EXECUTIVE REPORT

Connectivity solutions' Life Cycle Assessment

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1. Background and context

This life cycle analysis (LCA) has been prepared as part of the implementation of the **European Taxonomy for Sustainable activities**. Specifically, the analysis involves applying technical screening criteria in order to demonstrate Telefónica's alignment to the climate change mitigation environmental objective.

In 2022, as part of the taxonomy reporting requirements, Telefónica disclosed figures of eligibility for the fiscal year 2021. From 2023 onwards, the company will also report alignment and therefore compliance with the technical screening criteria (TSC) must be demonstrated.

The activity that requires the LCA is one of the main sustainable activities identified by Telefónica within the EU Taxonomy, the "8.2 Data-driven solutions for GHG emissions reduction". The TSC are:

- The ICT[1] solutions are predominantly used for the provision of data and analytics enabling GHG emission reductions.
- Where an alternative solution/technology is already available on the market, the ICT solution demonstrates substantial life cycle GHG emission savings compared to the best performing alternative solution/technology.

Main goals of the LCA study

- **To analyse connectivity from the LCA perspective and check if the approach shows a significant environmental impact considering previous and new data provision technologies.**
- **To demonstrate the potential positive environmental impact of 'Network as a Service'.**

The main objective of the study has been to assess the environmental impact/benefit of ICT solutions, specifically connectivity solutions. To do so, different items across the telecommunications networks have been analysed from an LCA perspective. Telefónica has carried out this exercise following the **ETSI[2] ES 203 199 methodology for environmental LCA of ICT goods, networks, and services**, as proposed in the Taxonomy Climate Delegated Acts. ISO 14040 and 14044 have also been considered as stated in the ETSI methodology.

In this study, Telefónica considers the International Telecommunication Union (ITU) Recommendation (in press) for ICT solution definition: "A system encompassing ICT goods, ICT networks and/or ICT services that contribute to meet a technical, societal or business challenge". Thus, connectivity solutions are ICT solutions by themselves as set out as well in the ETSI 203 199 standard and the EU Taxonomy[3].

Telefónica Spain has been chosen as the first market to develop this LCA study. Due to the existence of all the leading network technologies and the extensive knowledge in substituting and implementing new technologies through design processes, as well as KPIs and measures related to energy efficiency. Other markets are currently being assessed considering each operations' particularities.

It is worth mentioning that the LCA, apart from responding to the Taxonomy TSC, will serve to reinforce Telefónica's net-zero decarbonisation commitments and to support future decision-making processes to keep reducing GHG emissions.

1 Information and Communications Technology.
2 European Telecommunications Standards Institute.
3 According to this ICT solutions/services/networks have been used indistinctly throughout the report.

2. Scope

Considering the background, the scope has focused on data-driven solutions activities provided by Telefónica Spain. Outside of the scope of activity 8.2, there are other activities, such as those related to television broadcasting or data centres, that fall under a different TSC, according to the taxonomy regulation.

The main purpose has been to evaluate environmental impacts and benefits related to the ICT solutions provided by Telefónica.

The scope has been limited to connectivity solutions provided by network technologies in Telefónica Spain and the way to demonstrate substantial contribution has been to compare legacy and new technologies.

In summary, the networks considered with the scope are:

Fixed Network		Mobile Network	
Copper network (xDSL)	Fiber network (FTTH)	2G/3G	4G/5G

The criteria have been established mainly by comparing legacy technologies against new technologies that are currently being invested in across all or most of Telefónica's footprint.

Through these networks, Telefónica Spain offers different added-value digital services to its customers, given directly by Telefónica or by third companies, that can help to reduce their net GHG emissions, as they can provide alternative, less polluting ways to perform an activity.

