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## Conference Paper

# From broadband deployment to climate action: Key considerations in the development of climate policies across OECD countries

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## **From broadband deployment to climate action: Key considerations in the development of climate policies across OECD countries**

SarahKate Palmer<sup>1,2</sup>, Joe Rowsell<sup>3</sup>, Stephen Schmidt<sup>3</sup>

### **Abstract**

This research paper examines an underexplored facet of climate change mitigation – digital climate policies. Despite empirical evidence demonstrating the potential of broadband networks to substantially reduce greenhouse gas emissions (GHGe), these networks are conspicuously absent from the climate policies of G7 countries. To address this critical omission, the paper investigates three key areas: the countries and sectors with the greatest potential for adopting digital climate policies; the effectiveness of digital climate policies in reducing GHGe under various economic and social conditions; and the barriers hindering the development of such policies. Utilizing a mixed-methods approach, the study aims to provide a comprehensive understanding of the role digital climate policy can play in climate change mitigation, fostering an international community of practice and offering robust data for further empirical research. The findings of this paper hold significant implications for the design and implementation of climate policies in advanced economies.

**Keywords:** Telecommunications, Broadband, 5G networks, 5G solutions, digitization, telecommunications policy, climate change, digital policy, climate change policy

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## Key Results

- Adoption of high-speed broadband networks can enable a 15-20% reduction in GHG emissions, primarily by enabling low-carbon consumer behaviors and business operations.
- The indirect 'enabling' effect of broadband is approximately an order of magnitude greater than its direct impact, with broadband accounting for about 0.4-1.0% of global GHG emissions based on recent estimates
- Sectors such as remote work, precision agriculture, smart manufacturing, and green buildings have high potential for GHG reduction through broadband adoption by replacing or optimizing traditionally GHG-intensive activities.
- Estimates of the rebound effects associated with 5G remain speculative and highlight the intersection of technology, energy production, and energy consumption.
- Countries with substantial carbon footprints and strong digital infrastructure, such as South Korea, Australia, the US, and Canada, have high potential for adopting digital climate policies.
- Despite the potential, broadband networks are not included in the climate policies of any G7 country, indicating a significant knowledge gap among regulators and policymakers.
- As a starting point, this paper evaluates policies across seven factors, including impact on GHG emissions, technical feasibility, cost, regulatory alignment, public opinion, economic impact, and scalability.
- Access to high-speed networks, adoption of digital solutions in GHG-intensive industries, and integration of climate considerations into telecom policy are key to successful digital climate policy.

## Executive Summary

This research paper examines an underexplored realm of digital climate policies and their potential role in mitigating climate change. Despite compelling evidence demonstrating that the adoption of high-speed broadband networks can enable reductions in greenhouse gas emissions (GHGe) by approximately 15-20%, these networks are conspicuously absent from the climate policies of G7 countries. This omission is particularly striking given that the indirect 'enabling' effect of broadband, which facilitates low-carbon consumer behaviors and business operations, has a GHG reduction impact that is an order of magnitude greater than its direct impact, estimated to be between 0.4-1.0%.

The paper identifies sectors such as remote work, virtual healthcare, precision agriculture, smart manufacturing, and green buildings as having the highest potential for GHG reduction through broadband adoption. These sectors can replace or optimize traditionally GHG-intensive activities, leading to significant emissions reductions. For instance, a fast rollout of 5G, compared to a slow rollout, can lead to approximately 120 Mt fewer annual GHG emissions, on average, across OECD countries. This rapid broadband rollout could reduce global cumulative carbon emissions by 0.5 billion tonnes by 2030, equivalent to all international aviation in 2018.

Countries with substantial carbon footprints and strong digital infrastructure, such as the United States and Canada, are identified as having the greatest potential for adopting digital climate policies. Despite this potential, a significant knowledge gap among regulators and policymakers has resulted in broadband networks not being included in the climate policies of any G7 country. This gap is a key barrier to the development and implementation of digital climate policies.

The paper underscores the importance of three key strategies for successful digital climate policy: access to high-speed networks, adoption of digital solutions in GHG-intensive industries, and integration of climate considerations into telecom policy. Access can be achieved through spectrum policy reform, broadband funding, and promoting low-carbon technologies like 5G and fiber. Adoption can be driven by incentives for 5G, IoT, and AI use cases, along with low-carbon focused public procurement policies. Integration requires immediate actions like appointing climate advisors and incorporating Indigenous perspectives, along with medium-term strategies focusing on global cooperation.

The findings of this research provide a foundation for further empirical research and policy development in this critical area, offering a roadmap for the integration of digital climate policies into the climate action plans of advanced economies.

## **1. Introduction**

Historically, technology and nature have been seen as contrasting forces, yet they can interact meaningfully to address the pressing issue of our time: climate change. Within this context, broadband networks, often perceived merely as vehicles of personal connectivity and convenience, possess transformative potential that remains largely unutilized in our efforts to combat climate change. Envision a scenario in which an individual's carbon footprint is reduced not through radical lifestyle alterations, but through optimized usage of internet connections. Imagine a reality where intelligent agricultural tools enhance crop productivity and minimize waste, digital healthcare eliminates the necessity for a journey across town to a medical consultation, and where environmentally-friendly buildings function with a level of efficiency that resonates with even the most committed environmentalist. The key to this transformative change resides in the intersection of technology and policy, encapsulated in a concept yet to permeate mainstream climate dialogue: digital policy. We are at a critical juncture where digital technology can help us create a world in better balance with nature. We risk squandering the opportunity completely if actionable policies are not implemented.

In the face of the global climate crisis, it is crucial to investigate all avenues for potential greenhouse gas emissions (GHGe) reduction, including those provided by the ongoing digital transformation. Broadband networks, a key component of this transformation, may have significant potential to reduce GHGe, as will be explored in this research. Yet, this potential has not been adequately recognized or integrated into the climate policies of most advanced economies. A crucial factor in this omission is the lack of comprehensive research into digital climate policies, which support the adoption of broadband and broadband-enabled services to enable GHGe reductions. This research paper aims to address this gap in understanding and provide insights into the critical role of digital climate policy. Three central research questions guide this exploration: Which countries and sectors have the most significant potential for digital climate policy adoption? Under what economic and social conditions are various digital climate

policies most effective in reducing GHGe emissions? And what are the primary obstacles to the development and implementation of these policies on both national and global scales?

The paper consists of four main sections. The first section will study the GHGe produced by the telecom sector, providing a comprehensive overview of the environmental impact of the industry itself. The second section will analyze the potential for GHGe abatement offered by the telecom sector, using data and case studies from Canada. The third section will examine the relationship between GHGe and digital connectivity to identify countries with the greatest potential to leverage digital climate policies. The final section will present policy recommendations for G7 countries, offering a roadmap for the integration of digital climate policies into the country's climate action plan. The objective of this research is to inform and guide policymakers in developing comprehensive and effective digital climate policies.

## **1.1 Methodology**

This research paper adopts a mixed-methods approach, utilizing quantitative and qualitative research tools to provide a comprehensive analysis of the potential and challenges of digital climate policies to holistically analyze the opportunities and challenges of digital climate policies. For the first research question (RQ1), the paper employs a descriptive statistical approach to compare OECD countries and major industrial sectors on several key parameters: broadband network quality, broadband adoption, GHGe, industrial structure, among others. The goal is to identify countries and sectors where high IGHGe and in high quality networks suggest substantial potential for digital climate policy impact. Addressing the second research question (RQ2) involves conducting a traditional literature review. The goal is to analyze empirical studies from advanced economies, assessing the impact of digital climate policies on GHGe, either directly or indirectly, through the increased adoption of broadband services. This two pronged approach facilitates a wide exploration of the research questions, significantly enriching the understanding of digital climate policy, as an emerging area of policy.

## **2. GHG emissions produced by telecommunications**

Assessing GHG emissions produced by the telecommunications sector can be difficult due to the lack of sufficient publicly available data; many estimates are available only at the level of the Information and Technology Communications (ICT) sector, encompassing far more than

telecommunications. ICT combines manufacturing (e.g., production of computer parts) and services of goods that fulfil or enable technological communication,<sup>4</sup> whereas telecommunications refers to the more limited activity of operating and providing infrastructure and access for technological communication. Due to the lack of available data at the telecommunications sectoral level and an absence of relevant studies, this section will discuss the available data on the estimates of GHG emissions produced by the ICT and telecommunications sector when possible. A comprehensive understanding of the greenhouse gas emissions within the telecommunications sector is essential for policy makers in their efforts to assess the industry's environmental impact. They can identify key areas for improvement, establish emission reduction targets, and promote sustainable practices within the industry. A nuanced understanding of the environmental impact can guide the development of regulations and incentives that encourage the adoption of cleaner technologies and more efficient infrastructure, such as 5G networks, thus reducing the sector's GHG emissions.

It is important to note that emissions produced by the ICT sector are dependent on the country or countries in which they operate. When discussing ICT's impact on CO<sub>2</sub> emissions, a generally positive relationship (i.e. one entailing increased emissions) can be observed in developing, lower income countries.<sup>5</sup> Lower income countries exhibit an inverted U shaped relationship due to the emissions associated with mass urbanization and increased electricity consumption, which ultimately accelerate the pollution levels rather than reduce it.<sup>6</sup> Conversely, the scholarly literature suggests that in developed, middle and high income countries there is a negative correlation between CO<sub>2</sub> emissions and ICT, or an insignificant impact.<sup>7</sup> This

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<sup>4</sup> OECD, "Information and communication technology (ICT)," last modified October 11, 2017, <https://doi.org/10.1787/04df17c2-en>.

<sup>5</sup> Danish, et al. "Towards cross-regional sustainable development: The nexus between information and communication technology, energy consumption, and CO<sub>2</sub> emissions," *Sustainable Development* 27 (2019); Noheed Khan, et al. "The effect of ICT on CO<sub>2</sub> emissions in emerging economies: does the level of income matter?," *Environmental Science and Pollution Research* 25, no. 23 (2018), [d10.1007/s11356-018-2379-2](https://doi.org/10.1007/s11356-018-2379-2); Jianwu Zhang, et al., "Towards cross-regional sustainable development: The nexus between information and communication technology, energy consumption, and CO<sub>2</sub> emissions," *Sustainable Development* 27, no. 5 (2019); as cited in Wolfgang Briglauer, Monika Köppl-Turyana, and Wolfgang Schwarzbauer, "Evaluating the effects of ICT core elements on CO<sub>2</sub> emissions: Recent evidence from OECD countries," Research Paper, No. 22, EcoAustria - Institute for Economic Research, Vienna, 2022, 7-8.

<sup>6</sup> Khan, et al. "The effect of ICT," 22857.

<sup>7</sup> Thomas Koppp and Steffen Lange, "The Climate Effect of Digitalization in Production and Consumption in OECD Countries," Paper presented at CEUR Workshops, Lappeenranta Finland, June, 2019; Zhang et al., "Towards cross-regional sustainable development," (2019); Fethi Amri, "Carbon Dioxide Emissions, Total Factor Productivity, ICT, Trade, Financial Development, and Energy Consumption: Testing Environmental Kuznets Curve Hypothesis for Tunisia," *Environmental Science and Pollution Research* 25, no. 33 (2018); Chuanguo Zhang and Cong Liu,

phenomenon can be primarily attributed to the pre-existing infrastructure and urbanization present in many middle and high income countries. These nations possess a foundation and framework that better supports the development and utilization of ICT. For the purposes of this paper and subsequent sections, the studies and scenarios chosen reflect middle and high income countries to demonstrate ICTs potential to reduce GHG emissions. This section evaluates four different dimensions of GHG emissions by the telecommunications industry. The first part explains the framework for evaluating GHG emissions in the context of ICT and telecommunications (direct and indirect emissions), the second part discusses the GHG emissions that are aggregately produced by the ICT sector, and the third part goes into specifics about the emissions of 5G vs. 4G and legacy networks, and the direct and indirect impact on GHGe. Finally, we discuss the impact of wireline vs. wireless broadband networks and the impact this distinction has on GHG emissions.

## 2.1 Types of emissions associated with ICT

Understanding the types of emissions associated with the ICT sector allows policy makers to make clearer assessments on how digital policies will impact GHG emissions, and further drive evidence based policy making within the sector. Little distinction is made between ICT and the telecommunications sector, with some studies being labeled as “ICT” but refer to a telecommunications study (e.g., 5G technology). For this reason, we can apply the International Telecommunication Union’s (ITU) recommended methodology for assessing the environmental life cycle of ICT goods and services.<sup>8</sup> Studies within ICT and telecommunications refer to both direct and indirect effects, regardless of if they are following the ITU categorization meticulously. This methodology gives a guideline for classifying effects to better understand technology’s carbon footprint. The ITU methodology refers back to the research of Berkhout and Hertin (2001) and Hilty et al. (2006) that organizes ICT environmental impact into three order effects.

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"The Impact of ICT Industry on CO2 Emissions: A Regional Analysis in China," *Renewable and Sustainable Energy Reviews* 44 (2015); as cited in Ibid.

