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The greenhouse gas (GHG) reduction potential of ICT

A critical review of telecommunication companies' GHG enablement assessments

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Abstract

For about a decade, telecommunication network operators (TNOs) have explored the potential greenhouse gas (GHG) reductions their customers can achieve by using TNO services (e.g., by substituting physical travel with video conferencing), the so-called *GHG enablement*. Some TNOs also calculate a *GHG enablement factor*, which is the ratio between the GHG enablement and their own GHG footprint. Since GHG enablements usually exceed the footprint, they create the narrative that TNOs contribute to GHG reductions across society. In this paper, we systematically analyze TNO GHG enablement claims and the underlying methodological approaches. We find several methodological shortcomings and inconsistencies, such as different sets of TNO services considered, inconsistent system boundaries, potential double counting of GHG reductions, and a disregard for rebound effects. Most importantly, TNO assessments focus exclusively on those services likely to yield GHG reductions, neglecting possible GHG-increasing services. We conclude that current GHG enablement (factors) do not accurately and comprehensively represent TNOs' overall GHG impacts and create a flawed picture. To provide a reliable decision basis to stakeholders such as TNOs themselves, customers, investors, and policymakers, we provide eight recommendations on how to substantially improve the methodological basis.

KEYWORDS

avoided emissions, enablement effect, GHG abatement, GHG reduction, ICT, telecommunication companies

1 | INTRODUCTION

Given the substantial increase in using information and communication technology (ICT), public and academic interest in the opportunities and risks of digitalization for climate protection has grown. A widespread assumption is that ICT applications help to achieve climate goals (GSMA, 2022; ITU & WBA, 2023). For example, video conferencing can avoid greenhouse gas (GHG)-intensive air travel, intelligent heating systems may reduce building energy use, and precision fertilization can reduce fertilizer use (Bieser et al., 2023).

ICT organizations have emphasized the opportunities of ICT applications for GHG reduction for more than 10 years. In 2015, the Global Enabling Sustainability Initiative (GeSI) estimated that ICT applications could avoid up to 20% of global GHG emissions by 2030 (GeSI & Accenture Strategy, 2015). The mobile network operators' industry association, GSMA, estimated that in 2018 mobile connectivity enabled GHG reductions larger than the 2017 GHG footprint of Russia (GSMA, 2019). Even though the methodologies applied in these studies and the validity of their results were criticized (Bergmark et al., 2020; Bieser & Hilty, 2018b), many telecommunication network operators (TNOs) applied similar approaches to estimate the amount of GHG emission reductions their customers (can) achieve by using their services. TNOs refer to this effect using various names such as *GHG enablement*, *GHG abatement*, *avoided GHG emissions*, or *GHG savings*. They either publish the GHG enablement directly or in the form of an enablement factor, which is the quotient of the GHG enablement and the *GHG footprint* (the GHG emissions caused by the provision of all the TNO's services).

For example, British Telecommunications (BT) estimated that in 2020, their customers saved 3.1 times as much GHG emissions as BT generated itself; Swisscom arrived at a factor of 2.9, AT&T at 5.4, Deutsche Telekom at 7.1, and NTT at 10.5 (AT&T, 2020; BT, 2020; Deutsche Telekom, 2020b; NTT Group, 2021; Swisscom, 2021b). To calculate GHG enablements, TNOs select a set of their services and estimate how much GHG emissions their customers could potentially avoid, for example, by substituting conventional services with TNO services (e.g., by replacing physical travel with video conferencing). While in the past, public interest primarily focused on the unfavorable GHG footprint of TNOs, the enablement (factor) creates a narrative that focuses on desirable GHG effects.

The considerable difference in enablement factors across TNOs is striking since they offer similar services. Additionally, TNOs' enablement estimates usually consider only services that enable GHG reductions, whereas various academic studies showed that ICT services can also lead to an increase in emissions (Horner et al., 2016). For example, Internet of things (IoT) technology can be used to increase the yields of crops or intensify GHG-intensive livestock farming (Bieser et al., 2020). Several studies of ICT's GHG impacts have suggested that ICT applications reduce energy use or GHG emissions (Edquist & Bergmark, 2023; Hilty & Bieser, 2017; Kopp et al., 2023), whereas other studies yielded opposite indications (Hilty et al., 2006; Lange et al., 2020). Hence, the literature at this point does not provide a strong conclusion for one or the other side, which is why Horner et al. (2016) call them "known unknowns."

To increase the validity of studies on ICT GHG enablements, several researchers have systematically investigated the various methodological approaches and pointed out challenges that need to be addressed. For example, two articles presented at the conference ICT for Sustainability (ICT4S) 2020 highlighted various challenges, including the estimation of a hypothetical baseline before using ICT applications, the consideration of GHG-increasing effects such as rebound effects, or the extrapolation of results of individual case studies to larger populations (Bergmark et al., 2020; Coroamă et al., 2020). TNOs need to address such challenges to substantiate their enablement assessments. Only then could they help customers, investors, and ultimately themselves to consider GHG impacts in investment decisions, improve TNO services regarding GHG reductions, and benchmark GHG impacts across TNOs. In the worst case, however, enablement statements only serve TNOs' marketing, mislead decision makers, and convey the impression that ICT applications contribute to GHG reduction by themselves and that no further efforts by the stakeholders involved are necessary (Bieser et al., 2023).