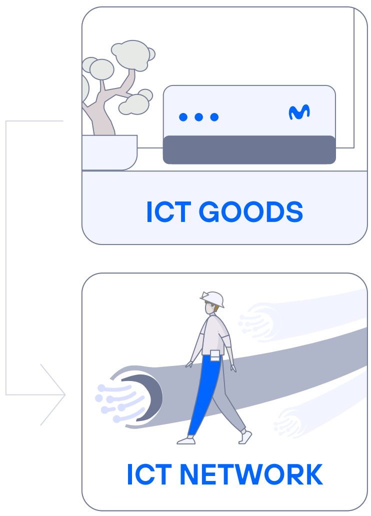
The LCA followed the international standards:

- ETSI ES 203 199 (2015): Environmental Engineering: Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks, and services.
- ISO 14040:2006: Environmental management - Life Cycle Assessment - Principles and framework.
- ISO 14044:2006: Environmental management - Life Cycle Assessment - Requirements and guidelines.

The ETSI 203 199 Standard structures the LCA for ICT in three different levels of product systems, "Goods, networks, and services". As ICT networks are composed of ICT goods the methodology for ICT goods has been the basis for the methodology of ICT networks.

The functional units for this LCA study have been defined as: "1 year of network use"; "1 network access" and "1 PB of data transmitted".

