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# The Impact of Networks in the Greenhouse Gas Emissions of a Major European CSP

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**Abstract**—Assessing the overall carbon footprint associated with the entire value chain of a mobile operator can be a tedious task. The evaluation of greenhouse gas (GHG) emissions in the information and communications technology sector is done with a substantial uncertainty due to the use of monetary emission factors. This paper analyzes the progressive implementation of a physical methodology based on physical emission factors and life cycle assessment of each product/service associated with a typical fix and mobile operator. The GHG Protocol divided greenhouse gas emissions into scopes. Scope 1 and 2 emissions primarily involve gas and fuel ignition (scope 1) and electricity generation for operations (scope 2), while scope 3 emissions consist in other indirect emissions, including the emissions of suppliers and clients. Many operators are committed to reduce their scope 1, 2, and 3 emissions in compliance with the European climate law, under which European countries must cut greenhouse gas emissions by at least 55% by 2030. This study presents an applicable methodology which examines different categories of greenhouse gas emissions associated with the activities of a communications service provider, and identifies the factors influencing energy consumption in networks. Various fixed and mobile connectivities are modeled to assess their energy consumption, and levers to reduce emissions from networks and devices are explored.

**Index Terms**—GHG Footprint, Networks, Life Cycle Assessment, GHG Protocol, Net Zero Carbon, Emission Factor

## I. INTRODUCTION

The Information and Communications Technology (ICT) sector encompasses a broad range of activities, including the production of end-user devices, data centers, fixed and mobile telecommunication networks, and software applications among other services. The impact of these activities on Greenhouse Gas (GHG) emissions has been mainly approached from two angles: direct impacts, or first order effects, capturing the footprints of ICT infrastructure and devices from production and usage phases to disposal and end-of-life treatment, and indirect, or second order effects, related to the implementation of an ICT-enabled solution [1] [2]. According to [3], the ICT sector accounts for approximately 1.5% to 4% of global GHG emissions, with a significant portion attributed to the manufacturing of devices. In the french digital sector [4], around 78% of the GHG emissions is linked to devices (computers, tablets, screens, phones, etc.) compared to 6% and 16% associated with networks and data centers respectively. In [5], Malmodin and Bergmark relied on currently available data regarding GHG emissions reductions achieved by various ICT

solutions and investigates the potential global reductions that can be achieved by 2030. The potential of these solutions in helping non-ICT sectors in reducing their emissions is known as the enablement effect [6] and can be assessed following the method introduced by the International Telecommunication Union (ITU) in its ITU-T L.1480 recommendation [7]. The principles and framework of Life Cycle Assessment (LCA) approach were introduced in [8]. Recently, Bergmark and Zachrisson explored in [9] the need to consider the Planetary Boundaries framework [10] in LCA of ICT.

A large amount of research works and efforts have been dedicated to tackling the complex problem of assessing the GHG footprint of telecommunications activities. In this paper, our aim is to contribute to this collective reflection by presenting a carbon footprint assessment that encompasses the activities of a major telecommunication operator. The goal is to provide the reader with keys to understand the various sources of GHG emissions caused directly or indirectly by a Communications Service Provider (CSP), present a comprehensive methodology that is applicable by other operators, and identify potential levers and initiatives for emissions reduction.

This paper is organized as follows: In Section II, we review the carbon footprint assessment methodology in compliance with the GHG protocol. In Section III, we discuss the network electricity consumption as part of scope 2 emissions. As for scope 3 emissions, we focus on upstream and downstream GHG emissions. We also present the results of our modeling of the carbon footprint of various connectivity solutions. In Section IV, a comprehensive analysis of our results is provided along with more details related to different emission categories. We highlight the levers to reduce the carbon footprint of a telecommunications operator in Section V, and finally summarize our findings in Section VI.

## II. METHODOLOGY

Assessing GHG emissions in the telecommunications industry comes with several challenges including data availability and accuracy especially from different suppliers in the value chain, compliance with international standards and regulations, precision of emission factors, and so on. An accurate quantification of carbon emissions allows CSPs to identify areas

of improvement, set reduction targets, and implement sustainable practices. In the following, we analyze the methodology used in the assessment and how we attempt to address the mentioned challenges.