In this study, we systematically analyze the GHG enablement (factor) assessments of TNOs as well as the underlying methodological approaches. We identify methodological inconsistencies and challenges in existing assessments and formulate recommendations that should help TNOs increase the validity of their GHG enablement claims. Companies in other ICT sub-sectors are also putting forward enablement claims, for example, Alphabet's Google for services such as climate-friendly routing with Google Maps or intelligent heating with Google Nest (Google, 2023). In this analysis, we focus on TNOs exclusively; however, many of our findings also apply to other ICT sub-sectors.

Bieser et al. (2023) have already discussed TNO GHG enablement (factors) in another article. We built on this analysis and systematically evaluate TNO assessments according to the methodological challenges discussed in the literature.

2 METHODS

In the research underlying this article, we performed three steps.

First, we performed a literature search on Google Scholar and Google using combinations of keywords in three categories:

- ICT, information and communication technology, digital technology
- GHG, greenhouse gas, CO_2, emissions
- Enablement, avoided, savings, reductions

We screened the first 50 results of each search for studies that addressed the ICT GHG enablement and methodological challenges in the assessment. The main articles stem from the ICT industry (GeSI, 2010; GSMA, 2019, 2022), sustainability consultancies (Carbon Trust, 2020), ICT standardization organizations (ETSI, 2014; ITU, 2014), the research community "ICT for Sustainability" (Bergmark et al., 2020; Bieser & Hilty, 2018a, 2018b; Coroamă & Mattern, 2019; Coroamă et al., 2020; Erdmann & Hilty, 2010; Malmodin & Bergmark, 2015; Malmodin & Coroamă, 2016;

Malmodin et al., 2014), and the Research Coordination Network on the Digital Economy and the Environment (Bremer et al., 2023a). Based on these articles, we described important terminology, the assessment approaches, and created a list of the most important methodological challenges described in the literature, which we use to examine the TNO enablement assessments in step three.

Second, we read the sustainability reports of the last 10 years of the 10 largest TNOs according to revenue (Reiff, 2023) to identify those that publish GHG enablements or enablement factors. This resulted in a list of five TNOs (Verizon, AT&T, Deutsche Telekom, NTT, and Vodafone), to which we added three large TNOs (BT, Telefonica, and Swisscom) that we know publish such claims. For the resulting set of eight TNOs, we compared their claimed GHG enablements and their development over time, whether they set a future target enablement (factor), and the number and types of services considered. TNOs often use different names for the same services or categorize several services into groups without naming the individual services. To compare services across TNOs, we have standardized their naming (e.g., *home office* and *flexible work* could be categorized into *telecommuting*) and sorted them into uniform categories (e.g., *travel & transport* or *energy, buildings, & infrastructure*).

Third, we critically reviewed the identified TNO enablement (factor) assessments identified in step two according to the methodological challenges identified in step one and other challenges we identified during the analysis. Finally, we assessed the overall enablement (factor) validity and derived recommendations to increase it.

3 | THE ASSESSMENT OF TNO GHG ENABLEMENT

3.1 | The GHG enablement (factor)

The GHG enablement of a TNO (EN_{TNO}) describes the sum of emissions that all customers i of the TNO (potentially) reduce (ER_i, *emissions reduced*) by using the services of the TNO. Customers can be private customers or business customers. For example, video conferencing and cloud storage can be used to avoid business and private travel.

$$\text{GHG enablement}: \; EN_{TNO} = \sum_i ER_i$$

For a certain TNO, its GHG enablement factor (EF_{TNO}) equals the quotient of the *GHG enablement* and the overall *GHG footprint* of the TNO (FP_{TNO}):

$$\text{GHG enablement factor}: \; EF_{TNO} = EN_{TNO}/FP_{TNO} = \sum_i ER_i/FP_{TNO}$$

An enablement factor greater than one means that more emissions were reduced than the emissions caused by the total provision of services by the TNO. A company can increase its enablement factor by reducing its footprint or by increasing the GHG enablement. The latter can be achieved by improving existing services or adding new services (Bieser et al., 2023). In practice, the GHG enablement may rather represent emissions reduced by some of the TNO's services (i.e., those assessed and expected to provide GHG reductions), while the footprint represents the TNO's full operation corresponding to its overall service portfolio. However, parts of the value chain emissions may be excluded (see Section 5.9 for details).

GHG enablement can occur through substitution effects (e.g., video conferences replacing business travel) or optimization effects (e.g., navigation apps suggesting fuel-efficient routes). *GHG enablement potentials* do not describe actually reduced emissions but theoretical potentials, often under optimistic assumptions in a best case scenario. Coroamă et al. (2020) distinguish further between "present" GHG enablement, "present potentials," and "future potentials" (potentials that are not available at present but in a possible future).

Several articles have presented methods for assessing GHG enablements in a simplified way (Bieser & Hilty, 2018a, 2018b; GeSI & Accenture Strategy, 2015). Fundamentally, they follow five steps, which we explain below and illustrate in Figure 1 using the example of telecommuting (working remotely, e.g., from home):

(1) Identifying GHG enablement levers (GHG reduction in commuting through working from home).
(2) Estimating baseline emissions (the emissions caused by commuting without home office adoption).
(3) Estimating the impact on GHG emissions per unit of adoption (the emissions reduced through one person working 1 day from home).
(4) Estimating the level of adoption of the service (the amount of employer office days replaced with home office days).
(5) Identifying and estimating rebound effects (e.g., additional trips to grocery stores or leisure trips that were originally conducted on the commute back home).