ETSI 203 199 methodology is based in product system levels



3. Setting the scene

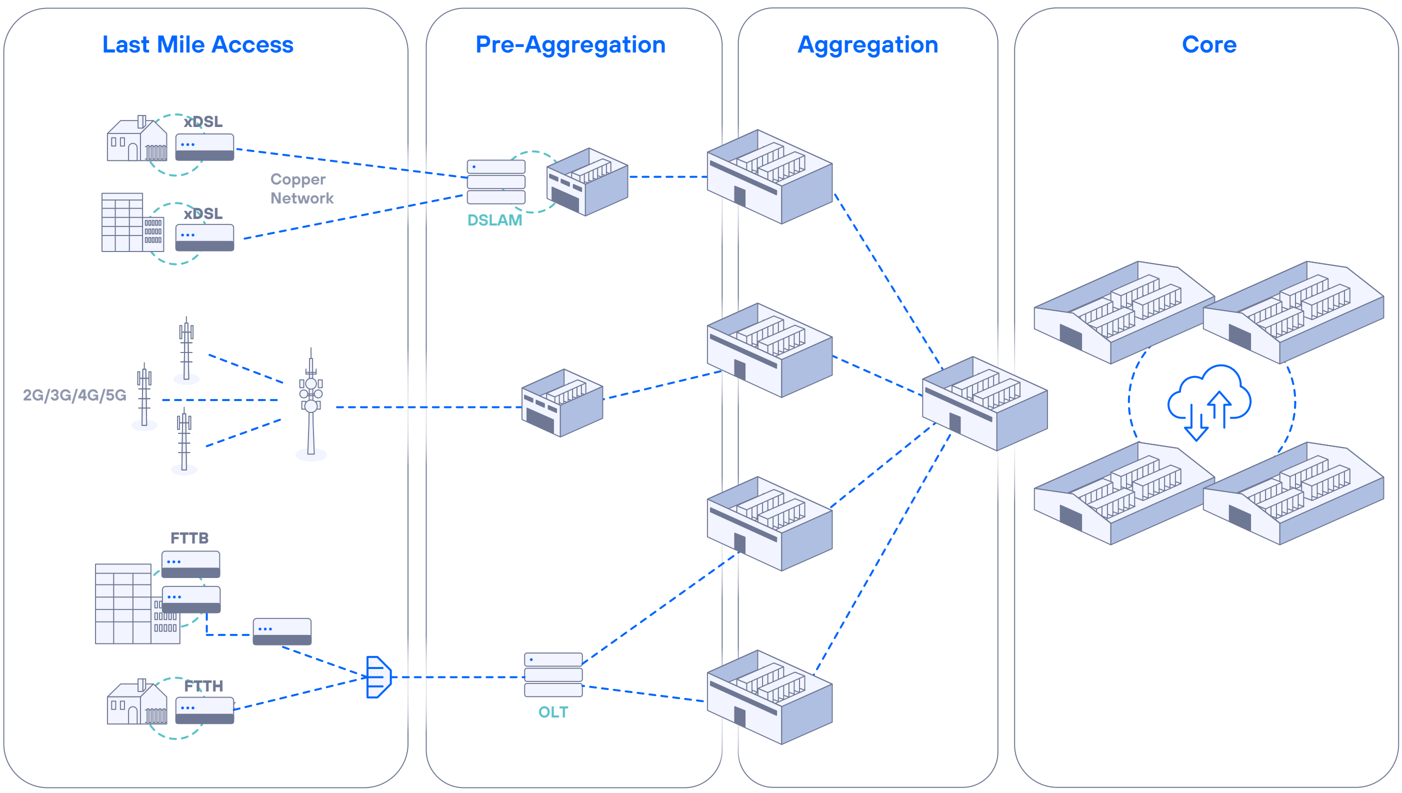
3.1. Network architechture

It is necessary to understand the network architecture in order to process all the information according to the structure and properly allocate and calculate all the impacts. In this regard, it is worth mentioning that four telecommunication technologies analysed in this study share a common network structure. The system (in both mobile and fixed network) has been split in different layers according to the development, design, and its internal management at Telefónica Spain. These are the layers that have been used to conduct the study:

Network Layers

Client	• Network equipment inside the customer's premises.
Fixed Access	• Network last mile used to connect the clients with the aggregation and transport networks.
Mobile Access	• Part of the mobile network between the client devices and the aggregation/transport network. It includes the base stations which connect to the clients using radio frequency.
Aggregation	• Fixed switch sites and other kinds of sites which are concentrated in zonal exchanges. Subsequently, those zonal exchanges are grouped and concentrated in bigger centres.
Transport	• Equipment that allows the transport of data to the core network.
Core	• Critical infrastructure that connects to core platforms, services, the internet, and international networks.

ICT Network structure



The life cycle model has also been structured in four additional areas considering certain environmental aspects within the network boundaries for each of the following areas. A non-exhaustive list of the elements considered is shown below.

The proposed structure has been useful for this study since there are many physical locations (e.g., a specific switch site) where we can find equipment and assets belonging to more than one of the network layers.

Elements included within the system boundaries

Customer	• **Raw materials and manufacturing process needed to build the customer premises equipment.** • **Electricity consumption at the client location, due to customer premises equipment.**
Wires	• **Raw materials and manufacturing process needed for all the wire deployed and the support poles along the network.** • **End of life of these elements.**
Fixed switch sites and base stations	• **Raw materials and manufacturing process needed for the network and support equipment in the different network layers.** • **Construction materials and manufacturing process needed to build the fixed switch sites and the base stations.**
Network operation activities	• **Electricity consumption during the operation of all the network and support equipment at the switch sites and base stations.** • **Fuel consumption during the operation and for vehicle mobility.** • **Refrigerant gases.** • **Water consumptions and waste management at the switch sites.**

3.2. What elements are considered in the LCA?

All direct and embodied emissions have been included in the study, except for those that are out of the scope based on qualitative or quantitative reasons and some of the emissions listed as recommendations in the standard.

Thousands of different items have been take into account in the building of this life cycle model, from the materials used in the manufacture of each of them to the end of their life (cradle-to-grave approach). Energy consumption has also been considered within the model.

Some specific examples of items:

- Base stations for mobile access: towers, antennas, wires, energy consumption, support machinery (HVAC, batteries...), etc.
- Wiring network: all type of cables (fiber/copper), submarine cables, support poles, etc.
- Switch sites: the building materials, the network equipment materials, support machinery, waste generation, electricity consumption, etc.

On the other hand, some items have been excluded according to the standard due to:

- Scope boundaries: equipment that does not form part of Telefónica's network such as devices owned by customers (i.e., smartphones).
- It is a recommendation and not a mandatory item to be considered within the scope according to the standard (i.e., fuel consumed by third parties due to network operation and maintenance activities).
- It has demonstrated a negligible contribution towards the overall results (i.e., transport stage of the installed equipment from the providers to the switch sites).