### A. GHG Protocol

The GHG Protocol [11] established global standards for organizations across various sectors to account for and report their emissions. The report introduced the concept of categorizing GHG emissions into scopes, namely scopes 1, 2, and 3. Several subsequent reports have also been released with sector-specific guidance and updates [12] [13]. These scopes serve as a framework to quantify different types of emissions as follows:

- Scope 1: Direct GHG emissions from sources that are owned or controlled by an organization. These emissions are produced from activities such as combustion of fossil fuels in stationary sources (e.g., boilers, furnaces) and mobile sources (e.g., vehicles, fleets), process emissions, and fugitive emissions (e.g., leaks from equipment).
- Scope 2: Indirect GHG emissions from purchased electricity, heat, and steam. These emissions occur outside the organizational boundaries but are associated with the organization’s activities.
- Scope 3: Other indirect GHG emissions resulting from sources that are not owned or controlled by the organization but are associated with its value chain. These emissions can be generated from activities such as business travel, employee commuting, transportation and distribution, procurement of goods and services, waste disposal, and upstream and downstream activities.

For a typical CSP, Scope 1 emissions mainly correspond to gas and fuel ignition, while scope 2 emissions are due to electricity generation by energy suppliers to satisfy operations’ electricity needs, and Scope 3 emissions consist of all the other emissions, including those of its suppliers and clients.

### B. Emission Factors

A monetary emissions factor is a coefficient that converts an estimate of financial data into an estimate of the quantity of GHG emissions. This is expressed as an average emission rate in kg CO<sub>2</sub> equivalent (kg CO<sub>2</sub>e) per euro spent. Thus,

$$\text{GHG Emissions} = \text{Monetary Value} \times \text{Monetary Emissions Factor}, \quad (1)$$

where the monetary value represents the financial data associated with a specific activity or expenditure. Although this method is not the most precise, it has gained widespread adoption due to its ease of conduct, high replicability, and the homogeneity of the analysis results. To improve the accuracy of the estimated emissions and reduce the uncertainty of the monetary methodology, a physical assessment based on physical emission factors should be applied. Such assessment requires the LCA of each product or service. A physical emission factor is expressed as an emission rate in kg CO<sub>2</sub> equivalent per physical allocation such as volume, quantity,

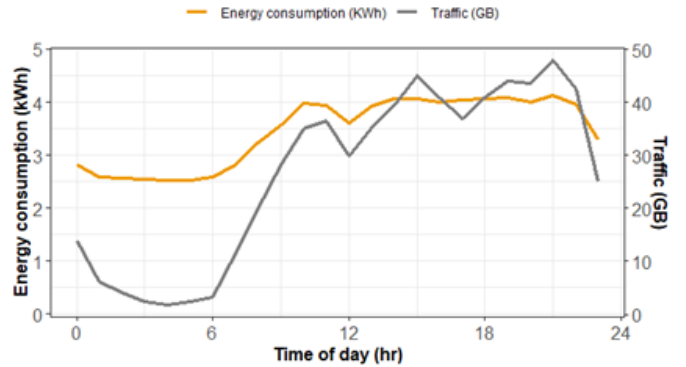


Fig. 1: Traffic and energy consumption of a characteristic European RAN provider 2G/3G/4G base station, over a typical 24-hour period.

unit or mass. A physical methodology is more reliable, and better reflects the real emissions as it allows specificity and differentiation of each product or service by supplier, country of manufacturing, production techniques, raw materials, and so on. Physical emission factors consider the entire lifecycle of a product or service, including the emissions associated with raw material extraction, manufacturing, transportation, use, and disposal. This comprehensive lifecycle perspective helps in identifying emissions throughout the supply chain and supports informed decision-making regarding emission reduction strategies. Monetary emission factors, by focusing primarily on financial data, may not adequately capture emissions from all lifecycle stages.

Orange collaborates with *Carbone 4* [14], a reference consultancy firm regarding energy and climate challenges, on the calculation of its scope 3 emissions and providing yearly updates. Carbone 4 estimated the 2018 GHG emissions of Orange based on monetary emission factors. This approach provides a global idea about the emissions categories. Since then, a physical assessment methodology based on physical emission factors is being progressively developed and implemented. For 2021 figures, the assessment of Orange emissions has been partially conducted using monetary emission factors (55% of purchases with the monetary approach vs 45% with the physical approach for 2021). Substantial uncertainty afferent to monetary emission factors and other extrapolations remains.