The method is usually used to quantify GHG-reduction levers. However, it would allow quantifying GHG-increasing levers as well.

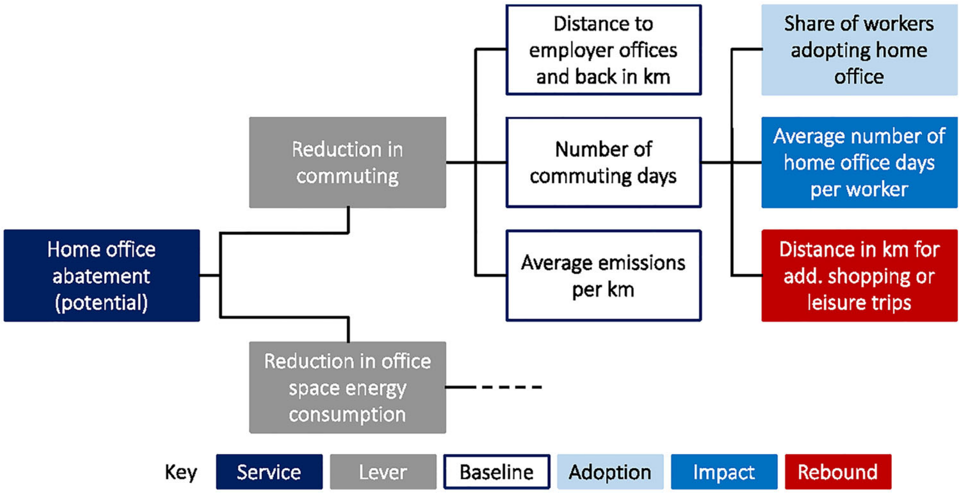

FIGURE 1 Information and communication technology enablement method for one service using the example of telecommuting from home. The illustration is based on GeSI and Accenture Strategy (2015) and Bieser and Hilty (2018b).

The emissions savings of a service could also be determined by conducting a comparative life cycle assessment (LCA), which is a method to determine the environmental impacts of a product system along its entire life cycle. However, this can be time consuming as two LCAs must be carried out and compared (before and after the introduction of the service). The method described in Figure 1 is less complex because it "only" quantifies the mechanisms that lead to emission reductions (Bieser & Hilty, 2018a).

If a TNO also calculates a GHG enablement factor, it puts the GHG enablement in relation to its GHG footprint. TNOs determine their GHG footprint according to the GHG Protocol Standard (WRI & WBCSD, 2004). The standard differentiates between Scope 1 emissions (from sources that the company directly controls, e.g., own delivery vehicles), Scope 2 emissions (from purchased energy), and Scope 3 emissions (from the upstream or downstream value chain, e.g., from the manufacture of purchased products). Accounting for Scope 3 emissions is complex, often resulting in incomplete or coarse emissions modeling (GSMA et al., 2023).

GeSI, the European Telecommunications Standards Institute (ETSI) and the International Telecommunications Union (ITU) were the first organizations to publish recommendations on GHG enablement calculations; however, these were rather generic and did not account for numerous methodological challenges in detail (ETSI, 2014; GeSI, 2010; ITU, 2014). Some TNOs state that they applied GeSI's method (BT, 2017; Vodafone, 2016), some state that they built on the ETSI/ITU method to calculate their GHG enablement (AT&T, n.d.; NTT Group, 2014). A more detailed standard for assessing GHG enablements exists since late 2022 (ITU, 2022). So far, only initial examples of its application exist (e.g., Labidurie Omnes et al., 2023; Thieme et al., 2023), and TNOs have not applied it yet. Its future uptake remains open, as will its potential effects on the quality of estimates when used. There are also no standards that address an enablement factor, only the *GHG footprint* and the *GHG enablement* of ICT services separately.

In a recent study co-authored with the World Benchmarking Alliance, the ITU presents the enablement factors put forward by several TNOs; however, only with light accompanying criticism (ITU & WBA, 2023). We complement this work by systematically comparing the results of TNOs' enablement assessments, analyzing the methodological approaches, pinpointing shortcomings, and suggesting ways to address them.

3.2 | Methodological challenges identified in the previous literature

In the following, we present the most important methodological challenges in assessments of ICT GHG enablement. We identified these challenges by reviewing the academic literature as described in Section 2, and apply them in Section 5 to critically discuss TNO enablement (factors).

3.2.1 | Selection of ICT services

Since ICT penetrates all domains of social life and the economy, an assessment cannot consider all potential ICT services (Bieser & Hilty, 2018b). Thus, a selection of ICT services must be made to calculate the GHG enablement. The choice of services influences the result considerably. Bergmark et al. (2020) warn against cherry picking, that is, focusing on services with an expected opportunity for reducing emissions while excluding less rewarding ones.

Several studies argue that only services for which ICT is a key enabler should be considered (Bergmark et al., 2020; Bieser & Hilty, 2018b). For example, ICT is a key enabler for "working from home." In contrast, electrification of mobility is only supported by ICT and mainly enabled by battery and electric drivetrain technology, so only additional emission reductions that could be attributable to ICT should count. However, in practice, it is challenging to find a suitable distribution of GHG enablement across technological domains. Therefore, services in which ICT plays only a minor role should be excluded entirely from the enablement.