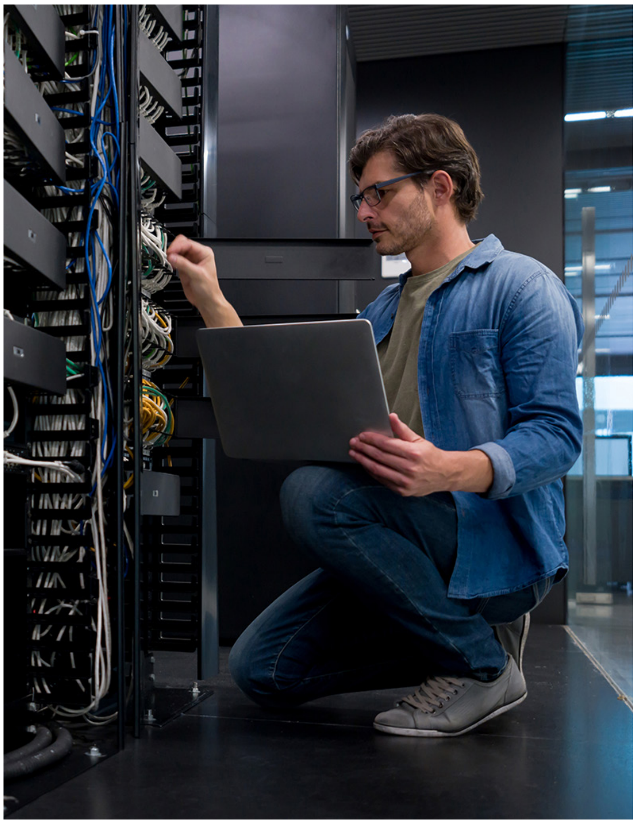
3.3. Data processing and allocations

The data-gathering process has started with the need to get the most accurate input data for the life cycle stages of the ICT goods. This process has relied on multiple data sources, depending on components, as well as if the information has been managed internally or externally, and the materiality of the data. For example, to address the impacts related to the raw material acquisition and manufacturing efforts for the different network or support equipment installed, Telefónica has gathered primary data information directly from manufacturers. When doing calculations about electricity impact, even though Telefónica consumes mostly renewable energy, information about the Spanish electricity market has been considered for the LCA.

According to the collecting process, each source has been classified as primary or secondary data and it has had an impact on the quality of the data during the audit process.

Although the main data points have been extracted from primary sources, some assumptions have been needed to allocate common items across networks. Due to the product system nature, many network elements are shared between more than one of the analysed networks. Therefore, the allocation procedures followed were a key factor when calculating the results in this LCA. Some examples of allocations considered:

- Equipment shared among networks.
- Fixed switch sites to each network.
- Third party base stations regardless of the ownership of the site.



4. Life cycle impact of networks

New connectivity solutions have a lower environmental impact than legacy networks, which allows for a more efficient provision of data.

4.1. Fixed networks

From a fixed network perspective the main outcome in relative terms has been that data traffic and access capacity of the fibre network results in significantly lower environmental impacts when compared to copper.

FTTH environmental impact per PB is 18 times lower than copper, and 5 times less per access.

These findings reinforce how new technologies has significantly reduced their environmental impact compared to previous technologies.

As of 2021, energy consumption per unit of traffic has been reduced up to 86% since 2015 and the percentage of renewable electricity consumption in own facilities is 79% at a global level. In Spain, renewable energy represents 100% of the owned electricity consumption. The results of this LCA would have been much higher without our prior efforts to increase energy efficiency, the design of new technologies and the deployment and investment in renewable energy (through Power Purchase Agreements, self-generation systems or the purchase of certificates of renewable origin). If we only take into account energy consumption based on the energy mix in Spain (instead of the real renewable energy consumption), the LCA would have been around 30% higher for the total carbon impact.

As an example, for FTTH operation activities environmental impact would have increased from 0.0024 to 0.0115 (tn CO_2eq/access) without renewable electricity.

Telefónica's plans to accelerate the rollout of FTTH connections and continue the shutdown of legacy fixed networks through the closure plan started in 2016 and the decommissioning of all copper plants by 2025. Thus, it is to be expected that the total environmental impact of copper technology will be progressively reduced until its disappearance.