### C. Networks Emissions

The GHG emissions associated with networks primarily arise from the energy consumption of network equipment during production and use phases. These emissions can be attributed to both direct and indirect sources. The use phase emissions are commonly classified as scope 1 (e.g., emissions from generator set fuel) and scope 2 emissions (emissions of electricity consumption), whereas the manufacturing phase as scope 3 emissions. It’s important to note that scope 3 emissions are not limited to the manufacturing of network equipment and cover a larger spectrum of emissions categories like the

purchase of services, the purchase of customers equipment (manufacturing), and the use of sold equipment. In the current reporting method, emissions are reported for the year in which they occur. This means that in the emissions report for manufacturing in year N, we include the emissions of all equipment purchased during year N (without amortization). Use phase emissions represent the electricity consumed in year N for all installed equipment (not limited to equipment purchased in year N). Installation emissions correspond to installations carried out in year N, and so on. Energy consumption is assessed for mobile and fixed networks as follows:

1) *Mobile Networks Emissions:* As energy consumption in mobile networks is mostly carried out by the Radio Access Network (RAN), our analysis will only focus on RAN energy consumption, which takes place at the base stations. Mobile networks emissions are linked to coverage requirements of passive and active equipments, and capacity requirements in manufacturing and use phases. Long-term increases in traffic requires adding new Radio Units (RUs) to meet capacity needs. Thus, we make a distinction between RUs for coverage and RUs for capacity based on the frequency at which a given Radio Unit (RU) operates. So-called coverage bands correspond to frequencies up to 900 MHz, while capacity bands correspond to frequencies above 900 MHz. It pertains to the physical consideration that lower-frequency bands have a higher range at the expense of the throughput (low-frequency spectrum being narrower), while higher-frequency bands are larger in terms of spectrum (entailing a bigger throughput) but with a smaller range.

2) *Fixed Networks Emissions:* Fixed Access Networks (FAN) consist mainly in three networks, at least in France: Public Switched Telephone Network (PSTN, known in French as Réseau Téléphonique Commuté or RTC), Digital Subscriber Line (DSL), both of which are supported by copper, and Fibre to the Home (FTTH). We will focus on the use phase emissions of the access part of fixed networks, namely FANs, as it represents the biggest share of energy consumption.

D. *Modeling energy consumption of various connectivity solutions (xDSL, FTTH, FTTO, and so on.)*

We have modeled the CO<sub>2</sub> impact per user (or other relevant unit of work) of several connectivity technologies: xDSL, FTTH (and FTTH Pro), Fiber to the Office (FTTO) and mobile networks in France based on scope 1, 2 and 3 estimations for year 2021. The general principle of modeling is as follows:

- Collect data and compute the entire carbon footprint of the equipment providing a given connectivity
- Share this carbon footprint between the subscribers in a fair manner.

The method of modeling primarily consisted of a “top-down” approach, where the unitary impact is the total impact of a network divided by the appropriate unit of work. We modeled the manufacturing phase and the use phase of the equipment of every connectivity. The perimeter is the core, aggregation, and access networks. Equipment mutualized between two or more connectivities had their carbon impact split between the

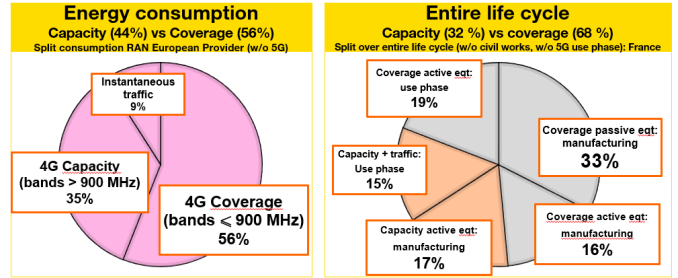


Fig. 2: Capacity and traffic versus coverage for energy (left) and total life cycle CO<sub>2</sub> (right) in RAN. Long-term traffic increases cause additional CO<sub>2</sub> emissions due to necessary capacity upgrades.

connectivities following the adequate unit of work (usually traffic). Gateways are not included in the models. For a given year, the main sources of data are the purchase of equipment for the manufacturing phase (multiplied by adequate manufacturing emission factors) and measured energy consumption for the use phase.

In the following, we present the results of our assessment of GHG emissions from scopes 1, 2, and 3.

### III. RESULTS

Companies across various sectors do not have the same level of control over scope 3 emissions as they do over scopes 1 and 2 emissions, yet for example, Orange scope 3 emissions make up approximately 80% of the entire footprint based on 2021 figures and emission factors. In 2020, scopes 1 and 2 represented almost 1.3 Mt CO<sub>2</sub>e<sup>1</sup> and scope 3 represented around 6 Mt CO<sub>2</sub>e, i.e., 83% of Orange emissions. More details can be found in Table II in Appendix A.

#### A. Weight of networks

As a telecommunications company, the core business revolves around operating telecommunication networks and providing telecommunication services. However, various diversification strategies have led Orange to offer additional services, such as television and entertainment, cybersecurity, device distribution, banking, dedicated B2B services, and more. It is estimated that network-related emissions accounted for 50 to 60% of Orange’s total emissions in France in 2020. The study focuses on France as the data is more readily available compared to other affiliates. Emissions related to the network primarily stem from equipment manufacturing, the use phase (electricity consumption) of the equipment, and installation and maintenance activities.