3.2.2 | Baseline

To estimate the impact of an ICT service, a scenario with and without the adoption of the ICT service (baseline) must be compared. Determining the baseline scenario is always hypothetical and becomes more challenging as the adoption of an ICT service increases and as we move further away from a world where the service did not exist (Coroamă et al., 2020). Coroamă et al. (2020) discuss different approaches for baseline determination such as fixed baselines or projection-based baselines. The ITU (2022) criticizes fixed baselines because, in addition to the introduction of an ICT service, other factors that influence the baseline may have changed (e.g., disinvestment in a country could be the reason for a reduction in business trips). They suggest using projection-based baselines considering uncertainty about future developments by using several baselines if they are equally likely and utilizing recognized scenarios if possible (e.g., from the Intergovernmental Panel on Climate Change, IPCC). Coroamă et al. (2020) recommend that no enablement claims should be made once the enabling technology has become part of the socio-technological mainstream.

3.2.3 | Allocation

Problems in allocating GHG enablements across companies arise when several companies contribute to realizing a specific service (Bergmark et al., 2020; Bieser & Hilty, 2018b). For example, video calls from home require connectivity services provided by TNOs as well as display devices, cameras, microphones, and video calling software. However, finding a fair allocation principle is challenging. Bergmark et al. (2020) discuss some options, such as cost-based allocation. ITU (2022) advises against quantitative allocation and suggests qualitatively analyzing how each actor contributes to the overall potential impact.

3.2.4 | Extrapolation

For some services, it is more straightforward to extrapolate the GHG enablements to a larger population (e.g., an entire country) than for others since data availability differs. For example, GHG reductions from telecommuting can be calculated using data on home office adoption, commuting distances, transport mode choice, and mode GHG intensity, which are often recorded by national statistical authorities. In contrast, it is more difficult to estimate the adoption of a specific smart farming service and its GHG-reducing effect, because often, only a few empirical case studies on the GHG effects of such a service are available (Bieser & Hilty, 2018b). Since the effects of ICT are very context-dependent and differ according to time, region, or population group, results from individual case studies cannot simply be extrapolated to larger populations (Coroamă et al., 2020; Malmodin & Coroamă, 2016): "volunteer biased sampling" or "the Hawthorne effect (case study participants behaving differently due to the knowledge of being observed) might […] skew the results" (Coroamă et al., 2020, p. 41).

3.2.5 | Double counting

Two services can impact the same "reference activity" (Bergmark et al., 2020). For example, telecommuting reduces the traffic volume and thus also the potential GHG reductions through navigation services. Double counting can occur if the two services are analyzed separately, and the emission reductions are aggregated (Bergmark et al., 2020; Bieser & Hilty, 2018b).

3.2.6 | Ignoring rebound effects

Originally, the term "rebound effect" described a reduction in the energy savings from energy efficiency gains due to the reduced price of the more efficiently produced good (or service) and the consequently increased demand for it (Jevons, 1865; Khazzoom, 1980). In today's broader understanding, rebound effects are typically seen as an "umbrella term for a variety of mechanisms that reduce the potential savings from improved efficiency" (Sorrell, 2009, p. 1457). A taxonomy of ICT rebound effects is provided by Coroamă and Mattern (2019). *Direct rebound* occurs when

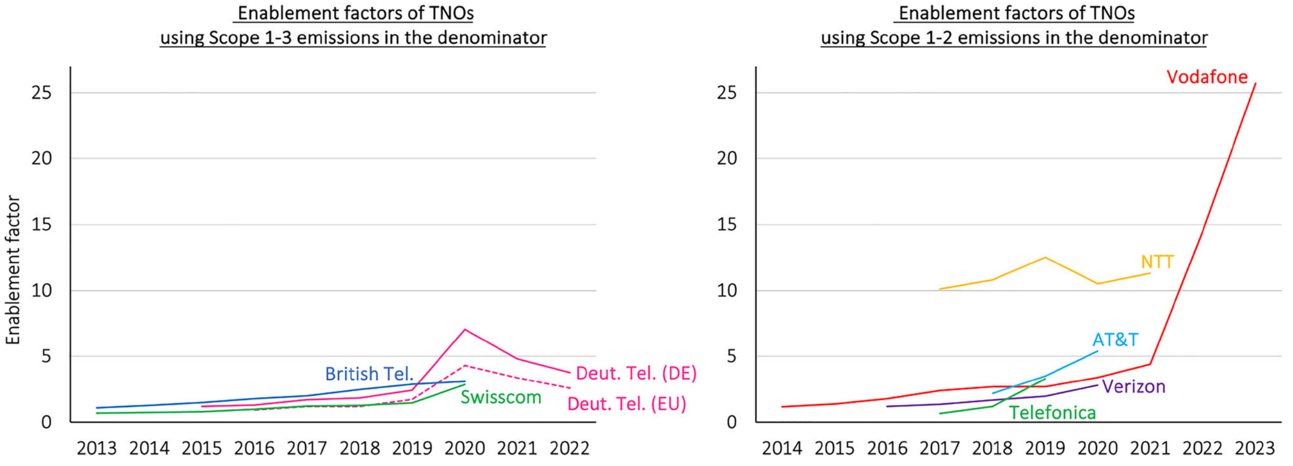

FIGURE 2 Development of telecommunication network operator (TNO) enablement factors over time based on their external reporting. The TNOs in the left chart use Scope 1–3 emissions in the denominator, and the TNOs in the right chart use Scope 1–2 emissions. When a line ends, the TNO has not reported a factor after that year. Underlying data for this figure are available in the Supporting Information.