<sup>8</sup> International Telecommunication Union (ITU), *Recommendation ITU-T L.1410 (2014), Methodology for environmental life cycle assessments of information and communication technology goods, networks and services*, December 2014, <https://www.itu.int/rec/T-REC-L.1410-201412-I/en/>.



	<b>Positive impacts</b>	<b>Negative impacts</b>
<b>First order effects (Direct)</b>	Environmental ICT applications (e.g., environmental monitoring)	Environmental impacts of production and use of ICTs (e.g., 5G network construction)
<b>Second order effects (Indirect)</b>	Dematerialisation and structural change (e.g., production optimisation)	Incomplete substitution and rematerialisation
<b>Third order effects (Indirect)</b>	Lifestyle changes (e.g., mass adoption of teleworking)	Rebound effects (e.g., leisure rides using self-driving cars)

Table 2.1: ICT impacts on the environment<sup>9</sup>

**First order (direct) effects:** First order effects occur due to the physical existence of ICT infrastructure. Negative effects include the production, use, recycling, and disposal of hardware (e.g., network cables), while the positive direct impacts refer to the use of ICTs for environmental protection purposes (e.g., monitoring for emissions).<sup>10</sup> First order effects can be quantified by performing a life cycle assessment.<sup>11</sup>

**Second order (indirect) effects:** The impacts and opportunities created by the use and application of ICTs. This includes environmental load reduction effects which can be either actual or potential, a positive impact would include the use of environmental control systems and e-government.<sup>12</sup> The most important negative second order effect could be the incomplete substitution of existing structures and activities, leading to more environmental damage.<sup>13</sup> For example, instead of driving to the store and shopping in person, consumers now enjoy the ease of buying online which leads to more consumption, production, and environmental impact.<sup>14</sup>

<sup>9</sup> Lorenz M. Hilty et al. (2006), “The relevance of information and communication technologies for environmental sustainability - A prospective simulation study,” *Environmental Modelling & Software* 21 (2006): 1619; Frans Berkhout and Julia Hertin, “Impacts of Information and Communication Technologies on Environmental Sustainability: speculations and evidence,” Report to the OECD, Brighton, UK (2001): 4-5; ITU 2014, vi-vii.

<sup>10</sup> Ibid.

<sup>11</sup> ITU, “Methodology for life cycle assessments,” vii.

<sup>12</sup> Ibid.

<sup>13</sup> Berkhout and Hertin, “Impacts of information and communication technologies,” 6.

<sup>14</sup> Daniel Z. Sui and David W. Rejeski, “Environmental Impacts of the Emerging Digital Economy: The E-for-Environment E-Commerce?” *Environmental Management* 29 (2002): 157, as cited by Miriam Börjesson et al., “Including second order effects in environmental assessments of ICT,” *Environmental Modelling & Software* 56, (2014): 108.

Second order effects can be quantified by the comparison of life cycle assessment results between ICT goods, networks and services product systems and a reference product system performing the same function.<sup>15</sup>

**Third order (indirect) effects:** Environmental effects of the medium or long term adaptation of behavior (e.g., consumption patterns) or economic structures due to the stable availability of ICT and the services it provides.<sup>16</sup> Positive impacts include the mass adoption of services like teleworking and telehealth applications leading to reduced need in travel. Negative impacts for third order effects are often called “rebound effects”: The time gained by an end user using an ICT service may cause them to have leisurely time to do things like personal travel and increase use of transportation (e.g., planes, cars).<sup>17</sup> Third order effects may be difficult to track and monitor compared to first and second order effects.

Studies have frequently theorized these effects, but often distinguish between direct and indirect, rather than first, second, and third orders.<sup>18</sup> Direct effects of ICT, such as production and construction of network infrastructure have a more absolute position in ICTs GHG emissions. Indirect effects may be more difficult to calculate because they rely on assumptions of widespread consumer behavior.

## **2.2 Assessing ICT Sectoral GHG Emissions**

### **2.2a Methodology**

The ICT sector lacks a standard methodology when calculating the absolute GHG footprint of the industry. Existing studies refer to different time frames or periods when evaluating the impact of ICT on GHG emissions, resulting in varying estimates from each study. This applies to all studies regarding direct and indirect effects.

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<sup>15</sup> ITU, “Methodology for life cycle assessments,” (2014): vi-vii.

<sup>16</sup> Hilty, et al., “The relevance of information and communication technologies,” 1619.

<sup>17</sup> ITU, “Methodology for life cycle assessments,” vi.

<sup>18</sup> This varies between studies, some authors are very specific about the type of GHG emissions they’re discussing, and others discuss more broadly about the subject.

## 2.2b Sector estimates of ICTs GHGe

There are four extensively cross-referenced works within ICT literature that assess direct effects of GHGe composition within the industry, and include user devices, data centres, and networks in their calculations. These studies explore the direct effects of the ICT sector on greenhouse gas emissions. In the context of our research, we will focus on ICTs aggregate impact estimates as well as specific estimates of the telecommunications sector when applicable.

Author(s)	Title	Year(s) of consideration	Telecom sector GHG estimates	Telecom future GHG estimates
Malmodin & Lundén (2018)	The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010-2015	2010-2015	0.4-1%	Decreasing <sup>19</sup>
GeSI (2012)	SMARTer 2020	2020	0.4-1%	Stabilizing
Andrae & Elder (2015)	On Global Electricity Usage of Communication Technology: Trends to 2030	2020-2030	0.4-1%	Increasing
Belkhir & Elmeligi (2018)	Assessing ICT GLObal emissions footprint: Trends to 2040 & recommendations	2020-2040	0.4-1%	Increasing

Table 2.2: Comparison of ICT literature and telecommunications sector contribution<sup>20</sup>

<sup>19</sup> Based on personal communication with Charlotte Freitag et al., (2021).

<sup>20</sup> Jens Malmodin and Dag Lundén, “The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010-2015,” *Sustainability* 10, (2018); GeSI, “SMARTer2020,” 2012; Anders S. G. Andrae and Tomas Edler, “On Global Electricity Usage of Communication Technology: Trends to 2030,” *Challenges* 6, (2015); Lotfi Belkhir and Ahmed Elmeligi, “Assessing ICT global emissions footprint: Trends to 2040 & recommendations,” *Journal of Cleaner Production* 177, (2018); Jan Bieser, et al., “A review of assessments of greenhouse gas footprint,” *Environmental Impact Assessment Review* 99, (2023): 4; Charlotte Freitag et al., “The real climate and transformative impact of ICT,” *Patterns* 2, no. 9 (2021): 4, doi: 10.1016/j.patter.2021.100340.

Each study used different data, carbon intensity, energy assumptions, end user behavior, and other variables that impact the results of the study. However, across all studies, the telecommunications sector contributes 24% of ICT GHG emissions across 2015, 2020, and 2030.<sup>21</sup> For future contribution estimates, the telecommunications sector has varying theories from all four reports. This may be due to the data and assumptions made about the ICT sector. Freitag et al. (2021) notes that the data used in Belkhir & Elmeligi and Andrae & Edler is from 2008-2012; considering the fast paced environment of ICT, their projections could be based on historical trends that no longer apply.<sup>22</sup> Belkhir & Elmeligi (2018) and Andrae & Elder (2015) use sources that assume the exponential growth in energy consumption of data centres and networks, an assumption that is now challenged by the increased use of renewable energy sources.<sup>23</sup> When estimating GHG footprint by lifecycle stage for the telecommunications sector there are varying estimates. The prevailing assumption is that the primary contributor to life cycle-related greenhouse gas emissions in the telecommunications sector is electricity consumption for infrastructure operation.<sup>24</sup> However, it is now understood that both fixed and mobile networks make an equivalent contribution to GHG emissions from telecommunications networks.<sup>25</sup> It is anticipated that the relative contribution of mobile networks will further escalate in the future.

<b>Authors</b>	<b>Title</b>	<b>Year of consideration</b>	<b>ICT % of global GHG emissions</b>
Freitag et al. (2021)	The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations	2020	1.8-2.8%
Bieser et al. (2023)	A Review of Assessments of Greenhouse Gas Footprint and Abatement Potential of Information and Communication Technology	2022	1.5-4%

<sup>21</sup> Given the differences in methodology, this identical finding is likely to be a coincidence; Ibid.

<sup>22</sup> Charlotte Freitag, et al., “The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations,” *Patterns* 2, no. 4 (2021): 4, <https://doi.org/10.1016/j.patter.2021.100340>.

<sup>23</sup> Ibid, 4.

<sup>24</sup> Andrae and Elder, “On Global Electricity Usage of Communication Technology,” (2015); Malmmodin and Lundén, “The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010-2015,” (2018) as cited in Bieser, et al., “A review of assessments of greenhouse gas footprint,” (2023): 5.

<sup>25</sup> Anders S. G. Andrae, “Projecting the chiaroscuro of the electricity use of communication and computing from 2018 to 2030,” Huawei Technologies Sweden, (2019), <https://doi.org/10.13140/RG.2.2.25103.02724>; Ibid, as cited in Ibid.

Table 2.3: Estimates of ICTs global GHG footprint<sup>26</sup>

Estimates for aggregate ICT GHGe also vary within a range based off of the aforementioned studies. Freitag et al., have adjusted for differences in scope of the studies and estimate that ICT, TVs, and other consumer electronics accounted for 1.8-2.8% of global GHG emissions in 2020.<sup>27</sup> Bieser et. al, concludes that the GHG footprint of the ICT sector today accounts for 1.5-4% of global GHG emissions.<sup>28</sup> This range considers the three scenarios of the sectors GHGe significantly increasing, stabilizing, and barely increasing. However, it is important to note that experts unanimously agree on the possibility of reducing the ICT sector's emissions with broad political and industrial action, which has occurred in recent years.<sup>29</sup> Industry leaders, such as Google and Amazon, have taken effective measures to reduce their emissions through the use of renewable energy sources, despite the absence of regulations that mandate these actions within the ICT field. The use of proactive climate policies would further the use of renewable energy within the ICT sector. More specifically for the telecommunication industry, implementing effective policies that leverage low-emission 5G network scenarios in 5G spectrum assignment, efficient deployment of 5G networks, and establishing industry standards for renewable energy sources, substantial reductions in ICT emissions can be achieved.

### **2.3 5G vs. 4G and legacy mobile generations**

The rollout of 5G networks, or 5G standalone (SA) is expected to abate global GHG emissions through its energy efficient network capabilities and the enablement of digital solutions. 5G SA is designed to facilitate the use of enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable low latency communication (uRLLC), all of which is necessary to enable the wide adoption and use of advanced 5G solutions (telemedicine, smart agriculture, etc) and has a significant impact on technological efficiency. The 5G SA network differs greatly from existing 5G that is deployed on 4G network equipment, 5G SA requires new base network installation. Due to the technical nature of this

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<sup>26</sup> Freitag, et al., “The real climate and transformative impact,” 2; Jan Bieser et al., “A Review of Assessments of Greenhouse Gas Footprint and Abatement Potential of Information and Communication Technology,” *Environmental Impact Assessment Review* 99 (2023): 10.

<sup>27</sup> Freitag, et al., “The real climate and transformative impact,” 2.

<sup>28</sup> Bieser et al., “A Review of Assessments of Greenhouse Gas Footprint and Abatement Potential of Information and Communication Technology,” 10.

<sup>29</sup> Freitag et al., “The real climate and transformative impact,” 4.

section, we will make the distinction between 5G SA (new 5G base) and 5G (4G base). The subsequent study was chosen through our literature review of current quantitative research on telecommunications impact on GHG emissions. To analyze the first order effects of 5G SA on the telecommunications sector, an assessment was conducted by Bieser et al., (2020) on Swisscom's network and the future impact on emissions in Switzerland. The inventory data for the 5G SA network infrastructure (access, core, and transport network) components and their related energy consumption were collected in close collaboration with technical experts from Swisscom and Ericsson. Additional information from existing literature was then used to complement this data.<sup>30</sup>

### **2.3a First order (direct) effects**

There is little existing research on the impact of first order (direct) effects of the telecommunications sector, especially 5G. However, Bieser et al. (2020) recent study examines the difference between 5G SA and 2G-4G's impact on first order effects.<sup>31</sup> This includes the impact of data transmission, network operation, and network construction. The global warming potential of 2G-4G and 5G networks will be impacted by the transfer of mobile data traffic to SA 5G. In 2020, 99% of mobile data was transmitted by 2G-4G networks and 1% is transmitted by 5G networks, by 2030 80% of this data traffic will be transferred over to standalone 5G networks.<sup>32</sup> Comparing mobile networks GHG emissions by per unit of data shows that 2G-4G, 5G (2020) networks caused 30 g CO<sub>2</sub>e/GB, while SA 5G (2030) are expected to cause 4.5 g CO<sub>2</sub>e/GB.<sup>33</sup>

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<sup>30</sup> Jan Bieser, et al., "Opportunities of 5G Mobile Technology for Climate Protection in Switzerland," in *Advances and New Trends in Environmental Informatics*, ed. by A. Wimmer and F. Scholz (Springer International Publishing, 2022), 19.

<sup>31</sup> *Ibid.*

<sup>32</sup> *Ibid.*, 26-7.

<sup>33</sup> *Ibid.*, 6.