While network construction and operation constitute most of the carbon footprint of Orange in France, it only represents a small share of the GHG emissions ( 5%) of the French digital sector as a whole, compared to data centers (16%) and devices

<sup>1</sup>CO<sub>2</sub>equivalent, or CO<sub>2</sub>e, is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP)

(78%) according to a 2022 study from ADEME and ARCEP (French telecommunications regulator) [4].

### B. Drivers of Network Energy Consumption (Scope 2)

In France, figures of Orange for 2021 indicate that the RAN represented 94% (813 GWh) of all mobile network energy consumption (867 GWh). We study the impact of traffic on a daily timescale, and the impact of capacity on a yearly timescale on RAN energy consumption in the base stations.

1) *Mobile networks - Impact of traffic on the daily timescale:* The energy consumption of a base station varies throughout the day and is correlated with traffic. Fig.1 displays the hourly electricity consumption and hourly traffic of a representative 2G/3G/4G base station of Orange in France throughout a regular day. The diurnal/nocturnal traffic pattern is characteristic. The site energy consumption (which includes the technical environment) increases at the same time the traffic does, except there is still a significant energy consumption at close to zero load.

2) *Mobile networks - Impact of capacity on the yearly timescale:* Capacity RUs, i.e RUs added to meet capacity requirements due to traffic increases, consume energy. The energy consumption of the capacity RUs is considered as traffic-induced, as the installation of these RUs was justified by long-term traffic increases or traffic forecast. Based on a study of a European RAN provider sites in early 2022, the energy consumption (5G excluded) is decomposed as presented in Fig. 2 (left panel). We can see that coverage (understood as zero-load consumption of  $\leq 900$  MHz RUs) corresponds to 56% of energy consumption while capacity (zero-load consumption of  $> 900$  MHz RUs) and traffic as in section III-B correspond to respectively 35% and 9% of energy consumption. Fig. 2 (right panel) presents the split of scope 2 and 3 emissions for mobile networks of Orange in France between coverage on the one hand and capacity/traffic on the second hand (5G and civil works excluded). Over this perimeter, coverage represents 68% and capacity+traffic represent 32%.

3) *Fixed networks:* The energy consumption of FANs scales directly with the number of switched-on ports. The current architecture of fiber-supported FANs in France is 1:64 with Gigabit PON (GPON), meaning that up to 64 subscribers share 1 Gbps on one optical tree whose root is one port. Unlike RAN, no significant correlation has been witnessed between passed traffic and FAN energy consumption. Regarding customer-premises equipment (CPE), the most contributing factor is the state of the interfaces (Wi-Fi, Ethernet...). Switching off Wi-Fi does entail reduction in CPE energy consumption, by up to 20-30% depending on the models. Additionally, traffic on the Wi-Fi interface causes an overconsumption that is linear with the throughput: +1.3 W every 100 Mbps for the 5 GHz band. In other fixed network segments (aggregation, core), traffic increases play a role on the dimensioning of the equipment, but the magnitude of the considered energy consumption is fairly small (less than 10% of all fixed networks energy consumption).

### C. GHG emissions for various B2C/B2B connectivities

The results of our modeling are displayed in Table I. Energy consumption of fixed connectivities does not depend on traffic, while the consumption of mobile connectivity has a dependency on traffic. This is consistent with the reasoning presented in section III-B. XDSL and FTTH have close GHG yearly emissions (respectively 10.5 kg and 9.4 kg per access).

TABLE I: GHG emissions for various B2C/B2B connectivities for one year on Orange networks in France.

B2C/B2B Connectivities	GHG Emissions (Kg CO2e/access/year)
xDSL	10.5
FTTH	9.4
FTTH Pro	9.4
FTTO	113 $\leq$ 1 Gbps 169 $>$ 1 Gbps
Mobile networks	20 g/GB*X GB + 2.5

### D. Other Indirect GHG emissions of Orange (Scope 3)

An internal assessment of Orange scope 3 emissions showed that the 2021 scope 3 emissions of Orange Group represent 6373 kt CO2e and are in majority caused by four main categories:

- Purchase of services (32% of Orange Group scope 3 emissions), such as installation, civil works, maintenance, subscribers connection, services insurances, and so on,
- Purchase of network equipment (28%), excluding customer premises equipment.
- Purchase of customer equipment (13%), including customer premises equipment, smartphones, and so on,
- Use of sold products (8%): including customer premises equipment, smartphones, and so on.