ICT-enabled efficiency gains make a good more affordable and thus increase the use of the same good. *Indirect rebound* occurs when either the consumption of other goods increases (e.g., through substitution or income effects; Binswanger, 2001) or when the mechanism is non-monetary (e.g., if ICT saves time; Coroamă & Pargman, 2020). *Economy-wide rebound effects* (also called transformational or structural rebound) are fundamental changes in production and consumption patterns and macroeconomic adjustments across sectors (Börjesson Rivera et al., 2014; Bremer et al., 2023a; Horner et al., 2016; Pohl et al., 2019). For example, the emergence of e-commerce has fundamentally transformed the last-mile logistics industry.

Accounting for such effects in enablement calculations is difficult because they are often not apparent at first glance and can only be observed over a longer time. They depend on complex supply–demand relationships, and especially indirect and economy-wide rebound effects can only be studied from a higher system level (Bieser & Hilty, 2018b; Widdicks et al., 2023; Bremer et al., 2023a). Bremer et al. (2023b) suggest a taxonomy for identifying, measuring, explaining, and mitigating direct and indirect rebound effects. The ITU (2022) standard distinguishes three types of assessments by level of detail, ranging from a qualitative identification to a quantitative assessment of rebound effects.

4 | GHG ENABLEMENT (FACTORS) REPORTED BY TNOS

In the following we describe TNO reporting on GHG enablement or enablement factors, which we discuss critically in Section 5.

4.1 | Overview of reported enablement (factors)

Comparing absolute GHG enablements across TNOs is impractical, as these differ considerably depending on a TNO's size and the number of customers. However, enablement *factors* can be compared as they represent a relative ratio. Figure 2 shows the development of the claimed TNO enablement factors over time. We can observe several phenomena:

(1) Enablement factors tend to increase over time.
(2) The size of the enablement factors of some TNOs differ by one order of magnitude in some reporting years. In 2019, for example, Swisscom reported an enablement factor of 1.5 and NTT of 12.5.
(3) In many reporting years, the enablement factors of TNOs that only consider Scope 1–2 emissions (right) or Scope 1–3 emissions (left) are of the same order of magnitude (except for NTT and Vodafone from 2022 onward).
(4) Between 2019 and 2020, many factors increased significantly. Deutsche Telekom, Swisscom, and Verizon attribute this to the skyrocketing adoption of telecommuting and video conferencing during the COVID-19 pandemic reducing work-related travel (Deutsche Telekom, 2020a, 2020b; Swisscom, 2021a; Verizon, 2020, 2021). Interestingly, NTT's enablement factor decreased between 2019 and 2020. The information provided in NTT's sustainability reporting does not suffice to explain this. However, NTT's factor was already significantly higher before the COVID-19 pandemic than those of other TNOs.

TABLE 1 Target enablement factors, target year, target status, and current targets of telecommunication network operators based on their external reporting.

Company	Target factor	Target year	Target status	Current absolute enablement target	
				Size of the GHG enablement	Time horizon
Vodafone (UK)	2	2018	Achieved in 2017	300 Mt CO_2e absolute enablement	Cumulative 2020–2030
Swisscom (CH)	2	2020	Achieved in 2020	1 Mt CO_2e absolute enablement	Yearly by 2025
Verizon (US)	2	2022	Achieved in 2020	20 Mt CO_2e absolute enablement	Yearly by 2030
BT (UK)	3	2020	Achieved in 2020	60 Mt CO_2e absolute enablement	Yearly by 2030
Telefonica (ES)	10	2025	Replaced in 2020	12 Mt CO_2e absolute enablement	Yearly by 2025
AT&T (US)	10	2025	Replaced in 2020	1000 Mt CO_2e absolute enablement	Cumulative 2018–2035
NTT (JP)	10	2030	Achieved in 2017	No current target	
Deutsche Telekom (DE/EU)	No target set				

TABLE 2 Number of services considered in the greenhouse gas enablement assessments in the respective reporting year. The numbers must be interpreted with care because some telecommunication network operators (TNOs) add services in hindsight and because TNOs use different abstraction levels and categorizations. For several reporting years, TNOs did not publish the number of services considered. Vodafone has a different reporting period than the other TNOs and, at the time of this study, had already published a value for their 2023 reporting year.

Company	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Deutsche Telekom (DE)			12	12	16	16	16	16	16	
Deutsche Telekom (EU)			12	12	16	16	16	18	17	
Swisscom (CH)	7			9	9	10	10	10	14	
BT (UK)	15	20					37			
Vodafone (UK)				10	10	10	9	11	13	28
Verizon (US)	4	4	5	6	7	7	7			
AT&T (US)					16		26			
Telefonica (ES)				5	5					
NTT (JP)	List or number of services not included in sustainability reporting									

(5) Vodafone's enablement factor rose rapidly from 4.4 to 25.7 between 2021 and 2023, according to the company, mainly due to solutions for smart logistics and fleet management (Vodafone, 2023a).

4.2 | Target GHG enablement (factors) of TNOs

Some TNOs set targets to increase their GHG enablement (factor) over time (Table 1), the size of which differs considerably across companies. NTT, Telefonica, and AT&T aimed to reach an enablement factor of 10 by 2030 and 2025, respectively. BT, Verizon, Swisscom, and Vodafone had more conservative targets with factors of 3 and 2 to be achieved in 2022, 2020, and 2018.

