with a single 2G-3G network (case 2)

In this case, there is no traffic from 2G-3G services on 4G/5G networks, so 4G/5G consumption is zero for these services. Furthermore, at Tm4, there is no carbon impact from terminals that do not support 4G/5G, as these terminals are now on the single network.

A 2G-3G network consumes **B** kWh per day, with **B** equal to: 24 * ($\mathbf{a_{23}}$ * **M** * MaxVoiceTraffic/$MaxVoiceCapacity_{23}$ + $\mathbf{b_{23}}$) ***Nb_BS** ("$Consumption\text{-}BS_{23}$" in the detailed note multiplied by the number of base stations at date Tm).

The single network consumes daily (based on 2G-3G services all migrating to the single network and no new terminals arriving on this network) **B'** kWh with **B'** equal to:

24 ($\mathbf{a_{23}}$ * **M** * 4* MaxVoiceTraffic/$MaxVoiceCapacity_{23}$ + $\mathbf{b_{23}}$) ***Nb_BS** ("$Consumption\text{-}BS_{45}$" in the detailed note multiplied by the number of base stations at date Tm)

Considering that:

(**B'**-**B**)/**B'** =
(3***a_{23}*****M***MaxVoiceTraffic/MaxVoiceCapacity$_{23}$)/(**a_{23}*****M***4*MaxVoiceTraffic/MaxVoiceCapacity$_{23}$ + **b_{23}**) = (3*540*44%*1.5/152.4)/(540*44%*4*1.5/152.4+585)= 1.2%.

The single 2G-3G network carrying all the 2G-3G traffic of the four 2G-3G networks before the Tm4 date consumes, to within 1.2%, as much as a 2G-3G network carrying the 2G-3G traffic of a single operator.

The daily power consumption surplus between the scenario with a single network (case 2) and the reference scenario is equal to:

(**B'** - 4 x **A**)/(4 x **A**) = **B** x 101.2% / (4 x **A**) -1 = 14.10*101.2% / (4 x 0.08) - 1 =4359%.

With the 2G-3G network maintained, it is possible to avoid (4***Ic**) at date Tm4, which multiplies by 4 the break-even points identified in the reference scenario of the detailed note (Refer to Section 2.3.9). This gain cannot, however, be taken in its entirety, as there will be an **Ic'** (which may be greater than **Ic** due to the possible effect of the announcement of keeping-on a single 2G-3G network on the purchase of new 2G-3G-only terminals) when the single 2G-3G network inevitably comes to an end.