The importance and the ranking of these four factors vary from one country to another, depending mainly on the country's electricity mix. For example, the largest emission category is the purchase of services in France, the purchase of network equipment in Spain, and the use of products sold to customers in Poland and Egypt (carbon-intensive countries).

In the following, we discuss the previous results and further detail the different emission categories.

## IV. DISCUSSION

Traditionally, the digital sector is split into three categories: User devices, networks, and data centres/service platforms. Thus, there is an apparent discrepancy between the weight of the networks in the footprint of Orange (50-60%) and in that of the digital sector (5%). Three considerations help explain this discrepancy: 1) Orange is not an Over-the-top (OTT) service provider 2) Orange in France operates a very large share of all fixed networks (well above its market share) 3) devices sold by Orange (mostly smartphones and routers) are not representative of the typical French market for devices (computers and TVs) which tend to represent a bigger absolute impact according to [4].

### A. Scope 2 Emissions

The total RAN energy consumption mainly increases with the growth of the number of sites, generally linked with coverage extension either to comply with legal requirements or to follow business incentives to expand the market of Orange. Energy consumption is also correlated to traffic in an “Ax+B” model, in which B corresponds to zero-load energy consumption and is relatively high. Most of the electricity consumption is due to this “base” consumption (national average of European RAN provider: 80-90%)<sup>2</sup>, and only a small part is due to traffic (10-20%). However, to some extent, the zero-load energy consumption of base stations indirectly depends on the traffic capacity as well, or to be more precise on dimensioning. In fact, long-term increases of traffic, over the course of one year or more, can cause the traffic to reach the limits of the dimensioning of given RAN sites, which can detrimentally affect the quality of service. Capacity upgrades which typically materialize as additional RUs, are then implemented to offer more frequency bands for communications. Theoretically, additional traffic-induced capacity requirements could be met by site densification, but the complexity of acquiring new macro sites in addition to network re-planification largely prohibits this solution in practice. The same differentiation between capacity and coverage can be applied to scope 3 emissions pertaining to network capital goods (installation and maintenance). The rationale for network capital goods emissions is to count manufacturing of passive equipment (poles, passive antennas, and so on) and of coverage RUs as “coverage capital goods emissions” and manufacturing of capacity RUs as “capacity capital goods emissions”.

The energy consumption of FANs is highly related to switched-on ports. For copper local loops (RTC, DSL), one port corresponds to one subscriber. Until recently, many ports whose corresponding subscribers terminated their RTC/DSL plan were not switched off, entailing a waste in energy consumption. Fibre-supported FANs are more efficient due to Passive Optical Network (PON) technology especially that each port corresponds to more than one subscriber due to optical splitters along the local loop.

As for fixed networks, fixed connectivities energy consumption does not depend on traffic, while mobile connectivities energy consumption does. In the following, we discuss emissions of various connectivities.

### B. B2B/B2C Connectivities

The fact that XDSL and FTTH have close GHG yearly emissions can appear paradoxical especially that fibre has lesser impact than copper. In fact, the comparison between the emissions of XDSL and FTTH considers energy consumption only. Although energy consumption per subscriber is three times lower for fibre FAN than for xDSL FAN, the ratio

<sup>2</sup>This study concerns only one vendor and it would be interesting to compare the results to those of other vendors’ RANs. However, we do not have enough metering data from other providers to replicate the study.

decreases to only two when aggregation and core network are taken into account. While fixed connectivities energy consumption does not directly depend on traffic, in practice, for the core and aggregation networks, traffic distribution is adjusted based on demand because FTTH subscribers consume 45% more traffic than xDSL subscribers (in 2020: 130 GB/month/xDSL customer, versus 189 GB/month/FTTH customer, average figures of Orange in France). In our study, we analyzed the entire life cycle of the equipment, including the manufacturing phase, without distinguishing between specific types of equipment such as fiber and copper. We combined manufacturing emissions for xDSL and FTTH equipment into a single value for fixed B2C network equipment. Indeed, the fibre local loop has been greatly rolled out in the studied year (2020), in comparison to the legacy copper local loop. As the method of computation is based on the purchase of equipment for a given year and not on the total installed equipment, it is hard to compare a mature network to a network being actively rolled out. Because the share of manufacturing fixed equipment is substantial (8.2 kg CO<sub>2</sub>e/access, mostly due to passive fibre local loop equipment manufacturing), the footprints of xDSL and FTTH evaluated in our study are similar. However, on top of the aforementioned greater energy efficiency per subscriber for fibre, there are indications based notably on passive equipment (cables) that fibre manufacturing has a lower impact by unit of work (linear metre) than copper. In the following, we analyze the different categories of scope 3 emissions.