Five of the seven TNOs that set enablement factor targets report to have achieved their targets, three in 2020 and two in 2017. Six TNOs have now switched from a relative GHG enablement factor target to an absolute GHG enablement target. Verizon and AT&T explain that they changed to an absolute target because they aim to reduce their GHG footprint (to zero) in the future (AT&T, 2020; Verizon, 2021). As a result, the denominator in the enablement factor formula would drop (to zero), which means that achieving a high enablement factor requires less GHG reduction or that the enablement factor cannot be calculated at all anymore.

4.3 | Number of services by reporting year

Table 2 shows how many services a TNO considered in the corresponding reporting year. We always show the number of services reported in the respective year, even if services were added retrospectively in subsequent years. Comparability across TNOs and over time is limited since some TNOs use different abstraction levels for services or change their categorization over time. For example, while one TNO reported video conferencing and telecommuting as two separate services, another TNO aggregated them under "flexible work." Still, the table shows that TNOs do not fix the number of services and add or even remove services over time. For example, Verizon added "Remote Patient Monitoring" in 2016, "Dematerialization" in 2017 and "Smart Parking" in 2018 (Verizon, 2016, 2017, 2019).

4.4 | Types of services considered

Table 3 shows that TNOs differ significantly regarding the type of services considered. For example, AT&T considers four different services in the *travel & transport* sector and six in *energy, buildings, & infrastructure*. In contrast, Swisscom has no services in either of these sectors. Also, some sectors have significantly more services than others. *Travel & transport*, *energy, buildings & infrastructure*, and *industry & logistics* have the most services.

The most frequently mentioned GHG-reduction lever is traffic avoidance. Many services, including in sectors outside of *travel & transport*, aim to avoid traffic. For example, telecommuting avoids commuting and IoT solutions in industry avoid maintenance trips.

5 | CRITICAL REVIEW OF TNO GHG ENABLEMENT (FACTOR) ASSESSMENTS

In this section, we discuss the assessment of the GHG enablement (factors) according to the methodological challenges described in Section 3.2 and other challenges we have identified in the analysis. Unfortunately, we cannot do any recalculations or estimate error margins because the detailed calculations and assumptions are not published by TNOs. Nevertheless, it is likely that enablement claims are over-optimistic for the reasons discussed below.

5.1 | Service selection

The guiding question of TNOs' GHG enablement assessment is: "How can our customers save emissions with the help of our services?" To answer this question, TNOs identify and quantify specific emission-reducing impact mechanisms. Services that mainly lead to emission increases are out of scope; even though they do exist. For example, personalized advertising, also enabled by the connectivity provided by TNOs and advanced algorithms, can increase overall consumption and, thus, emissions (Kaack et al., 2022). Therefore, the TNO enablements are biased toward impacts that can reduce emissions.

TNOs also differ in the set of services they analyze. For example, BT includes e-commerce because it would not be possible without broadband connectivity (Carbon Trust, 2020). By this argumentation, all other TNOs also enable e-commerce, but only three out of seven consider it.

Often, TNOs add new services over time. It is not always clear whether a TNO added a new service because they developed a new service or because they extended the assessment scope, and the service was already on the market. When TNOs increase their assessment scope, it could seem like they increase their efforts for GHG reduction due to rising enablement, which is not necessarily the case.

Some TNOs also consider efficiency increases in providing their ICT services as an enablement effect. For example, BT reduced the size of its SIM card and estimated the GHG emissions saved (Carbon Trust, 2020). This is not a GHG enablement effect customers achieve by using their services, but a reduction of BT's Scope 3 emissions and should not be included in the GHG enablement.

5.2 | Baseline

Most TNOs did not explain how they set the baseline. BT states that they calculated the baseline for the year before (2012; Carbon Trust, 2020) and AT&T for 3 years before the introduction of the enablement (2015; AT&T, 2017).

In any case, the baseline is hypothetical because many services were available before 2012, respectively 2015, and a world without them no longer exists. For example, BT uses survey data from 2011 on telecommuting adoption and implicitly assumes that telecommuters would have traveled to the office on all days they telecommuted, if telecommuting was not possible. However, the possibility of telecommuting may have influenced people's choice of employer and living location (e.g., further away from the employer's office) already before 2011 and thus influenced commuting distances and the choice of transport modes before 2011. It is complicated to isolate such effects in hindsight. Still, the baseline remains hypothetical and does not depict a comparison of a telecommuting versus a non-telecommuting world, but a comparison of the status quo with a hypothetical *2011-world* in which telecommuting was not possible, but all other factors stayed the same.

A regular update of the baseline considering new developments could help address some of these challenges. However, TNOs make no statement as to whether they did so.

TABLE 3 Services that telecommunication network operators have considered when calculating the greenhouse gas enablements. The data come from the most recent reporting year, in which the TNOs reported an overview of the services. We harmonized terminology and categories across TNOs.