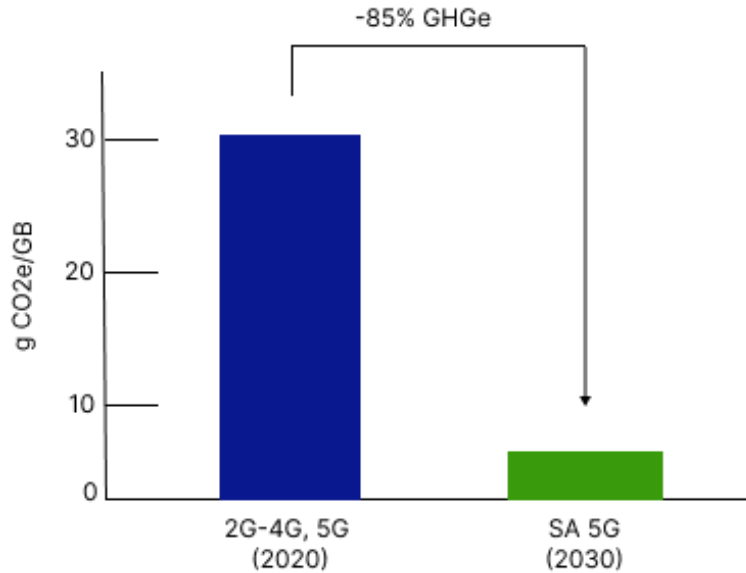


Figure 2.1: GHGe (g CO<sub>2</sub>e) potential per GB of transmitted data from Bieser, et al.<sup>34</sup>

Bieser et al., have also considered another scenario, if 5G SA were not adopted and data traffic was only transmitted on 4G networks in 2030. The result of this would lead to GHG emissions of about 8 g CO<sub>2</sub>e/GB if data were transmitted on only 4G networks (2030) compared to if the same amount of data traffic were on 5G SA networks.<sup>35</sup> Thus, if we were only assessing each network by data traffic management, 5G SA networks would emit significantly less emissions (4.5 g CO<sub>2</sub>e/GB compared to 8 g CO<sub>2</sub>e/GB) due to its enhanced network capabilities. However, 5G SA's emissions did not always appear lesser in the calculation estimates. 5G SA networks (2030) are expected to cause 11% more GHGe than 2G-4G networks in 2020.<sup>36</sup> To further investigate this number, a life cycle assessment was then conducted to determine the sources of GHGe (network operation, network construction/infrastructure) by 5G SA (2030) and 2G-4G, 5G (2020). 57% of emissions would be caused by producing the network infrastructure and 43% by providing the electricity required for operating the infrastructure.<sup>37</sup>

<sup>34</sup> Ibid, 27.

<sup>35</sup> Ibid.

<sup>36</sup> Ibid, 27.

<sup>37</sup> Ibid.

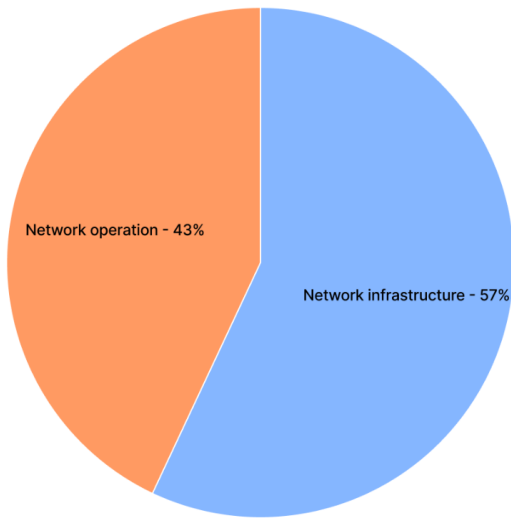


Figure 2.2: 5G SA (2030)<sup>38</sup>  
*Projected network GHG emissions composition*

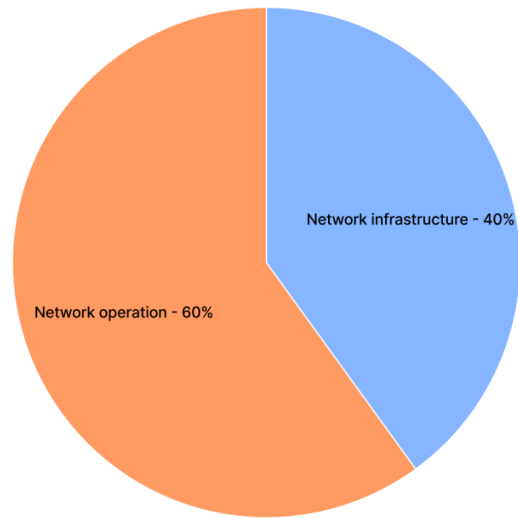


Figure 2.3: 2G-4G 5G (2020)<sup>39</sup>  
*Network GHG emissions composition*

Comparatively, for mobile networks (2G-4G and 5G) in 2020, more GHG emissions were caused by energy required to operate the network infrastructure (60%) than by producing the network infrastructure (40%).<sup>40</sup> We can therefore expect that the majority of the GHG emissions emitted from 5G SA networks will be due to the construction of its network, while the majority of 4G networks emissions will be due to the network operation. This is important to consider when determining the long term use of technologies, 5G SA could appear to have an initial increase in GHG emissions due to the construction of new networks, but will induce greater energy efficiency than 4G and legacy networks. When considering the two, efforts should be made to prioritize network operation efficiency over legacy technologies that may ultimately increase GHG emissions as more devices are connected to the network.

### 2.3b Second and third order (indirect) effects

Beyond first order (direct) effects related to mobile networks, 5G SA is expected to have second and third (indirect) effects on energy use impacts, or 5G SA driven energy use changes in

<sup>38</sup> Ibid, 28.

<sup>39</sup> Ibid.

<sup>40</sup> Ibid.



user behaviour and other sectors of the economy.<sup>41</sup> Typically, these quantitative studies review ICT indirect effects in general, rather than categorizing them by second or third order effects. Distinctions are usually made within ICT literature when assessing general rebound effects, or the changes in behaviour as a response to new technologies that increase the efficiency of the resource use.<sup>42</sup> These responses offset the beneficial effects of the new technologies and measures that were introduced. Many assessments focus on ICTs production rather than on consumption patterns, both of which are required to fully understand how ICT will change economic processes.<sup>43</sup> To better evaluate the rebound effects of 5G applications in a contemporary light, we will discuss the historical methods used to assess ICT indirect effects and then recent observations that have been made about smart solutions in recent years.

In prior ICT literature, evaluating the indirect effects can take up a wide range of methodologies, in a 2018 review 15 different approaches were identified in the ICT literature.<sup>44</sup> Life cycle assessment (LCA), ICT enablement method (ICTem), and partial footprint methods were the most frequently used by authors.<sup>45</sup> These three methods reflect different objectives and use cases of ICT applications. LCA and partial footprint are commonly used in single use case studies to investigate relative change that occurs by applying a specific ICT technology, while ICTem is used in multiple use case studies and (sometimes) to estimate and compare environmental impact of digitization.<sup>46</sup> Additionally, some works assume only one scenario for user behaviour (e.g., completely pessimistic vs. completely optimistic) instead of creating multiple scenarios relating to their specific use case.

### 2.3b.1 Rebound effects of teleworking

Rebound effects are difficult to calculate because they are assumptions about future behavior. A frequently debated rebound effect is the effect associated with teleworking. There are various arguments that a potential rebound effect relates to workers living farther from their

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<sup>41</sup> Laurence Williams, Benjamin K Sovacool, and Timothy J. Foxon, “The energy use implications of 5G: Reviewing whole network operational energy, embodied energy, and indirect effects,” *Renewable and Sustainable Energy Reviews* 157 (2022): 11.

<sup>42</sup> Börjesson et al., “Including second order effects,” 107.

<sup>43</sup> Jan Bieser and Lorenz M. Hilty, “Assessing indirect environmental effects of Information and Communication Technology (ICT): A Systematic Literature Review,” *Sustainability* 10, no. 8 (2018): 14, <https://doi.org/10.3390/su10082662>.

<sup>44</sup> Ibid, 10.

<sup>45</sup> Ibid, 10, 13.

<sup>46</sup> Ibid, 14.

workplace, and having more free time for personal activities could lead to more emissions. Numerous studies have found that teleworkers live farther away from work and therefore commute longer distances when applicable.<sup>47</sup> Despite reducing the number of commuting trips, the distance traveled over the working week may still be greater due to the longer spatial distance between home and the workplace.<sup>48</sup> Based on the first available data, the COVID-19 pandemic encouraged families with two homes to generally spend more time in their second home, simultaneously motivating populations to move from urban to rural areas.<sup>49</sup> The pandemic has also established the trend of “digital nomads” or those who travel the world holding remote positions and teleworking. Assessing the trends of emissions from any of the aforementioned scenarios and their impact on GHG emissions.<sup>50</sup> To further understand the impact that teleworking has on GHGe, it will be important to understand workers behaviors, motivations, and mobility patterns to better understand the impact of teleworking on rebound effects.<sup>51</sup>

### 2.3b.2 Rebound effects of smart agriculture

While rebound effects remain theoretical, Bieser et al., (2022) quantitatively analyzes 5G enabled use cases (flexible work, smart grid, automated driving, and precision farming) with their potential rebound effects. This was done through a critical examination process and uses data available from academic and industrial sources and additional interviews with experts from

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<sup>47</sup> Eugênia D.V. Cerqueira, et al. “Does working from home reduce CO2 emissions? An analysis of travel patterns as dictated by workplaces?” *Transport and Environment* 83 (2020): <https://doi.org/10.1016/j.trd.2020.102338>; Duco de Vos, Evert Meijers, and Maarten van Ham. “Working from home and the willingness to accept a longer commute,” *Annals of Regional Science* 61, no. 2 (2018), <https://doi.org/10.1007/s00168-018-0873-6>; D.G. Janelle, “Metropolitan expansion and the communications - Transportation Trade off,” *The geography of urban transportation*, ed. Susan Hanson, (New York: The Guilford Press) 1986; Saim Muhammad, et al., “Telecommunication and residential location preferences: a case study of the Netherlands,” *Journal of Housing and the Built Environment* 22, no. 4 (2007), <https://doi.org/10.1007/s10901-007-9088-3>; Jack M. Nilles, “Telecommuting and urban sprawl: mitigator or inciter?” *Transportation* 18, no. 4 (1991), <https://doi.org/10.1007/BF00186567>; Emmanuel Ravalet and Patrick R  rat, “Teleworking: Decreasing Mobility or Increasing Tolerance of Commuting Distances?” *Built Environment* 45, no. 4 (2019), <https://doi.org/10.2148/benv.45.4.582>; as cited by Laura Hostettler Macias, Emmanuel Ravelet, and Patrick R  rat, “Potential rebound effects of teleworking on residential and daily mobility,” *Geography Compass* 16, no. 9 (2022): 8-10, <https://doi.org/10.1111/gec3.12657>.

<sup>48</sup> Ravalet and R  rat, “Teleworking: decreasing mobility or increasing tolerances,” 582-602; as cited by Ibid.

<sup>49</sup> Muhammad Ahsanul Habib and Md Asif Hasan Anik, “Examining the long term-impacts of COVID-19 using an integrated transport and land-use modelling system,” *International Journal of Urban Sciences* 25, no. 3 (2021), <https://doi.org/10.1080/12265934.2021.1951821>; Phillipe Bachimon, Patrick Eveno, and C  sar G  lvez Espinel, “Primary and secondary place of residence, the digital link and the rise of presence,” *Worldwide Hospitality & Tourism Themes* 12, no. 4 (2020), <https://doi.org/10.1108/WHAT-05-2020-0033>; as cited by Ibid.

<sup>50</sup> Macias, Ravelet, and R  rat, “Potential rebound effects of teleworking on residential and daily mobility,” 8-10.

<sup>51</sup> Ibid.

Switzerland and other countries.<sup>52</sup> Each use case evaluates specific factors (e.g., precision farm and number of connected devices) before calculating the baseline GHG emissions, GHG abatement potential and adoption (for potential and adoption: pessimistic, expected, optimistic, theorized). Specifically, for precision agriculture, the expected calculations for the GHG abatement potential of the reduction of fertilizer use through variable rate nitrogen applications was 5%, with adoption rates at 10% and an estimated rebound effect of 100%.<sup>53</sup> This rebound effect result is based on an interview with an expert in the agricultural sector in Switzerland, who showed that even though farmers might be able to reduce fertilizer use through precision farming technologies, they could still apply the maximum amount of fertilizer to increase output.<sup>54</sup> Conversely, the estimated GHG abatement potential of enteric fermentation in cattle through precision farming was expected to be 5%, with adoption rates at 29% and projected to experience a rebound effect of 2%.<sup>55</sup>

Quantitative studies must assess or operate under assumptions of certain actors that may not reflect current policy practices. For example, some rebound effects that are calculated may be mitigated through government and sector intervention to prevent harmful effects (e.g., the fertilizer rebound effect of 100%) that compete with abatement tactics. Although these estimates remain conceptual, the studies on rebound effects should caution the heavy reliance on the positive effects that 5G can facilitate. Furthermore, because there is a lack of specific literature on 5G use cases rebound effects additional research should be conducted to better understand negative indirect effects.