### C. Scope 3 Emissions

As presented in section III-D, other GHG emissions are indirect and correspond to four main categories.

1) *Purchase of network equipment (28% of Orange scope 3 emissions)*: Network equipment is purchased for several reasons: roll-out of new networks, expansion of existing networks, upgrade of dated or obsolete equipment, maintenance. Sorting purchases in these categories would help prioritize future purchases and possibly reduce associated emissions. If a given country is significantly deploying a network in a given year, it can skew the overall perception of network equipment purchase emissions. For example, the purchase of FTTH equipment for deployment in France has caused significant GHG emissions, but the future impact of the purchase of FTTH equipment will be much smaller as deployment slows down. The LCA of active equipment often reveals a striking contrast between scope 3 emissions from network equipment purchases and scope 2 emissions. This disparity can lead to misconceptions about the relative impact of equipment use-phase emissions versus manufacturing emissions. On the one hand, manufacturers claim that most impacts are during the use phase, based on LCAs of active equipment. Indeed, in LCAs, active equipment usually has an 80/20 use-to-manufacturing emissions ratio, even when powered with low-carbon electricity as in France<sup>3</sup>. On the other hand, when looking at

<sup>3</sup>The use phase emissions are the electricity consumption multiplied by the emission factor of electricity used to power the equipment.

overall network-related emissions, our internal study (available on demand) suggests that the use-to-manufacturing ratio is reversed: 25/75 for France in 2020. (Average for Orange group is 50/50 and 68/32 for Poland, a country with a high-carbon electricity mix.) This apparent paradox is solved considering three principal reasons, listed here in order of significance:

- Passive equipment (cables, poles, cabinets, and so on) contributes to scope 3 emissions (manufacturing, deployment, maintenance) but does not correspond to any electricity consumption (no impact on scope 2).
- Actual conditions of use may differ from LCA hypotheses (notably in terms of life duration or 'intensity' of use).
- Electricity emission factors differ from LCA practitioners' databases and what Orange uses for accounting. Indeed, some emissions related to electricity generation are being included in LCAs but not accounted for as Scope 2 emissions by Orange, following guidelines from the GHG Protocol<sup>4</sup>. This is an accounting inconsistency not corresponding to actual GHG emissions, but it can explain differences of up to several dozens of percentage points. Additionally, LCAs typically have no way of considering changes in electricity sourcing (e.g., power purchase agreements with renewable energy).

Furthermore, LCAs typically do not consider the frequent software upgrades delivering energy consumption optimizations (such as sleep modes on RAN equipment) that occur during the lifetime of a piece of equipment. On the contrary, these software upgrades result in energy savings which are measured and accounted for in Orange energy consumption and GHG emissions. Fundamentally speaking, the outcome of comparing use-phase and manufacturing emissions for Orange network equipment should be interpreted carefully because it typically compares use-phase emissions (from electricity consumption in a given year) for the entire installed equipment, with manufacturing emissions from the purchase of equipment in one year. Yet, this comparison remains a useful endeavor, as companies are expected to identify and tackle their largest addressable emissions first.

*2) Purchase of services (32% of Orange scope 3 emissions):* The purchase of services is a wide category that encompasses everything that is delegated to subcontractors, from tertiary building management to the construction of networks and connection of clients to the network. As shown earlier, the purchase of services accounts for 32% of Orange Group scope 3 emissions. Around 41% of total services emissions are related to networks. They are mainly referred to as "FieldOps" emissions. For fixed networks, in France, FieldOps emissions are mainly caused by the civil works for site construction (40% of fixed networks FieldOps emissions), FTTH deployment (30%) and subscriber connections (15%). For mobile networks, FieldOps emissions are mainly caused by wireless networks infrastructure construction (62%

of mobile networks FieldOps emissions). Emissions related to equipment deployment and maintenance represent 22% of mobile networks FieldOps emissions.

*3) Purchase of customer equipment (13% of Orange scope 3 emissions):* The purchase of customer equipment corresponds to manufacturing emissions of equipment purchased by Orange and sold to customers (an exception being the Home and Enterprise gateways, which are accounted for here but are sometimes leased by Orange instead of purchased, as they are not sold but let to customers). These emissions represented 845 kt CO<sub>2</sub>eq in 2021 (13% of Orange Group scope 3 emissions). Of these 845 kt, 401 kt (47%) corresponded to handsets while 317 kt (38%) corresponded to customer premise equipment (CPE: gateways, set-top boxes, Wi-Fi repeaters). Internet of Things (IoT) devices (mainly smart TVs) made up for 82 kt (10%). Others, including mobile broadband (MBB, mainly routers for fixed wireless access) accounted for 45 kt (5%). It is important to encourage customers to return their old devices to the store and to purchase refurbished equipment. This allows the reduction of unitary emissions per device. Another factor to reduce emissions per sold device is the improvement of the manufacturing processes by the equipment manufacturers. More information regarding levers for emissions reduction can be found in Section V.