Sector	Service (example GHG-reduction lever)	AT&T, 2020	Verizon, 2020	Deut. Tel., 2020	Telefonica, 2018	Vodafone, 2023	BT, 2020	Swisscom, 2022
Travel & transport	Smart traffic lights (smoother traffic flow)						x	
	Smart parking (less driving for searching parking places)	x	x			x		
	Fleet optimization (more efficient routing and dispatching)	x	x		x	x	x	
	E-mobility (not specified)			x				
	Connected e-mobility (e-scooter replacing car trips)					x		
	E-mobility charging infrastructure (spread of e-mobility)	x		x		x		
	Car sharing (less car production)	x		x				
	Ride sharing (less vehicle kilometers)			x				
	Connected car (higher fuel efficiency)					x		
	Navigation systems (more efficient routes)					x	x	
	Smart taxis (optimized dispatching)					x	x	
	Usage-based car insurance (improved driving behavior)					x	x	
	Software engine optimization (increase in fuel efficiency)						x	
	Vehicle performance monitoring (improved driver behavior)						x	
Energy, buildings, & infrastructure	Smart building energy management (less energy use)	x	x		x			
	Smart metering/grid management (less energy use)	x	x			x	x	
	Oil and gas pipeline monitoring (less maintenance visits)	x						
	Smart street lighting (less energy use)	x				x	x	
	Solar/PV panel monitoring (less maintenance trips)	x				x		
	Water metering (leakage reduction)	x				x		
	Smart landscape irrigation (less water use)	x						
	Optimization of biogas generation from food waste (faster scaling)	x						
	Accommodation sharing (not specified)			x				
	Smart bins (optimization of waste collection routes)					x		

(Continues)

TABLE 3 (Continued)

Sector	Service (example GHG-reduction lever)	AT&T, 2020	Verizon, 2020	Deut. Tel., 2020	Telefonica, 2018	Vodafone, 2023	BT, 2020	Swisscom, 2022
Industry & logistics	Smart logistics (not specified)			x				
	Smart pallet management (longer pallet lifetime)	x						
	Remote monitoring and control (logistics/heating optimization)							x
	Smart water cooling (less water use)	x						
	Cooling process optimization (less energy use)	x						
	Environment management software (faster GHG reduction)							x
Agriculture & nutrition	Smart farm irrigation (less water and energy use)	x						
	Soil condition and crop monitoring (less crop waste)	x						
Healthcare	Remote patient monitoring (less hospital energy use)	x	x			x		
Retail	E-commerce (less retail space)			x			x	x
Finance	Remote ATM monitoring (less maintenance trips)						x	
	Electronic payments (less cash transport)						x	
Work	Telecommuting (less commuting and office energy use)	x	x	x	x	x	x	x
	Virtual conferencing and remote collaboration (less business travel)	x		x	x	x	x	x
Education	Virtual conferencing and remote collaboration (less educ. travel)			x				
	E-learning (less education travel)			x				
Media	Virtual media (fewer physical media such as DVDs/paper)		x	x			x	x
ICT	Cloud computing (use of more efficient data centers)	x		x	x	x	x	x
	Dematerialization of ICT hardware (less network devices)	x				x	x	
	Optimization of data formats (less data traffic)	x						
	Device take-back programs (higher device lifetime)					x		x
	Hardware recycling (less primary production)						x	

5.3 | Allocation

Some TNOs briefly discuss allocation issues in their method documents and state that they usually applied a *100% for TNO* allocation rule, that is, allocating the entire emission reductions enabled by a certain service to the TNO (e.g., AT&T, Vodafone, and BT). However, many services can only be realized in combination with the services of other ICT and non-ICT companies. Since the emissions from the provision of those services are neglected in the denominator of enablement factors, the contribution of TNOs to GHG reduction of their services could be considered overestimated. This is particularly delicate for those services where ICT is far from being the key enabler, such as electric drivetrains replacing combustion engines requiring some ICT-based monitoring.

5.4 | Extrapolation

BT, AT&T, and Vodafone extrapolate GHG enablements from individual units to company-wide values using company-specific and country-wide data. For example, BT extrapolates GHG reductions through telecommuting using national statistics on telecommuting adoption and BT's market share in broadband lines (Carbon Trust, 2020). Extrapolation based on country-specific indicators introduces uncertainty because of potential biases in the underlying case study and because the case studies used to estimate GHG reductions may not be representative (Coroamă et al., 2020; Malmodin & Coroamă, 2016). Best and worst case scenarios could be developed to address the uncertainty. Verizon did so for some of the reporting years (Verizon, 2014, 2016).

5.5 | Double counting

Double counting of GHG enablement can occur in assessments of TNOs. For example, Vodafone estimates the emission reductions of replacing combustion engines with electric drivetrains, of call conferencing replacing business trips, of navigation enabling more efficient routes, and of smart parking reducing distances for searching parking spots (Vodafone, 2023b). All four GHG enablement levers target the same reference activity, GHG emissions from road transport. Only AT&T states that they systematically avoided such overlaps (AT&T, n.d.) by counting the enablement of services that avoid the same emissions only once. Vodafone mentions it for one service (Vodafone, 2023b).

Double counting would also occur if each company that is part of a service's ecosystem would entirely claim the achieved enablement, as discussed in Section 5.3, and such enablements were aggregated across companies.

5.6 | Rebound effects

For most TNOs, it was not transparent to what extent they considered rebound effects. Vodafone, BT, and AT&T explicitly stated that they do not systematically consider rebound effects (AT&T, n.d.; Carbon Trust, 2020; Vodafone, 2023b). Swisscom states that they account for rebound effects for the services e-commerce and dematerialization (Swisscom, 2021a); however, the detailed assumptions are not presented.

If a TNO accounted for rebound effects, these are likely exclusively direct ones. Economy-wide rebound effects should not be considered by TNOs, because they depend on conditions that TNOs themselves cannot influence. However, it is important to be aware of their existence. For example, the combination of digital marketing (e.g., social media marketing and personalized advertising) and the global integration and efficiency increases in logistics enabled by ICT significantly contributed to establishing the fast fashion system (Camargo et al., 2020; Cheema, 2018). This increases the production and consumption of garments and, thus, GHG emissions.