## **2.4 Wireline vs. wireless broadband networks**

Briglauger, et al., make a significant contribution to the telecommunications literature by distinguishing between fixed fiber (wireline) and mobile (wireless) broadband networks in their GHGe analysis.<sup>56</sup> Fixed fiber or “wireline networks” transmit data faster, higher bandwidths, and are less likely to experience interruptions during peak hours of activity.<sup>57</sup> Compared to wireless

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<sup>52</sup> Bieser and Hilty, “Assessing indirect environmental effects of information and communication technology,” 33.

<sup>53</sup> Ibid, 62

<sup>54</sup> Ibid, 60.

<sup>55</sup> Ibid, 62.

<sup>56</sup> Briglauger, Köppl-Turyna, and Schwarzbauer, "Evaluating the effects of ICT core elements on CO2 emissions: Recent evidence from OECD countries," 10.

<sup>57</sup> Shirley Lim, “The Key Differences Between Fiber Optic & Wireless Broadband,” VIAVI, last modified July 13, 2023,

networks, which use network towers and WI-FI routers to enable internet connection, and are more frequent to experience reduced connectivity and interruptions. This is due to a user's position in relation to the tower or router, and the amount of devices connected to the wireless network source.<sup>58</sup> The distinction between the two captures the substantial differences in electricity consumption and their fundamentally different network architectures.<sup>59</sup> Furthermore, the study utilised country-level panel data from the Global Carbon Atlas.<sup>60</sup> 34 OECD member states were observed from 2002-2019, a timeframe that covers almost the entire fiber-based and mobile broadband deployment period.<sup>61</sup> The countries chosen were all in the middle-high income bracket and developed economies.

<b>Average CO2e emissions in OECD countries</b>	387.538 Mt CO2
<b>Average CO2e abated by adoption of wireline and wireless broadband in OECD countries</b>	79 Mt CO2

Table 2.4: 2002-2012 results of basic and fibre broadband adoption in 34 OECD countries<sup>62</sup>

The study focused on understanding how broadband impacted ICT's GHGe, and took into account other ICT variables into account (ICT device usage, manufacturing), but were concluded to be statistically insignificant in all the models. A lowering effect was observed, related to the increased adoption of both wireline and wireless networks, by about 20%.<sup>63</sup> This should be taken into account when considering ICT as a tool for GHG abatement, or whether to install fiber or basic wireline networks.

<https://blog.viavisolutions.com/2022/07/13/the-key-differences-between-fiber-optic-wireless-broadband/#:~:text=Considering%20the%20difference%20in%20speed,strong%2C%20even%20during%20peak%20h>

<sup>58</sup> Wolfgang Briglauer, Carlo Cambini, and Klaus Gugler, *The Economic Significance of Modern Broadband Internet Infrastructures and Services* (2022).

<sup>59</sup> Briglauer, Köppl-Turnya, and Schwarzbauer, "Evaluating the Effects of ICT Core Elements on CO2 Emissions," 10.

<sup>60</sup> Ibid.

<sup>61</sup> Ibid, 14.

<sup>62</sup> Ibid, 19.

<sup>63</sup> Ibid, 2.

### 3. GHG abated by telecommunications

Recent empirical research demonstrates that the adoption of broadband, specifically 5G networks, can enable substantial reduction in greenhouse gas emissions by between 15-20%.<sup>64</sup> These calculations are frequently estimating 2030 projections, and consider the abatement potentials or “abatement levers” of 5G (5G SA) solutions. For example, teleworking and telehealth reduce GHG emissions due to decreased traveling obligations to work or health offices, avoiding the vehicle emissions that would be necessary for travel. Despite these substantial potential environmental impacts, digital policies have yet to be integrated into any G7 country’s official climate mitigation plan. Recognizing and acknowledging this potential for GHG abatement is imperative as policymakers strive to formulate and implement effective strategies aimed at reducing emissions and fostering the adoption of sustainable practices. This section analyzes the methodologies for calculating ICT’s potential impact on GHG abatement. Subsequently, we evaluate the role of spectrum policy, broadband deployment, 5G use cases, and other GHG abatement measures that can be taken by the industry and policy makers. Lastly, we present a case study from Germany that utilizes digitization as a climate change mitigation tactic.

#### 3.1 Methodology for calculating ICTs aggregate GHG abatement

When calculating GHG emissions more broadly, the ICT sector lacks an international standard for calculating the effects of ICT’s GHG abatement potential. Thus, results of studies on GHG abatement have the potential to differ slightly, but each result falls within a similar range.<sup>65</sup> Studies use the general language of “ICT solutions” but, for the purpose of this study and the scope of their research (smart grid, smart buildings, smart transport, etc.), we can conclude that these estimates apply *mutatis mutandis* to the telecommunications sector due to their role in enabling these solutions. Without telecommunications infrastructure, the abatement estimated by such studies cannot occur. The potential reductions in emissions can be equally attributed to the availability of telecommunications infrastructure as the existence of the ICT solutions.

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<sup>64</sup> GeSI, “SMARTer2030,” (2015); Accenture, “Accelerating 5G in Canada: The Role of 5G in the Fight Against Climate Change,” (2020); Equidist and Bergmark, “How is mobile broadband intensity affecting CO2 emissions?,” 2022; GSMA, “The Enablement Effect,” 2019; Malmudin and Bergmark, “Exploring the effect of ICT solutions,” (2015); Farrpoint, “Digital Policy and Climate Change,” (2022); GSMA, “Spectrum: the Climate Connection,” (2023).

<sup>65</sup> Bieser, et al. “A review of assessments of the greenhouse gas footprint,” 2.

The most frequently cited study amongst the ICT sector is GeSI's SMARTer2030 (2015). This study estimates that ICT can enable a 20% reduction of global CO<sub>2</sub>e emissions by 2030.<sup>66</sup> Use cases included in this calculation are smart manufacturing, smart agriculture, smart buildings, smart energy, smart logistics, traffic control & optimization, connected private transportation, e-work, e-commerce, e-health, and e-learning.<sup>67</sup> GeSI (2015) assess these calculations through the following approach:

- I. Utilizing IPCC's projected "business as usual" (BAU) scenario where global emissions are expected to grow between 2015-2030 as a baseline (This BAU scenario integrates estimates for renewable energy in 2030)
- II. Removing the estimates for renewable energy savings, so that there is not an overestimate of ICT enabled savings (double counting of ICT aggregate savings)
- III. Avoidance of double counting use cases by integrating the abatement lever that applies to multiple use cases into the most relevant case
- IV. Adding ICT enabled savings to IPCC BAU forecast and calculating the abatement<sup>68</sup>

GeSI further clarifies that the decrease in the ICT sector's GHG footprint they assume is due to a range of investments that companies in the sector have been making to reduce their emissions and anticipate the expected improvements in the efficiency of ICT devices.<sup>69</sup> Ericsson researchers Malmudin & Bergmark (2015) offer a different perspective on 2030 estimates. Use cases included in their models consist of the smart grid, smart buildings, smart transport, smart work, smart travel, smart services, and smart agriculture. Malmudin & Bergmark implement the following methodology for GHG abatement:

- I. Creating a model for future GHGe that can be reduced by ICT solutions on a basic energy and sector level using end user perspective
- II. Gathering data on GHGe reductions due to ICT solutions by applying a life cycle perspective to the greatest extent possible, preferably based on measurements, calculations or estimates for the future
- III. Defining relevant scenarios and setting "reduction factors" for different ICT solutions

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<sup>66</sup> GeSI, "SMARTer2030," 8.

<sup>67</sup> Ibid, 18.

<sup>68</sup> Ibid, 17, 111-112.

<sup>69</sup> Ibid, 10.

- IV. Adding applicable solutions and reduction factors to each scenario and calculating potential reductions of global GHG emissions for the assessed year
- V. Avoiding double counting by multiplying reductions that address the same emissions (done both within and between sectors)<sup>70</sup>

Additionally, medium and high reduction scenarios were assessed to address the uncertainties that can occur when conducting this kind of study.<sup>71</sup> Malmodin & Bergmark (2015) estimate in a medium reduction scenario that GHG emissions abated by 5G solutions are 7.4% of total global emissions, and in a high reduction scenario about 15.3% for 2030.<sup>72</sup> It is difficult to meaningfully compare the GeSI (2015) and Malmodin & Bergmark (2015) estimations due to the clear methodological differences in approaches. Furthermore, estimating the future ICTs abatement potential is onerous due to the uncertainties about the future and adequately capturing all relevant variables. Yet, both studies confirm that ICT has substantial potential to mitigate GHG emissions if we enable it to do so.<sup>73</sup> Research should continue in this field to calculate the GHG abatement potential of the ICT and telecommunication sectors. Specifically, sector estimates for telecommunications allows policy makers and industry leaders to understand the sector's abatement potential of greenhouse gas emissions.

### **3.2 GHG abatement through spectrum policy**

Spectrum policy regulates how, when, and where efficiency-improving broadband network technologies can be deployed.<sup>74</sup> A recent empirical study by GSMA (2023) evaluates the impact of spectrum allocation on GHGe, demonstrating that the speed at which spectrum is allocated by regulators has a significant impact on emissions. A two year delay to 5G spectrum assignment can increase emissions by 2.6 MtCO<sub>2</sub>e for high income countries.<sup>75</sup> Additionally, assigning 100 MHz less to 5G is associated with a 15 MtCO<sub>2</sub>e increase in emissions. With less spectrum, more base stations are needed to meet demand for mobile data and increases the sector's GHG impact

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<sup>70</sup> Jens Malmodin and Pernilla Bergmark, "Exploring the effect of ICT solutions on GHG emissions in 2030," in *Proceedings of EnviroInfo and ICT for Sustainability 2015* (Atlantis Press, 2015): 37, doi:10.2991/ict4s-env-15.2015.5.

<sup>71</sup> Ibid, 44.

<sup>72</sup> Ibid.

<sup>73</sup> Ibid, 45.

<sup>74</sup> GSMA, "Spectrum: the Climate Connection," 7.

<sup>75</sup> Ibid, 3.

throughout the supply chain.<sup>76</sup> Overall, the GSMA (2023) modeled four aspects of spectrum policy that continue to inhibit allocation, consequently increasing GHG emissions.

<b>Delay to 5G assignments</b>	Delay in the adoption of more efficient network technologies, increasing emissions	Emits an additional 2.6 MtCO <sub>2e</sub>
<b>Restricted 5G assignments</b>	More base stations and higher emissions in their manufacture	Emits an additional 0.5 MtCO <sub>2e</sub>
<b>Fragmented 5G assignments</b>	Reduce spectrum usage, resulting in network inefficiencies and higher emissions	Emits an additional 0.4 MtCO <sub>2e</sub>
<b>No refarming to 5G</b>	Prevention of refarming to more efficient technologies	Emits an additional 0.8 MtCO <sub>2e</sub>

Table 3.1: Spectrum policy aspects affect the emissions of the mobile sector from GSMA<sup>77</sup>

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<sup>76</sup> Ibid.

<sup>77</sup> All calculations presented were for high income countries; Ibid, 9, 11.



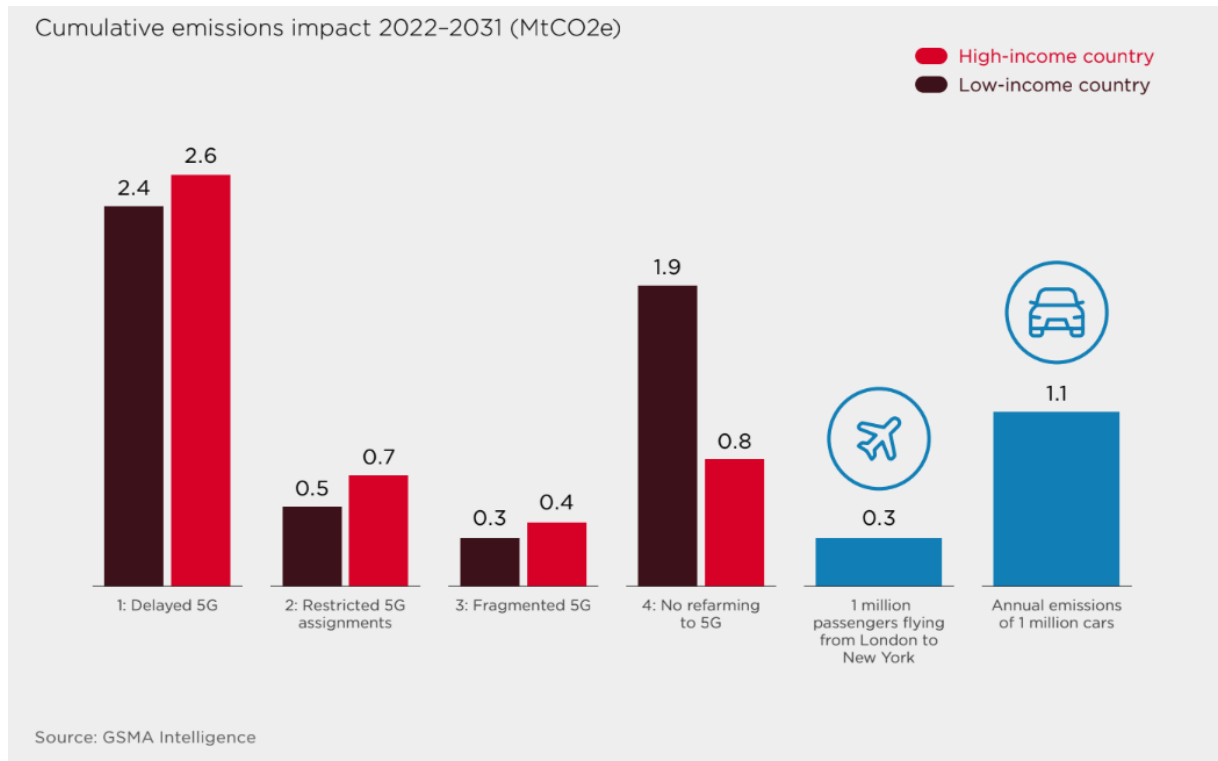


Figure 3.1: Cumulative emissions impact 2022-2031 of 5G spectrum assignments<sup>78</sup>

Delay in the adoption to 5G assignments prolongs the use of less efficient mobile technology. Each successive mobile generation (2G, 3G, 4G, 5G) has been more efficient in terms of energy use per unit of data.<sup>79</sup> Estimates reveal that 4G networks improved the efficiency of 3G networks by nearly 30 times over, with a similar improvement expected for 5G compared to 4G.<sup>80</sup> The restriction of 5G spectrum assignments will eventually be unsustainable for the amount of IoT devices that will continue to grow in the future. With limited spectrum, operators will require more base stations to serve the same amount of traffic, meaning an increased footprint in terms of equipment, construction, and transport, all of which contribute to GHG emissions.<sup>81</sup>

<sup>78</sup> Ibid, 10.