*4) Use of sold products (8% of Orange scope 3 emissions):* The use of sold products corresponds to the emissions associated with the generation of electricity consumed by customer equipment during their lifetime. As countries have different grid electricity mixes, the emissions associated to the same energy consumption are different from one country to another. Note that the emissions from the use of sold products during their entire lifetime are all counted on the year of purchase of the equipment, using a representative yearly energy consumption and a representative expected lifetime, which depends on the type of equipment. The emissions associated to the use of sold products represented 555 kt CO<sub>2</sub>eq in 2021 (9% of Orange Group scope 3 emissions), shared mainly between CPE (286 kt, 52%), MBB (118 kt, 21%), IoT (64 kt, 12%), Orange Business Services (OBS) enterprise market equipment (62 kt, 11%) and handsets (23 kt, 4%). The order is significantly different than the one for the purchase of customer equipment. Indeed, CPEs and MBBs are typically switched on 24/7, entailing high energy consumption, while IoT mainly corresponds to smart TVs (high unitary energy consumption, long life duration at 8 years, mainly sold in Spain and Poland which have a rather carbon-intensive electricity mix). Handsets correspond to a small fraction of use phase emissions despite representing a lot of manufacturing emissions. However, it is well known that the manufacturing phase of smartphones can represent up to 90% of all the emissions of its life cycle.

<sup>4</sup>Emissions pertaining to transportation and distribution losses, as well as to the electricity supply chain, are not counted as Scope 2 emissions in the GHG protocol, but as Scope 3 emissions.

In the following, we identify levers that could help meet Orange sustainability goals.

## V. LEVERS TO REDUCE OUR FOOTPRINT

In its strategic plan *Lead the Future* [15], the commitment of Orange is to reduce GHG emissions from scopes 1, 2, and 3 by 45% between 2020 and 2030 (-6.7% yoy). To achieve such ambitious goals, we identify levers for Networks and devices, which represent about 70% of Orange’s emissions.

### A. Information Technology Networks (ITN)

The main sources of emissions for IT & Networks are electricity consumption, field interventions, and purchase of IT and network equipment.

1) *Electricity consumption*: Shutdown of copper local loop will bring a massive reduction in electricity consumption (37% of 2020 total network energy consumption for France). However, according to a 2022 internal study on Orange Group CO2 trajectories, RAN electricity consumption is foreseen to increase by 64% between 2021 and 2030. As discussed in section III-B, a substantial amount of energy is consumed while there is no traffic to be delivered. Faced with this issue, Orange implements energy saving features to dynamically control the network resources depending on the traffic demands. This paradigm shift from “always-on” to “always available on need” saves up to 5% of total RAN energy consumption.

Radio cells are also deactivated during the night, when the traffic goes down using cell switch-off features and deep sleep technologies. Idle consumption is also due to the installation of overdimensioned capacity equipment, needed to serve very high data rates according to French telecom authority, ARCEP, and other quality of service (QoS) Key Performance Indicators (KPIs). As such data rates are not required for the majority of the daily usages, ongoing discussions between operators and ARCEP aim to define more sustainable KPIs. Active or passive network sharing with a Tower Company (TowerCo) or an Energy Supply Company (ESCo) should be accelerated especially in the access part of the network. About 30% of savings on scope 1&2 emissions in Orange Poland (OPL) with active sharing could be achieved depending on the sharing contour and the number of assets that are still managed by Orange.

Decommissioning 2G/3G networks can also help reduce consumption. Ongoing assessment of the impact takes into account the negative impact of device migration to 4G, which is balanced by refarming frequencies and maintenance avoidance. Orange is engaged with its affiliates in a 2G/3G extinction roadmap before 2030.

Regardless of the evolution of the electricity consumption, a strong lever to reduce emissions is to decarbonize electricity through direct site solarization or through the signature of long-term contracts with renewable energy producers such as Power Purchase Agreements (PPA). Note that in the case of non-terrestrial networks envisioned for future releases of 5G and 6G, satellites source all their use-phase energy from the sun, by design.