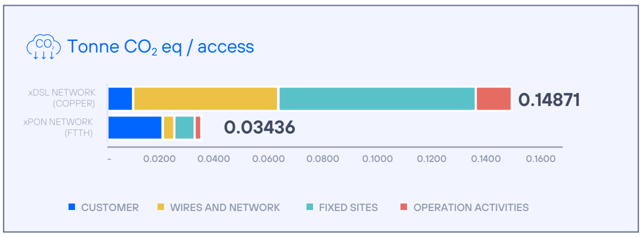
According to the figures, the two major impacts of copper take place at the switch sites and in the wire network.

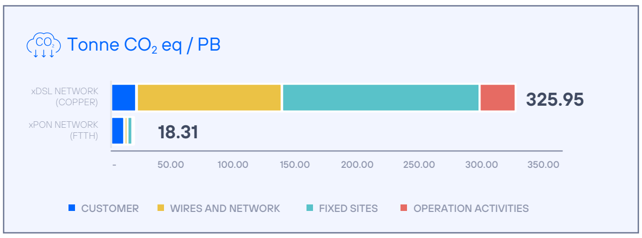
In the case of FTTH, the biggest impact in both cases (per PB and access) corresponds to the energy consumption of Customer Premises Equipment (CPEs) as the operational activities are based on renewable energy as mentioned before. To reduce the environmental impact of these devices, Telefónica promotes circularity, and reuses a high percentage to reduce material consumption, and is continuously working on its ecodesign with the aim of improving energy efficiency. At the current time, Telefónica's HGU (Home Gateway Unit) consumes 30% less energy than our previous solutions.

4.2. Mobile networks

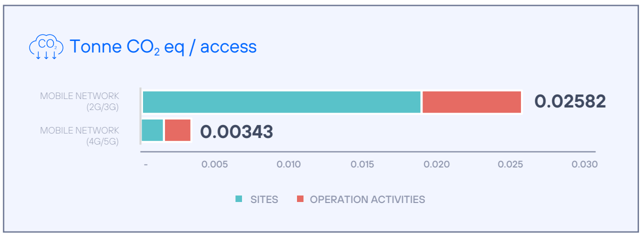
Regarding mobile networks, 4G/5G technologies have shown a lower environmental impact compared to 2G/3G. This is associated with a more efficient and lower energy consumption during the transport and processing of data in the network system.

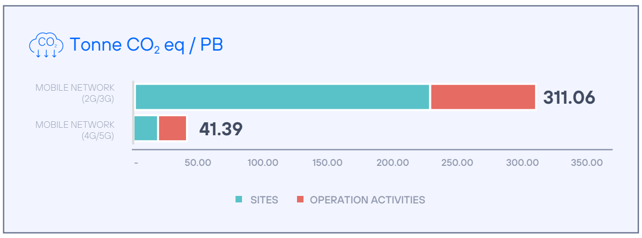
Fixed network environmental impact





Mobile network environmental impact





4G/5G environmental impact per access and per PB is more than 7 times lower than 2G/3G.

Telefónica's efforts to increase energy consumption from renewable sources has impacted positively on the 2021 LCA. Without renewable energy, results would have been 58% and 127% higher for 2G/3G and 4G/5G respectively. As an example, for 4G/5G operation activities environmental impact would have increased from 0.0019 to 0.0062 (tn CO_2eq/access) without renewable electricity.

The main environmental impact of the 4G/5G network arises from network operations activities and assets at the bases stations, as in the case of the 2G/3G network. As mentioned above, customer premises equipment have not been considered under the mobile networks scope as they are not part of Telefónica's network (i.e., smartphones are owned by customers).

From an environmental perspective, fibre and 4G/5G technologies shall be gradually promoted across the network over legacy technologies.

According to the strategic plans on mobile technologies, Telefónica Spain will keep investing to transform mobile networks (e.g., evolving from 2G and 3G to 5G capacity) and modernising radio equipment thanks to 5G deployment with new technologies much more efficient in power consumption.