<sup>79</sup> Ibid, 13.

<sup>80</sup> Comparisons based on: Hanna Pihkola et al., “Evaluating the Energy Consumption of Mobile Data Transfer - From Technology Development to Consumer Behaviour and Life Cycle Thinking,” *Sustainability* 10, no. 7 (2018), <https://doi.org/10.3390/su10072494>; Jens Malmodin et al., “Life Cycle Assessment of ICT: Carbon Footprint and Operational Electricity Use from the Operator, National, and Subscriber Perspective in Sweden,” *Journal of Industrial Ecology* 18, no. 6 (2014), <https://doi.org/10.1111/jiec.12145>; Orange, “5G: energy efficiency ‘by design,’” last modified February 10, 2020, <https://hellofuture.orange.com/en/5g-energy-efficiency-by-design/>; as cited by Ibid.

<sup>81</sup> Ibid.

Additionally, spectrum fragmentation, or the assignment of certain spectrum blocks or bands that are narrow and scattered, have an adverse impact on emissions.<sup>82</sup> A single mobile operator may have two MHz channels, with each channel separated by assignments to other operators, instead of a single, continuous 100 MHz band.<sup>83</sup> This fragmentation leads to reduced network performance and reduced bandwidth for user data, effectively forcing operators to increase the number of base stations required for the same level of service.<sup>84</sup> Therefore, generating additional emissions by increasing the number of base stations when compared to a policy that prioritizes contiguity. Failure to re-farm spectrum to 5G technologies indicates that certain spectrum assignments are reserved for a specific pre-existing technology, inhibiting spectrum migration to the latest technologies and effectively preventing energy efficient gains.<sup>85</sup> Further emissions from the sector can be avoided through the timely, contiguous assignment of 5G spectrum blocks. Regulators who are concerned with the environmental impact of 5G should consider the effects of continuing the use of legacy technologies that are not as energy efficient. Effective spectrum policies will play a key role in the future of GHG abatement within the telecommunications sector, an area that will be further explored in our policy recommendations section.

### **3.3 GHG abatement by broadband rollout scenario**

For OECD countries without full 5G network capabilities, a timely rollout of network infrastructure will play a crucial role in enabling broadband's GHG abatement potential. The deployment of broadband infrastructure will no doubt contribute to the sector's first order (direct) GHG emissions. However, the pace at which broadband is deployed will greatly affect its carbon footprint. According to estimates by STL Partners (2019) rapid 5G SA rollout could reduce the cumulative carbon emissions by 0.5 billion tonnes by 2030, the equivalent of all international aviation in 2018.<sup>86</sup> This estimate is based on data collected from 240 countries, then summed up regionally<sup>87</sup> and globally.<sup>88</sup>

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<sup>82</sup> Ibid, 14.

<sup>83</sup> Ibid.

<sup>84</sup> Ibid.

<sup>85</sup> Ibid.

<sup>86</sup> STL Partners, "Curtailling Carbon Emissions - Can 5G Help?," (2019): 3-4.

<sup>87</sup> North America; Latin America; Western Europe; Central and Eastern Europe; North East Asia; South East Asia and Oceania; India; Nepal and Bhutan; the Middle East; and Sub-Saharan Africa

<sup>88</sup> Ibid, 26.

Four scenarios were modelled by STL Partners (2019), with assumptions about each rollout varying by country.<sup>89</sup> The scenarios also consider launch dates of 5G SA networks based on rollout, the volume of data running on 5G SA, 4G and legacy networks, and make assumptions about the future of existing mobile networks (e.g., the eventual decommission of 3G and 2G networks).

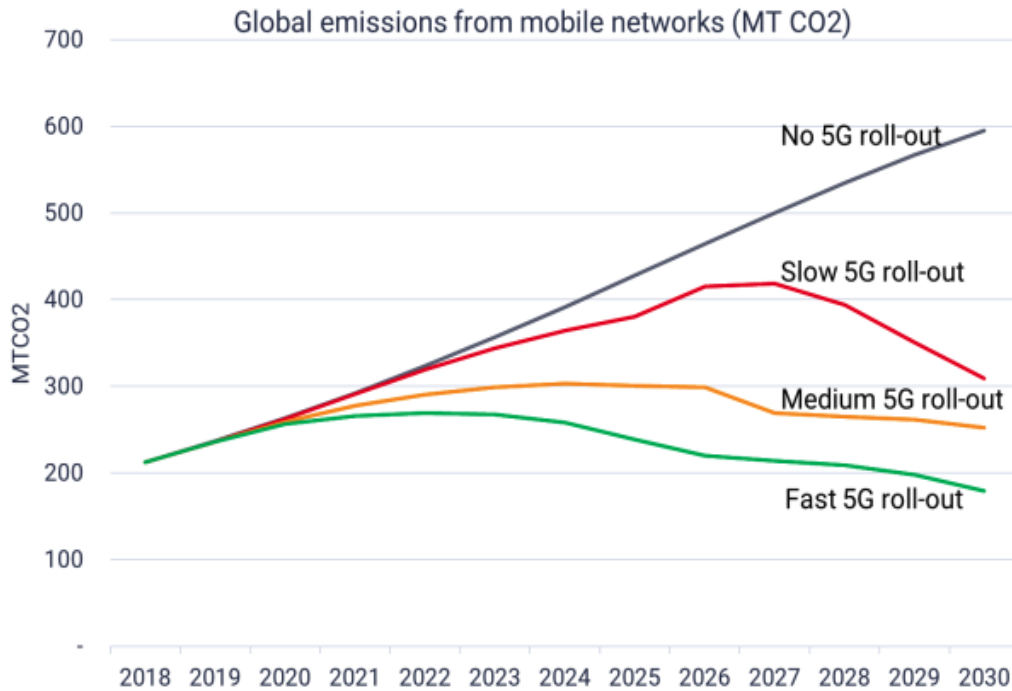


Figure 3.2: Projected CO2 emissions from mobile networks under 4 scenarios by STL Partners<sup>90</sup>

5G network deployment speeds	Approx. network launch dates for users	Data share volumes
No 5G SA rollout	-	Data shares remain on 4G networks and lack energy efficiency
Slow 5G SA rollout	2021-2024	5G accounts for 10-25% of data shares by 2025 and 60-80% by

<sup>89</sup> Ibid, 11.

<sup>90</sup> Ibid, 13.

		2030
<b>Medium 5G SA rollout</b>	2019-2022	5G accounts for up to 60% of data shares by 2025 and 85% by 2030
<b>Fast 5G SA rollout</b>	2019-2021	5G accounts for up to 99% of data shares in 2030 for advanced economies

Table 3.1: Impact of 5G SA network deployment speeds<sup>91</sup>

5G SA technology offers various improvements in network architecture, such as improvements in energy use through automated sleep modes on base station functions.<sup>92</sup> However, there are three main improvements in the access network from 5G SA that will significantly reduce the energy consumption of the network: (i) a collection of technologies referred to as “New Radio” (NR), (ii) new spectrum and higher array of massive MIMO antennas associated with ‘New Radio’, and (iii) millimeter wave (mmWave) spectrum.<sup>93</sup> 5G New Radio (NR) and massive MIMO provide higher network efficiency and will be paired alongside the other network functions offering greater energy efficiency.<sup>94</sup> STL Partners expects that as networks are scaled and optimized, by 2030 we can expect that the energy consumption of 5G NR will eventually fall to 10% of current 4G access technologies.<sup>95</sup> Millimeter wave spectrum is expected to increase the amount of data that can be transmitted per unit of energy due to the use of smaller and cheaper power cell towers.<sup>96</sup> Moreover, mmWave can provide a far more efficient mechanism to support peaks in demand and improve utilization and energy performance.<sup>97</sup> Several other factors will affect the improvements in energy efficiency from 5G SA infrastructure, such as the investment in infrastructure and decommissioning legacy networks,

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<sup>91</sup> Ibid, 11-12.  
<sup>92</sup> Ibid, 15-16.  
<sup>93</sup> Ibid, 16.  
<sup>94</sup> Ibid.  
<sup>95</sup> Ibid.  
<sup>96</sup> Ibid, 17.  
<sup>97</sup> Ibid.

end to end network slicing (only possible through 5G SA) that will result in more efficient use of core network resources, and edge computing which significantly reduces core traffic volumes.<sup>98</sup>

There will be an inevitable increase in emissions produced by the telecommunications sector as the deployment and adoption of 5G SA networks take place. As in the aforementioned studies referenced in this paper,<sup>99</sup> STL Partners provides evidence that a slower rollout of the 5G will result in more emissions due to the increase of devices transmitting over legacy networks, which are inefficient compared to 5G SA networks. The majority of emissions produced by 5G SA networks will be in the construction of the network infrastructure, not the network operation. We can conclude from these studies that prolonging the deployment of 5G SA networks will produce more emissions due to the continuous reliance on outdated 4G technology that does not have the same 5G SA energy saving capabilities. As a result, the prioritization of 5G SA deployment should be seriously considered to reduce GHG emissions.

**3.4 Identified GHG abatement levers (5G use cases)**

5G has a variety of use cases that will be applicable in abating GHG emissions. These are known as GHG abatement levers, or more commonly as 5G use cases. Different sources frequently cite a variety of use cases and the selected uses frequently overlap.

Author	Identified 5G use cases
Accenture (2020)	Smart transportation, smart living, working & health, smart buildings, smart energy, smart agriculture
Bieser et al (2020)	Smart work, smart energy (smart grid), smart transport (automated driving), and smart agriculture (precision farming)
Exponential Road Map (2019)	Smart energy, smart transport, smart industry, smart buildings, smart food consumption

<sup>98</sup> Ibid, 16.

<sup>99</sup> GSMA, “Spectrum: the Climate Connection,” (2023); Bieser et al., “Opportunities of 5G Mobile Technology for Climate Protection in Switzerland,” (2022).

GSMA (2019)	Smart working, living, & health, smart transportation & cities, smart manufacturing, smart buildings, smart energy, smart agriculture
GeSI (2015)	Smart manufacturing, smart agriculture, smart building, smart energy, smart logistics, traffic control & optimization, smart work, learning, commerce, health, & banking

Table 3.2: Identified 5G use cases by author<sup>100</sup>

Specifically, Bieser et al. (2020) states that their use cases were chosen based on a preliminary literature review for GHG abatement levers that have the highest potential and the most frequently cited. For others, it depends on the timeline and purpose of the report. GSMA (2019) states that smart working, living & health accounting for 39% abatement potential, while smart transport & cities accounts for 30%, but this is likely due to their analysis of 2018 carbon emissions.<sup>101</sup> In contrast, GeSI (2015) projects 2030 use cases, identifying smart manufacturing (22%) and smart agriculture (17%), smart buildings (16%), and smart energy (15%) as the majority of use cases.<sup>102</sup> This is most likely due to the assumptions on adaptation of 5G and the gradual maturity of technology as time goes on. Accenture (2021) does not give a time frame for their analysis period but cites GMSA (2019) as the source for their model calculations for use cases.<sup>103</sup> The Exponential Road Map (2019) identifies sectors for potential impact but not a proposed period of time. Since the recommended use cases are similar to GeSI (2015) predictions of 2030 use cases, we can assume that the Exponential Road Map (2019) is referring to mature GHG abatement levers for the future. The main documents of the literature provide mixed perspectives and time periods for use cases and provides an understanding of both our immediate abatement potential and how the future can be impacted. In order to paint a broad perspective of use cases, we will analyze smart work, smart health, smart transportation, smart

<sup>100</sup> Accenture, CWTA, “Accelerating 5G in Canada: The role of 5G in the Fight Against Climate Change” (2020); GeSI, “SMARTer2030,” (2015); Bieser et al., “Next generation mobile networks,” (2020); GSMA, “The enablement effect,” (2019); Exponential RoadMap Initiative, “Exponential Road Map 2030,” (2019)

<sup>101</sup> GSMA, “The enablement effect,” 10

<sup>102</sup> GeSI, “SMARTer2030,” 18

<sup>103</sup> Accenture, CWTA, “Accelerating 5G in Canada: The role of 5G in the Fight Against Climate Change” (2020); GSMA, “The enablement effect,” (2019)

agriculture, and smart energy, and smart buildings as they have been widely cross referenced amongst the literature in this field. These were chosen based on the literature review and the percentage of impact they propose to have for both present and future cases.