2) *Field interventions*: Mostly done in countries with fixed networks, and will decrease once fiber networks rollouts slow down. Improving the quality of networks and deployments,

moving towards automatized and softwarized networks, as well as data and AI-assisted operations should also reduce the need for field intervention. Another lever is to change the motorization of the fleet of on-field techs, whether they are contractors (in 80% of cases in France for example) or employed by Orange. Switching to electric, fuel cell or biogas commercial vehicles will result in lower carbon footprint from interventions.

3) *Purchase of network equipment*: Emissions from the purchase of network equipment can be reduced through equipment usage extension. As many suppliers are also engaged in carbon reduction objectives, emissions by equipment are also expected to decrease. Through its procurement system, Orange is actively pushing the ecosystem towards better understanding and involvement in manufacturing emission reductions. Additionally, the rationalization of networks (for example, switching from legacy, application-specific networks to highly mutualized IP networks, or the non-redundancy of mobile and fixed networks in some areas) will provide gains both in energy consumption and manufacturing emissions. Revisiting the way we do business with our vendors (renting equipment instead of purchasing it) can incentivize the vendors to make their equipment more durable and longer-lasting. Another lever is the increase of the share of refurbished equipment, notably through the OSCAR program [16]. Orange has a 2025 objective of 10% of ITN CAPEX spent in refurbished equipment. As a last resort option, slowing down the rollout of new networks (FTTH, 5G, ...), can be considered to curb emissions from equipment manufacturing, since fewer equipment is then purchased each year. without compromising the commitments to ARCEP in terms of coverage and the broader societal benefits brought about by connectivity (such as e-bill, teleconsultation, telecommuting, etc.).

### B. Devices

The two principal levers to decrease emissions from user devices are reducing the emissions by device (both for manufacturing and use phase) and reducing the volume of sales per year. Emissions by device will decrease as manufacturers improve their processes, similarly to network equipment vendors. Another way to reduce emissions by device is to increase the share of refurbished devices. Regarding the use phase, the improvement of electricity mixes in our various geographies will also decrease the emissions from the electricity consumption of sold devices. Efforts on customer premise equipment, such as home gateways, will also entail important savings in electricity consumption and thus GHG emissions, e.g. through intelligent deep sleep modes. In addition, the number of sold devices should go down in order to reduce emissions. The increasing lifetime of user equipment goes in the right direction for this purpose. This can also be done through a shift in business model (from selling to leasing user devices). Focusing on devices with higher unitary margin can also help decouple CO2 emissions and profit. Finally, a strategic review of profit-to-CO2 for each sold product (or category of products) should be undertaken, e.g., use phase



emissions from the sale of 147k Smart TVs in the European countries in which the CSP operates (mostly carried by Spain and Poland) correspond to about the same amount of CO<sub>2</sub> as the use phase emissions of the mobile network in France (around 40 kt CO<sub>2</sub> in 2020), which serves 35M accesses.

## VI. CONCLUSION

The assessment of the GHG emissions associated with the activities of a major telecommunications operator has been partially conducted using physical emission factors which require the LCA of each product and service. This gives more accurate results than monetary emission factors. Several sources of emissions are investigated along with factors influencing energy consumption in networks and various fixed and mobile connectivity solutions. The study reveals that fuel and electricity consumption is the main driver of Scope 1&2 emissions for fixed and mobile networks. In particular, the growth of traffic and the coverage extension incur a substantial rise in energy consumption of mobile networks. Networks represented over half the emissions of Orange in France in 2020. It is mainly due to the manufacturing, use phase, installation and maintenance of equipment. Between 2020 and 2021, the main increase of the scope 3 of Orange is due to network deployment emission. While the scope 3 associated to purchase and use of devices decreased between 2020 and 2021, it does not compensate the increase linked to network deployment. The analysis helps in identifying potential levers to reduce emissions from networks and devices.

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## APPENDIX

%	Scope	Category	Subcategory	ktCO <sub>2</sub> e
4%	Scope 1	fuel - gas - coal	fuel - gas - coal	224
		Vehicles	vehicles	63
		GHG	GHG	7
13%	Scope 2	Electricity	Electricity	989
83%	Scope 3	Upstream	Purchased goods or services	2718
		Upstream	Capital goods	1884
		Upstream	Energy-related emissions	976
		Upstream	Upstream transportation and distribution	62
		Upstream	Waste generated in operations	34
		Upstream	Business travel	6
		Upstream	Employee commuting	128
		Downstream	Downstream transportation and distribution	12
Downstream	Use of sold products	555		

TABLE II: Orange Group Scope 3 (2021) and Scope 1&2 (2020) emissions in ktCO<sub>2</sub>e