5.7 | GHG enablement potential versus actually reduced emissions

Many TNOs state that the estimated GHG enablements have been realized in real life. Other TNOs take a more cautious approach by talking about *GHG enablement potentials*, presumably because the assessments are often not based on empirical measurements carried out by TNOs but on assumptions derived from secondary literature or expert assessments.

Still, in the case of *GHG enablement potentials*, caution is required when interpreting the enablement factor. The GHG footprint (the value in the denominator) describes emissions that have actually occurred and were calculated using an accounting standard. GHG enablement potentials, however, include a hypothetical element (ITU, 2022; WBCSD, 2023). Therefore, GHG enablement potentials should not be subtracted from actual GHG footprints to calculate the net emission effects of TNOs.

5.8 | Biased incentives

TNO stakeholders could interpret a stable or falling GHG enablement so that the TNO does not increase its efforts for GHG reduction or even decreases them. Thus, TNOs have an incentive to increase their enablement once they report it externally.

Some TNOs delegate the GHG enablement assessment to third-party service providers (e.g. BT, Vodafone, Swisscom, and Verizon) who may have other interests. However, vested interests remain due to the *client-service provider relationship*.

Certainly, vested interests do not necessarily influence the enablement assessment. Still, they should be considered when interpreting the results because calculating the GHG enablement leaves many degrees of freedom regarding methods and assumptions TNOs can use to their advantage.

5.9 | GHG footprint of TNO operations

If a TNO calculates an enablement factor, they put their GHG enablement in relation to their GHG footprint. Even though the GHG Protocol provides standards to assess the GHG footprint (WRI & WBCSD, 2004), sources of variation exist.

While most TNOs include all three scopes (GHG Scopes 1–3) in the GHG footprint, some exclude Scope 3. Excluding Scope 3 significantly reduces the GHG footprint (in the denominator) and should imply a higher enablement factor. However, the enablement factors of many TNOs are of the same order of magnitude, although they included different scopes in the denominator. Even if TNOs include Scope 3, differences can exist. For example, GHG Scope 3 includes the production emissions of purchased products. Louis-Philippe et al. (2020) showed considerable uncertainty in calculating production emissions for smartphones and tablets. In total, Scope 3 includes 15 distinct categories, each with its own complexities.

The ITU (2022) standard suggests that even if TNOs report absolute GHG enablements, the GHG footprint for providing the required services should be subtracted from the absolute GHG enablement.

6 | CONCLUSION AND RECOMMENDATIONS

The GHG enablement assessments by TNOs encounter several methodological challenges, leading to inconsistent estimations and limited validity of results. The current GHG enablement (factors) do not accurately represent TNOs' overall GHG impacts and create a flawed narrative.

Nevertheless, TNOs should continue to pursue the GHG-reducing potential of their services to enhance their contributions to climate protection. This should not only involve assessing the status quo but also measures to increase GHG enablement and mitigate rebound effects.

Our key recommendations for improvement are:

1. **Service selection**: TNOs should avoid cherry-picking services with expected emission savings. Instead, they should systematically analyze all services, considering both GHG-reducing and GHG-increasing effects.
2. **Substantial contribution**: A service should only be considered if the TNO substantially contributes to its realization. Determining what constitutes a "substantial" contribution is context-dependent and requires an individual assessment for each service.
3. **Baseline**: The baseline scenario is as important as the scenario that includes the GHG reductions and should be described transparently. Projection-based baselines are more suitable than fixed baselines.
4. **Allocation**: Finding a fair allocation principle to distribute GHG enablement among all involved companies for all services is challenging. Using a "100%-for TNO" allocation is the most pragmatic approach. A TNO claiming 100% of a reduction should be transparent about the nature of its involvement and how the enablement depends on other actors.
5. **Double counting**: TNOs should avoid double counting of GHG enablement by ensuring that several services do not target the same baseline emissions or deduct overlapping GHG enablements. Aggregating GHG enablement across multiple companies can also lead to double counting and should be avoided.
6. **Rebound effects**: TNOs should include direct and indirect rebound effects quantitatively or at least describe them qualitatively when sufficient data is unavailable. Economy-wide rebound effects do not need to be considered because TNOs cannot directly influence them.
7. **Extrapolation**: When extrapolating results from individual case studies, TNOs should apply techniques for considering uncertainties (e.g., sensitivity analyses) because the emission enablement achieved in specific case studies might not be representative. Even then, we suggest that TNOs always explicitly refer to "enablement potentials" rather than "actual avoided emissions" unless the TNO makes empirical measurements of actual service impacts.
8. **Independent review**: TNOs can commission an auditor with a review to reduce bias due to vested interests. However, complete independence is unlikely to be achieved due to the *client-service provider relationship*, a problem that also exists in financial audits.

TNOs should collaborate to create opportunities for co-learning and agree on harmonized reporting formats to increase comparability. This can also involve companies in other ICT sub-sectors because many services are not provided by TNOs alone. Existing standards can also inform this process, but further advancements are necessary, especially as many recommendations go against the interests of TNOs to report rising GHG enablements. Given the various methodological challenges, enhancing result validity requires a systematic, continuous, and substantial improvement process. Standardization organizations such as the ITU can coordinate this process.

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The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are presented in the article and the supporting information.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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