### 3.4a Smart work

Smart work, or teleworking allows employees to work from home while still fulfilling their tasks through collaborative working software and video conferencing technology (Zoom, GoogleMeet, etc.)<sup>104</sup> Working from home facilitates the avoidance of emissions from travel for business, daily commuting, and reducing the energy consumption in office buildings.<sup>105</sup> Although working from home requires energy use at home and results in a rebound effect, according to GSMA (2019) on average this is outweighed by the carbon savings of avoiding commuting.<sup>106</sup> A study from Dell U.S. found that by enabling their employees to work from home they were reducing their carbon footprint by over 1 tonne of CO<sub>2</sub>e per year, even when taking into account rebound effects of the increased energy use in employees homes.<sup>107</sup> As an overall result of Dell's program, Dell reduced its emissions by 9,800 tonnes of CO<sub>2</sub>e.<sup>108</sup> Similarly, Accenture (2021) reports that a 10% reduction in traffic congestion in the cities of Montreal and Vancouver would result in the reduction of 130,000 tonnes and 55,000 tonnes of CO<sub>2</sub>e respectively.<sup>109</sup>

More collective efforts should be made to enable smart working, as it is a readily available use case for GHG abatement. The deployment of 5G SA can further smart working by facilitating VR, AR, and other mixed reality innovations for workers, but this is not something that the field is reliant on.

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<sup>104</sup> GSMA, "The enablement effect," 20.

<sup>105</sup> Ibid, 20.

<sup>106</sup> Ibid.

<sup>107</sup> Alex Muresianu, "Utah Is Letting Lots of Government Employees Work from Home," Reason, last modified on July 30, 2019, <https://reason.com/2019/07/30/utah-is-letting-lots-of-government-employees-work-from-home/>; Dell, "The Sustainability Benefits of the Connected Workplace," (2016); Sara Sutton, "How Telecommuting Reduced Carbon Footprints at Dell, Aetna and Xerox," Entrepreneur, last modified April 22, 2015, <https://www.entrepreneur.com/article/245296>; Andrea Loubier, "Benefits of Telecommuting for the Future of Work," Forbes, last modified July 20, 2017, <https://www.forbes.com/sites/andrealoubier/2017/07/20/benefits-of-telecommuting-for-the-future-of-work/#7ca1bc8c16c6>; as cited by Ibid, 21.

<sup>108</sup> Ibid.

<sup>109</sup> Accenture, CWTA, "Accelerating 5G in Canada: Benefits for Cities and Rural Communities" (2019); as cited in Accenture, CWTA, "Accelerating 5G in Canada: The role of 5G in the Fight Against Climate Change," 26.

### 3.4b Smart health

The smart health initiative is another use case that can be rapidly implemented to abate GHG emissions. Specifically, the use of technology through remote monitoring of patients using machine to machine (M2M) technology reduces the travel for both health professionals and patients, and reduces overcrowded hospitals.<sup>110</sup> Additionally, increasing the ability to remotely monitor patients provides patients in remote and underserved communities with limited access to daily healthcare professionals increased medical assistance.<sup>111</sup> A 2021 review of telehealth outcomes across rural communities in the United States indicates telemedicine models were associated with positive outcomes for both patients and healthcare professionals.<sup>112</sup> In the UK, the National Health Service (NHS) deals with over 1 million patients every 36 hours.<sup>113</sup> To serve numerous patients they utilize the N3 network, a secure national broadband network built for the NHS, connecting over 1.3 million staff, general practitioner, clinic, and hospital.<sup>114</sup> This broadband network ensures healthcare professionals have quick and easy access to information, and ensures the best patient care.<sup>115</sup> It allows for 39,000 hospital appointments to be booked electronically and 675,000 prescriptions to be sent daily and offers a range of services like videoconferencing and mobility solutions.<sup>116</sup> The N3 network has reduced NHS carbon emissions by more than 50,000 tonnes of CO<sub>2</sub>e in the near decade it has been operational.<sup>117</sup>

Smart health may be reliant on the broad implementation of 5G SA technology because it offers increased network security and optimization for networks. However, increasing the access in rural and remote areas is a broadband network adoption issue that is yet to be addressed in many OECD countries.

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<sup>110</sup> GSMA, “The enablement effect,” 22.

<sup>111</sup> Ibid.

<sup>112</sup> Michael Butzner and Yendelela Cuffee, “Telehealth Interventions and Outcomes Across Rural Communities in the United States: Narrative Review,” *J Med Internet Res* 23, no. 8 (2021), DOI: [10.2196/29575](https://doi.org/10.2196/29575).

<sup>113</sup> NHS Confederation, “NHS Statistics, Facts, and Figures,” last modified May 2, 2023, <https://www.nhsconfed.org/articles/key-statistics-nhs>; BT, “NHS N3 network case study,” last modified October 29, 2019, <https://business.bt.com/why-choose-bt/case-studies/nhs-n3-infrastructure/>; as cited in GSMA, “The enablement effect,” 23.

<sup>114</sup> Ibid, 23.

<sup>115</sup> Ibid.

<sup>116</sup> Ibid.

<sup>117</sup> Ibid.



### 3.4c Smart agriculture

Agriculture, forestry, and other land uses currently account for 25% of global GHG emissions<sup>118</sup> due in part to high emissions from fertilizer use, irrigation systems, and food waste.<sup>119</sup> Precision agriculture is the leading technology of smart agriculture, which encapsulates increased access to data from the use of IoT devices like sensor monitoring to collect crop data and evaluate crop health.<sup>120</sup> This leads to the increased efficiency of agriculture management and saves farmers time and reduces waste of resources (e.g., Irrigation systems). California asparagus farmers that have integrated precision agriculture systems utilizing the LTE network and cloud, have seen reductions in water use (6%), greenhouse gas emissions (5%), and labor costs (5%).<sup>121</sup>

Additionally, these savings are projected to reduce the annual use of pesticides, specifically in Canada once precision agriculture technologies receive widespread adoption the average oilseed farming worker<sup>122</sup> in the canola industry can expect to save upwards of \$40,000 annually.<sup>123</sup> Applying the estimate of \$40,000 of savings per farmer to the total number of oilseed farms in Canada, and using the average selling price of one of the key pesticides used in Canola crops, we can estimate the reduction in pesticide use.<sup>124</sup> Based on this data, we can assume that oilseed across Canada can reduce the annual usage of pesticides by 20%, leading to a possible 15.6 tonnes of pesticides savings per year in oilseed farming.<sup>125</sup> Outcomes for smart agriculture can be supported by policy to ensure the widespread adoption of technology and further education of farmers on precision agriculture capabilities.

### 3.4d Smart energy

Smart energy can efficiently manage the operations of energy grids and optimize the use of resources. Electricity will increasingly rely on smaller, more dispersed, and less consistent electricity as many industries transfer renewable energy sources.<sup>126</sup> 5G technologies are a critical

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<sup>118</sup> IPCC, “AR5 Synthesis Report,” (2014): 47 as cited in Ibid, 29.

<sup>119</sup> Ibid.

<sup>120</sup> Accenture, CWTA, “Accelerating 5G in Canada: The role of 5G in the Fight Against Climate Change,” 34.

<sup>121</sup> AT&T, “AT&T IoT for Good Case Study: Asparagus Has a Lower Water Footprint Thanks to Devine Organics, WaterBit and AT&T,” (2018); as cited by GSMA, “The enablement effect,” 31.

<sup>122</sup> In Saskatchewan, Canada.

<sup>123</sup> Accenture, CWTA, “Accelerating 5G in Canada,” (2019) as cited by Accenture, CWTA, “Accelerating 5G in Canada: The role of 5G in the Fight Against Climate Change,” 34.

<sup>124</sup> Ibid, 34.

<sup>125</sup> Ibid.

<sup>126</sup> MIT Technology Review, “Decarbonizing industries with connectivity & 5G,” Produced in partnership with Ericsson, (2021): 10.

tool in allowing power companies to transition to renewable energy by providing higher levels of reconfigurability for power grids, allowing local networks to also work separately from the main network, and help renewable energy installations to operate more efficiently and dynamically.<sup>127</sup> Utilizing smart energy will be further enabled through broadband deployments that have the infrastructure to monitor multiple power grids and allocate network resources to proper domains.

### **3.4e Smart buildings**

Heating, ventilation, and air conditioning (HVAC) are critical building systems that account for approximately one third of a building's energy usage.<sup>128</sup> In connected buildings, automated monitoring and control of HVAC systems is currently one of the biggest enablement mechanisms for the smart building use case.<sup>129</sup> These solutions run on the current generation communication technologies, however 5G SA will allow for more sophisticated and extensive adoption of the use case across the sector. 5G SA will facilitate a higher density of devices and decreased latency in data transmission, allowing information about a building's energy use to be delivered in real time.<sup>130</sup>

### **3.4f Smart transportation**

Smart transportation can impact route optimization and fuel efficiency, but also act as a catalyst for the increase of electric vehicles by facilitating the use of charging points.<sup>131</sup> Furthermore, it can increase monitoring and management of traffic congestion by communicating between traffic lights, optimizing wait times at junctions and overall improving traffic flow and allow drivers to maintain a more consistent speed.<sup>132</sup> Improving city traffic management reduces fuel consumption and emissions, all of which is enabled by 5G SA's capacity to accommodate a dense network of vehicles.<sup>133</sup> A collaboration between service providers, mobile networks, and heavy-goods vehicles has resulted in an app that allows professional drivers to access mobile refuelling, fuel consumption optimization, GPS position,

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<sup>127</sup> Ibid, 11.

<sup>128</sup> Accenture, CWTA, "Accelerating 5G in Canada: The role of 5G in the Fight Against Climate Change," 30.

<sup>129</sup> Ibid.

<sup>130</sup> Ibid.

<sup>131</sup> Ibid, 24.

<sup>132</sup> Ibid.

<sup>133</sup> Ibid, 25.

and tachograph data for transfer optimization.<sup>134</sup> This system helps both drivers and managers to plan and drive individual HGVs and the fleet more efficiently, saving up to 15% of the vehicles consumption, therefore reducing emissions.

### **3.5 Other abatement tools**

Digital solutions should not be the only tools that telecommunications companies are limited to in reducing GHG emissions. Efforts to increase the use of renewable energy in production and operation should be taken in addition to decarbonization measures. The Exponential Roadmap (2019) outlines targets for digital companies to take in climate leadership. This includes measures such as:

- Tech companies setting strong emission reduction targets and increase investments in renewable energy
- Companies stimulating innovation and creativity, especially related to decarbonization
- Carbon footprint information for digital products being tracked and readily available for businesses and consumers
- Rapid increase in onsite renewable energy and production
- Non renewable energy used in production and manufacturing drastically reduced<sup>135</sup>

The sector can take charge of its own emissions but policy can further support abatement potential in GHG emissions by explicitly integrating climate change mitigation tools. Moreover, the telecommunications sector does not have to rely on exclusively technology to reduce their carbon footprint. Increasing renewable energy sources and other tools should be used in tandem with digital GHG abatement levers.

### **3.6 Case study: Germany's Digital Policy Agenda for the Environment**

Germany has led groundbreaking research in the digital policy and climate policy space with the publication of the “Digital Policy Agenda for the Environment” (2020) a white paper by Germany's Federal Ministry for the Environment, Nature Conservation And Nuclear Safety

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<sup>134</sup> Telia Company, “Telia Company in Co-Operation to Lower Emissions from Transports,” last modified May 30, 2018, <https://www.teliacompany.com/en/news-articles/telia-company-in-co-operation-to-lower-emissions-from-transports>, as cited by GMSA, 24.

<sup>135</sup> Exponential RoadMap Initiative, “Exponential Road Map 2030,” 76.

(BMU). The paper was prepared during a three week environmental workshop where the Federal Environment Ministry drew up the agenda together with around 200 experts from politics, administration, industry, research, and from municipalities from civil society.<sup>136</sup> Common values and strategies were discussed to create environmentally friendly IT, particularly in the fields of mobility, agriculture, industry & circular economy, and everyday consumption.<sup>137</sup> The report outlines measures that address digitalization in an environmentally friendly way through four packages of measures: (i) future programme for environmentally friendly digitalization (ii) transparency initiative (iii) digitalization for social and environmental restructuring, and (iv) environmental policy 4.0.<sup>138</sup> It includes over 70 measures, some of which were underway at the time of the publication, while others were in progress.