5. Lessons learnt and takeaways

Any significant study like this one also provides a detailed level of management information, as well as thousand of new data that can be used as inputs for future actions and decision-making processes. Starting with the positive outcomes, Telefónica now has a better understanding of its network from an environmental perspective and will use that knowledge to reduce the current and future impact of connectivity solutions in all markets in which operates.

It is also relevant to highlight the considerable amount of time, resources and data that have been required to complete this analysis. During a year, more than 100 people across Telefónica Spain, as well as external experts, have been involved, providing information, tracing data, getting in touch with suppliers to obtain primary data, working on the assumptions, etc. Thousands of buildings, equipment, and km of wires have been processed in the database to become CO_2eq.

The usage of renewable electricity has reduced the carbon impact of the networks in operational activities by more than 70% for optical fibre and 4G/5G.

A major proportion of the time spent has been invested in asking for supplier's data. The complexity and the lack of information concerning the LCA, the knowledge of ICT goods, publicly available data, and regulation on these topics, have been the main reasons for the efforts needed. In this sense, resources will be needed to cover all the gaps to avoid every single company to dedicate this relevant exercise to get verified LCA results on ICT digital solutions.

From the EU Taxonomy implementation perspective, the scope and boundaries of the study have been defined trying to cover the technical screening criteria. However, there is still no clarity regarding some relevant requirements within the legal text such as the lack of definition for ICT solutions, substantial contribution or how to interpret 'alternative solutions/technology', as well as the difficulty to demonstrate the 'predominantly aimed at' when the LCA has not been conducted or demonstrated during the alignment exercise. Any clear statement related to the taxonomy activity of data driven solutions or any of the gaps identified, would be useful in order to obtain comparable results.

Annexes

A. LCA software, database and environmental impact methodology

The network environmental evaluation models have been created using SImapro 9.0 software, from Pre Consultants.

All the life cycle inventory for materials and processes have been taken from the Ecoinvent 3.8 cut-off version database (published on 2021). Ecoinvent is one of the most well-known LCA database worldwide used in more than 40 countries.

This database contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services.

The environmental impact factors for the carbon footprint have been obtained from Appendix 8.A-Lifetimes, radioactive efficiencies and metric values, of the report "Climate Change 2013".

The Physical Science Basis Working Group I contribution to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change". On that report, the factors according to the GWP 100 years method have been selected.

B. External verification

A verification of the data used for the LCA as well as the alignment with ETSI requirements have been performed by AENOR INTERNACIONAL, SAU (Asociación Española de Normalización) in June 2022.

AENOR had access to Telefónica Spain's facilities and to more detailed information on the input data used, the LCA software model and the calculations made.

In addition, AENOR has developed a verification procedure with the criteria for the evaluation of Telefónica LCA that covers the requirements from the verification point of view for each phase of the LCA process in accordance with the methodology and standards considered in the study.

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C. Additional detailed information

Detailed results of the LCA per network technology

Copper Network	Kg CO_2eq / Access	Tonne CO_2eq / PB
Customer	9,49	20,80
Wires and Networks	53,42	117,08
Fixed Sites	72,59	159,10
Operation Activities	13,24	29,01

Fibre Network	Kg CO_2eq / Access	Tonne CO_2eq / PB
Customer	20,48	10,91
Wires and Networks	4,12	2,20
Fixed Sites	7,39	3,94
Operation Activities	2,37	1,27

2G/3G Network	Kg CO_2eq / Access	Tonne CO_2eq / PB
Wires and Networks	0,09	1,12
Fixed Sites	18,94	228,19
Operation Activities	6,79	81,75

4G/5G Network	Kg CO_2eq / Access	Tonne CO_2eq / PB
Wires and Networks	0,01	0,09
Fixed Sites	1,57	18,91
Operation Activities	1,86	22,39

Complementary information of networks´ energy consumtion in operation activities

Energy consumption from operation activities	kWh / Access	kWh / PB
Copper Network	220	481.784
Fibre Network	45	23.772
2G/3G Network	83	1.000.628
4G/5G Network	24	293.086

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