The first measure, the future programme for environmentally friendly digitization intends to reduce energy needs and resource consumption of digital technologies by closing loopholes in European rules and provisions regarding hardware, software, and cloud services.<sup>139</sup> Furthermore, the programme will be accompanied by criteria for sustainable artificial intelligence.<sup>140</sup> The second measure, the transparency initiative, creates measures like the Digital Product Passport containing the environmental data on the life cycle of products and services that will aid consumers, industry, and the waste management sector more sustainably.<sup>141</sup> Digitalization for social and environmental restructuring enables artificial intelligence projects for the environment, climate, and nature resources.<sup>142</sup> Measures within this category promote innovations like the AI Support Programme for environment, climate, nature and resources to promote projects that use AI to tackle environmental challenges.<sup>143</sup> Lastly, environmental policy 4.0 intends to strengthen environmental administration through increased access to the environmental data and nature conservation system.<sup>144</sup>

Germany's Federal Ministry for the Environment has yet to release an update about the status of their digital policy measures. Their current digital agenda for the environment website

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<sup>136</sup> The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, "Digital Policy Agenda for the Environment," 3.

<sup>137</sup> Ibid.

<sup>138</sup> Ibid, 4-5.

<sup>139</sup> Ibid, 4.

<sup>140</sup> Ibid.

<sup>141</sup> Ibid.

<sup>142</sup> Ibid.

<sup>143</sup> Ibid, 29.

<sup>144</sup> Ibid, 5.

has not been updated since 2020 with many links broken. However this does not mean that all measures were abandoned. A current ongoing measure is the AI lighthouse project is currently ongoing, 300 ideas were submitted in the first funding period in 2021, 35 of which were approved, receiving a total funding of 46 million euros.<sup>145</sup> The publication of the paper was likely to generate public interest and garner support for digital and climate policies. Furthermore, it demonstrates Germany's clear interest and expertise in the matter, despite not having digital policies implemented in their official climate change strategy.

#### **4. GHGs and Connectivity in OECD countries**

The relationship between greenhouse gas emissions and broadband connectivity is an underexplored facet in this field, and further research will be necessary to better understand the relationship. However, we may be able to generally conclude which mature OECD countries can utilize digital policies to abate GHG emissions by looking at their current emissions and broadband network connectivity.<sup>146</sup> In this section we discuss our methodology for connectivity measurements and data collection on GHG emissions and other included variables, then discuss OECD countries' GHG profiles and broadband network metrics.

##### **4.1 Methodology for GHG emissions and connectivity**

In the following sections, we will utilize descriptive statistics on a country's GHG emissions (total and per capita) and weighted averages of 5G upload, download, and network adoption rates in each country. The data collected for GHG emissions is the most recent publicly available data. To ensure data was being collected on GHG emissions for the same year across OECD countries, Our World in Data was employed for total GHG emissions and total GHG emissions per capita. GHG emissions per capita reflects differences in population size across the world and calculates the average person's "footprint" in a given country.<sup>147</sup> Other specific sector

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<sup>145</sup> The German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, "BMUV funding initiative 'AI lighthouse projects for the environment, climate, nature and resources,'" accessed on April 2023, <https://www.bmuv.de/en/topics/sustainability-digitalisation/digitalisation/our-support-programme-for-artificial-intelligence>.

<sup>146</sup> GeSI explores certain countries in SMARTer2030 and makes further recommendations based on their broadband networks and specific sectors.

<sup>147</sup> Hannah Ritchie, Max Roser, and Pablo Rosado, "CO2 and Greenhouse Gas Emissions," OurWorldInData.org, data visualization, accessed May 24, 2023, <https://ourworldindata.org/co2-and-greenhouse-gas-emissions>.

data for GHG emissions was collected from various government websites when available. OpenSignal data was collected on each country and was employed based on an OECD assessment of broadband networks measurement tools. OpenSignal’s methodology for broadband speeds measures “end to end” consumer experience, and does not rely on dedicated test services by users, but rather the full path from the user device all the way to content delivery networks such as Google, Akamai, and Amazon.<sup>148</sup> It collects measurements of network speeds based on both user-initiated tests and automated background tests to avoid sample selection bias, unlike other platforms such as Ookla.<sup>149</sup> Thus, OpenSignal was the chosen database for our analysis for broadband network metrics.

## **4.2 OECD Countries**

Countries were chosen based on economic maturity and association with Canada (i.e., G7 members) were included for comparison. For this reason, Australia, France, Germany, Japan, Italy, South Korea, Spain, the United Kingdom, and the United States were chosen.

### **4.2a GHG Profile**

When looking at overall contribution to CO2 emissions, this only takes into account each country’s aggregate emissions and how it contributes to global GHG emissions, including emissions from fossil fuels, industry, and land use change. This leaves quite a large skew between the United States and the other countries of analysis. Adjusting for per capita emissions, the distribution of countries changes instead of leaving a larger skew.

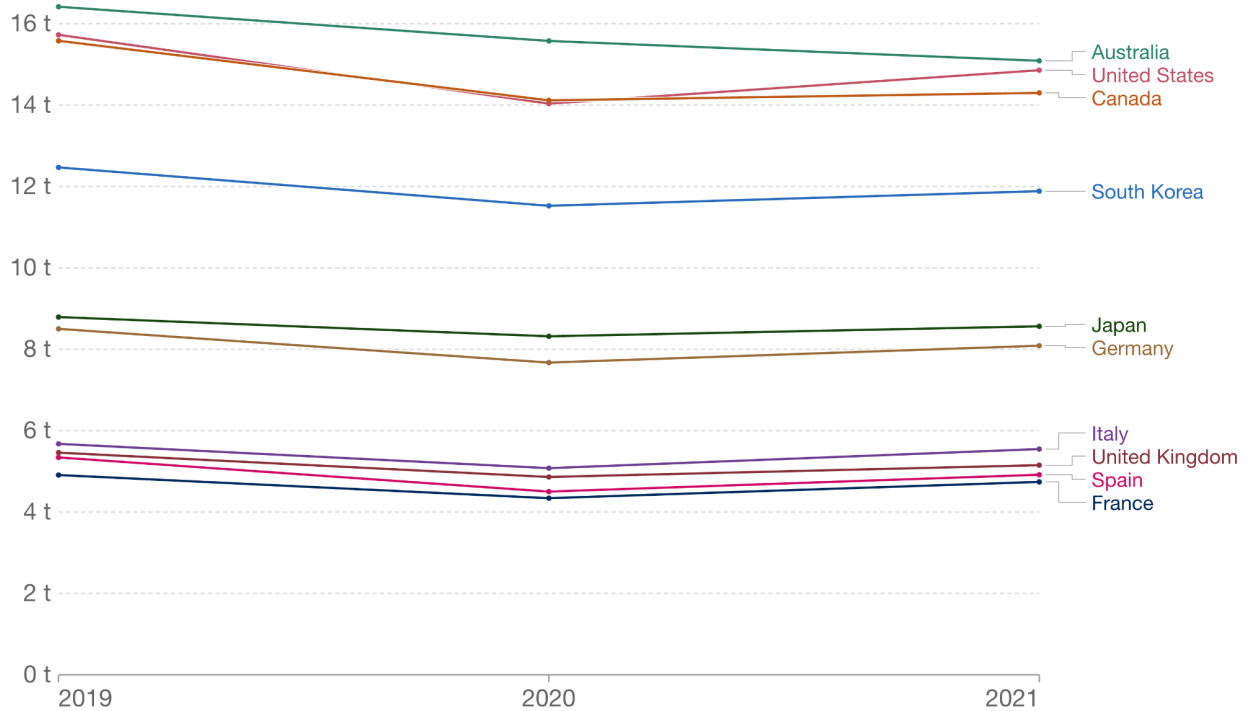
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<sup>148</sup> OECD, “Broadband networks of the future,” *OECD Digital Economy Papers*, no. 327 (2022): 45.

<sup>149</sup> *Ibid.*

## Per capita CO<sub>2</sub> emissions

Carbon dioxide (CO<sub>2</sub>) emissions from fossil fuels and industry<sup>1</sup>. Land use change is not included.



Source: Our World in Data based on the Global Carbon Project (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions • CC BY

**1. Fossil emissions:** Fossil emissions measure the quantity of carbon dioxide (CO<sub>2</sub>) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO<sub>2</sub> includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Figure 4.1: Per capita CO<sub>2</sub> emissions controlled for GHG emissions per capita (2019-2021)<sup>150</sup>

Australia (15.09 tonnes), the United States (14.86 tonnes), and Canada (14.30 tonnes) have some of the highest emissions per capita, or per person's CO<sub>2</sub> footprint.<sup>151</sup> South Korea has the fourth highest at 11.89 tonnes, while Japan and the OECD countries are all around 10 tonnes and under per capita.<sup>152</sup> High emissions per capita in Australia, the United States, and Canada may be explained by their energy sources. Specifically, Australia has the highest greenhouse gas emissions from coal power in the world on a per capita basis, nearly doubling those in China.<sup>153</sup>

<sup>150</sup> Ibid.

<sup>151</sup> Ibid.

<sup>152</sup> Ibid.

<sup>153</sup> Adam Morton, "Australia shown to have highest greenhouse gas emissions from coal in world on per capita basis," *The Guardian*, last modified on November 11, 2021, <https://www.theguardian.com/environment/2021/nov/12/australia-shown-to-have-highest-greenhouse-gas-emissions-from-coal-in-world-on-per-capita-basis>.

Australia's energy production sector is the largest contributor to carbon emissions, 71% of which is reliant on fossil fuels.<sup>154</sup> In the U.S. a similar issue is apparent, with the biggest emissions arising from the transport (28%) and electricity (25%) sectors.<sup>155</sup> Emissions generated by the transportation sector are driven by the use of fossil fuels for the vast amount of vehicles that are utilized in the United States (cars, trucks, ships, trains and planes).<sup>156</sup> In addition to this, the electricity sector employs the majority of its energy consumption from burning fossil fuels (79%).<sup>157</sup> Canada generates the majority of its emissions from the oil and gas sector (28%) and the transport sector (22%), both of which are fossil fuel intensive.<sup>158</sup> For mining, oil and gas extraction, the sector uses oil based fuels for heating and electricity, with increased usage during the harsh winters.<sup>159</sup> Additionally in Canada, the country is vast yet more sparsely populated which leads to longer travel times and compared to smaller and/or densely populated countries<sup>160</sup>

The rest of the OECD countries within our sample have smaller per capita emissions, besides South Korea, the rest have around 10 tonnes and below.<sup>161</sup> This is due to the difference in geography, population, and other factors like the distances required to travel for work. Japan, Germany, EU, Italy, UK, and France all have smaller, more densely populated geographies compared to Canada, US, and Australia who have larger geographies. Additionally, Canada and Australia both have a smaller population dispersed amongst a larger area. There are other

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<sup>154</sup> Australian Government, Department of Climate Change, Energy, the Environment and Water, "Australian electricity generation - fuel mix," accessed on May 23, 2023, <https://www.energy.gov.au/data/australian-electricity-generation-fuel-mix>.

<sup>155</sup> The United States Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," last modified on April 28, 2023, <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#:~:text=Human%20activities%20are%20responsible%20for,over%20the%20last%20150%20years.&text=The%20largest%20source%20of%20greenhouse,electricity%2C%20heat%2C%20and%20transportation>.

<sup>156</sup> Ibid.

<sup>157</sup> Ibid.

<sup>158</sup> Government of Canada, "Greenhouse gas emissions: drivers and impacts," last modified April 14, 2023, <https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions-drivers-impacts.html>.

<sup>159</sup> Canada Energy Regulator, "Market snapshot: Why do Canadians use so much oil?" last modified January 24, 2018, <https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-why-do-canadians-use-so-much-oil.html#:~:text=These%20sectors%20use%20oil%2Dbased,high%20oil%20use%20per%20person>.

<sup>160</sup> Government of Canada, "Greenhouse gas emissions: drivers and impacts," <https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions-drivers-impacts.html>.

<sup>161</sup> Ritchie, Roser, and Rosado, "CO<sub>2</sub> and Greenhouse Gas Emissions," <https://ourworldindata.org/co2-and-greenhouse-gas-emissions>.



lifestyle factors as well such as the more frequent use of public transportation within European countries compared to cars being the common method of transportation within the US. South Korea’s higher emissions per capita is likely due to its large energy and industrial production sector. According to 2018 data, electricity and heat generation made up 51% of energy related CO2 emissions, with more than 50% of the energy supply consisting of fossil fuels.<sup>162</sup> This is still prevalent today, as the largest percentage of CO2 emissions in South Korea come from the use of coal.<sup>163</sup>

### 4.3b Broadband Connectivity

Digital adoption will be an essential tool for abating GHG emission, as the realization of these solutions heavily relies on the presence of appropriate technology and infrastructure. Resilient networks that have consistent, high speed, reliable network coverage will facilitate the use of the GHG abatement levers we have previously identified. For example, smart grid utilization will require a reliable 5G tower that has continuous connectivity and coverage in order to monitor energy consumption. This is also important for telehealth as a reliable connection is integral for retrieving and sending patient data, as well as constant network connection and security to ensure the privacy of health data. Countries with high emissions and stable broadband connectivity capabilities can benefit from introducing digital policies that abate GHG emissions. When analyzing countries with the highest potential for implementation would be the ones with the strongest broadband infrastructure. Additionally, countries with high GHG emissions can also benefit from deploying digital policies that abate GHGe.

	5G Download Speed (mbps)	Network adoption rates	Total emissions (tonnes)	GHG emissions per capita (tonnes)
<b>Australia</b>	198.3	93	399.14 million	15.09
<b>Canada</b>	142.56	90	655.99 million	14.30
<b>France</b>	201.32	75	290.25 million	4.74

<sup>162</sup> Climate Transparency, “Brown to Green: The G20 Transition to Low Carbon Economy, South Korea,” (2018): 4.

<sup>163</sup> Hannah Ritchie and Max Roser, “South Korea: CO2 Country Profile,” accessed on May 23, 2023, <https://ourworldindata.org/co2/country/south-korea>.

<b>Germany</b>	133.3	85	668.78 million	8.09
<b>Italy</b>	152.85	72	290.69 million	5.50
<b>Japan</b>	162.7	69	1.07 billion	8.57
<b>South Korea</b>	421.5	94	609.63 million	11.89
<b>Spain</b>	126.12	87	208.14 million	4.92
<b>United Kingdom</b>	139.1	88	353.04 million	5.15
<b>United States</b>	114.09	89	5.12 billion	14.86

Table 4.1: 5G download speeds (2022-2023), network adoption (2016), total GHG emissions (2021) and GHG emissions per capita of OECD countries (2021)<sup>164</sup>

Combining data on GHG permissions, as well as a weighted average of network speed and adoption, yields Figure 4.3. The weighted average of 5G upload and download (U/D) speeds were calculated with equal weights given to each telecommunication operator (25% or 33.33%) depending on how many operators were within each country. We then calculated the weighted average of the 5G (U/D) and network adoption rates, both assigned an equal weight of 50%. This is to ensure we have considered the network capabilities of each country

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<sup>164</sup> Please see references for extensive list of OpenSignal sources; OpenSignal, “Network Experience Insights,” <https://www.opensignal.com/>; Jacob Pushter, "Internet Access Growing Worldwide but Remains Higher in Advanced Economies" (Pew Research Center, February 22, 2016), accessed June 6, 2023, <https://www.pewresearch.org/global/2016/02/22/internet-access-growing-worldwide-but-remains-higher-in-advanced-economies/>; Hannah Ritchie, Max Roser, and Pablo Rosado, "CO2 and Greenhouse Gas Emissions," <https://ourworldindata.org/co2-and-greenhouse-gas-emissions>.

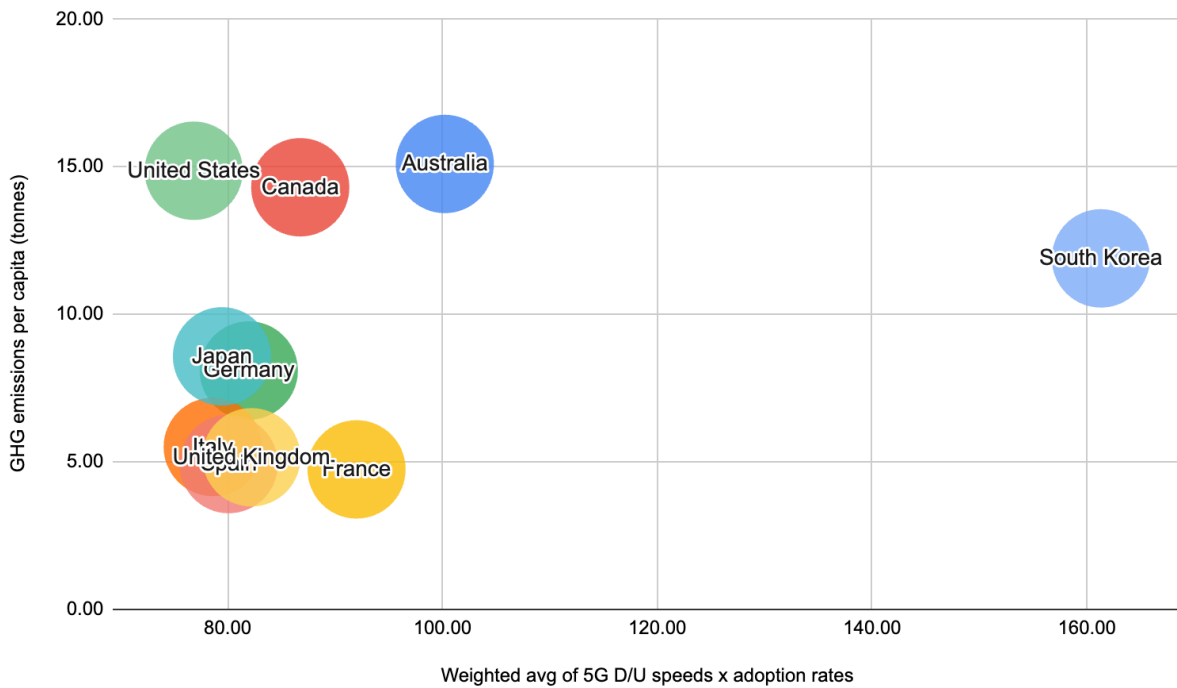


Figure 4.3: GHG emissions per capita (tonnes) vs. weighted average of 5G download and upload speeds (2022) x network adoption rates (2016)<sup>165</sup>

Based on the assessments of broadband connectivity metrics, South Korea would benefit greatly from digital policies due to their fast and extensive 5G network capabilities. Additionally, they have the fourth highest GHG emissions per capita and regularly use fossil fuels for energy consumption. The adoption of digital policies can further encourage the use of renewable energy sources through smart grid technology. Other countries can also benefit from these policies, particularly those with high emissions and stable network connectivity. Canada, US, Australia should take advantage of this approach to further efforts in reducing high per capita emissions. Digital adoption can impact smaller changes in the lifestyle behaviors of citizens that reduce their carbon footprints (e.g., working from home). Fast upload and download speeds and consistent network availability can increase adoption and reliability of solutions. Moreover, the timely rollout of 5G broadband (5G SA) networks reduces the network's overall carbon footprint and ensures the lowest possible GHGe are emitted, compared to more time consuming rollout scenarios. 5G networks allow for the adoption of innovative energy efficient

<sup>165</sup> Ibid.

technology, and directly translates to the reduced reliance on 4G networks and their resource intensive physical infrastructure.

Digital adoption plays a pivotal role in driving GHG reductions by influencing positive changes in lifestyle behaviors. In South Korea and Australia, efforts to divert from the use of fossil fuels to more renewable energy sources when possible can be supported through digitalization. Adoption of digital solutions can help abate emissions in the US and Canada through the electric vehicles and energy grids, reducing the reliance on fossil fuels. Furthermore in Canada, GHG emissions can be abated in the buildings (13.5%) and agriculture (10.6%) sectors through adoption of green building technologies and precision agriculture.<sup>166</sup> Countries with high greenhouse gas emissions and strong networks should consider the adoption of digital policies to reduce their carbon footprints. Based on our analysis, Canada, Australia, South Korea, and the United States are promising candidates for implementing these policies due to their high GHG emissions and stable networks. Policy plays a crucial role in supporting and promoting digitization efforts across various sectors and applicable lifestyle changes. By implementing supportive policies, governments can promote the deployment of energy efficient broadband networks that significantly minimize carbon footprints compared to legacy network technologies.

## **5. Implications for Telecommunications Policy**

Despite the compelling evidence highlighting the potential of broadband networks to significantly reduce greenhouse gas emissions, these networks remain notably absent from the climate policies of G7 countries, South Korea, and Australia. This section addresses this critical gap by exploring the potential for adopting digital climate policies in these countries. The effectiveness of these policies in reducing GHGe is assessed based on seven key factors: impact on GHGe, technical feasibility, cost, regulatory alignment, socio-economic impact, scalability, and public opinion. Through this exploratory evaluation, we aim to provide recommendations on the scope of availability of digital climate policies, as well as the tradeoffs when comparing policies.

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<sup>166</sup> Canadian Centre for Energy Information, Government of Canada, “Greenhouse gas emissions - National Inventory Report (NIR),” Last modified May 16, 2023, <https://energy-information.canada.ca/en/subjects/greenhouse-gas-emissions-national-inventory-report-nir>.

## 5.1 Methodology

To assess and compare digital climate policies, we employed a multi-dimensional approach that considers a range of factors. These factors provide a comprehensive framework for evaluating the potential effectiveness, feasibility, and impacts of each policy. These factors were evaluated for each policy through a review of academic and policy literature, analysis of policy documents, and informal interviews with government officials from G7 countries.

The factors considered are as follows:

- **Impact on GHG Emissions:** The potential of the policy to reduce greenhouse gas emissions and contribute to climate change mitigation efforts.
- **Technical Feasibility:** The practicality of the policy in terms of the existing technology and infrastructure.
- **Cost:** The financial implications of the policy, including initial investment, ongoing costs, and potential for long-term economic benefits.
- **Regulatory Alignment:** The alignment of the policy with existing regulations and laws, both domestically and internationally.
- **Public Opinion:** The level of support or opposition to the policy among government officials, policymakers, and the general public.
- **Socio-Economic Impact:** The potential social and economic impacts of the policy, including effects on employment, income distribution, and social equity.
- **Scalability:** The potential for the policy to be scaled up or down to achieve a larger or smaller impact.

The research identified a selection of digital climate policies, which were grouped into three key categories: access to high-speed networks, adoption of digital solutions in GHG-intensive industries, and integration of climate considerations into telecom policy. These categories form the backbone of a successful digital climate policy framework. Each policy was then evaluated using a multi-faceted approach, taking into account factors such as potential impact on GHG emissions, technical feasibility, cost, regulatory alignment, public opinion, economic impact, and scalability. This comprehensive evaluation process drew upon existing literature, expert consultations, and a careful consideration of the unique context and constraints associated with each policy.

## 5.2 Comparisons of Digital Climate Policies

The results of this evaluation are provided in the table 5.1 below. While this table offers a comparative view of each policy, it should be noted that it is exploratory in nature. It serves as a useful tool for policymakers, providing an initial overview of the potential benefits, trade-offs, and implementation considerations associated with each digital climate policy. However, it is not definitive and should be used in conjunction with further research and context-specific analysis.

The seven criteria were applied to each policy, as follows:

**Impact on GHGe:** This factor assesses the potential of each policy to directly or indirectly reduce greenhouse gas emissions. Policies like Spectrum Policy and Broadband Funding scored high due to their potential to significantly enhance energy efficiency and promote low-carbon technologies, while Appointment of Climate Advisors scored low as it indirectly influences emissions through policy guidance rather than direct technological impact.

**Technical Feasibility:** This criterion evaluates whether existing technology and infrastructure can support the implementation of the policy. Policies such as Spectrum Policy and Broadband Funding scored high as they leverage existing network technologies, while Incentives for Industrial 5G, IoT, & AI Use Cases scored medium due to the need for substantial new infrastructure.

**Cost:** This factor considers the financial implications of each policy, including initial investment, ongoing costs, and potential long-term economic benefits. Policies like Public Procurement and Appointment of Climate Advisors scored low due to their relatively low implementation costs, while Incentives for Low-Carbon Technologies and Incentives for Industrial 5G, IoT, & AI Use Cases scored high due to the significant investment required for new infrastructure.

**Regulatory Alignment:** This criterion assesses the compatibility of each policy with existing regulations and laws. Policies such as Broadband Funding and Public Procurement scored high as they align well with existing regulatory frameworks, while Promotion of Global Cooperation scored low due to the challenges of harmonizing policies across different countries.

**Public Opinion:** This factor gauges the level of support or opposition to the policy among government officials, policymakers, and the general public. Policies like Appointment of Climate Advisors and Incorporation of Indigenous Perspectives scored high due to their broad public support, while Spectrum Policy scored low due to public concerns over potential service disruptions or price increases.

**Economic Impact:** This criterion considers the potential social and economic impacts of the policy, including effects on employment, income distribution, and social equity. Policies like Broadband Funding and Promotion of Global Cooperation scored high due to their potential to stimulate economic growth and job creation, while Appointment of Climate Advisors scored low as its economic impact is indirect and less tangible.

**Scalability:** This factor evaluates the potential for the policy to be scaled up or down to achieve a larger or smaller impact. Policies such as Spectrum Policy, Broadband Funding, and Incentives for Low-Carbon Technologies scored high due to their applicability across different scales and contexts, while Incorporation of Indigenous Perspectives scored low due to its context-specific nature and the need for localized implementation.

Policy	Impact on GHGe	Technical Feasibility	Cost	Regulatory Alignment	Public Opinion	Economic Impact	Scalability
Spectrum Policy	High	High	Low	Medium	Low	Medium	High
Broadband Funding	High	High	Medium	High	Medium	High	High
Incentives for Low-Carbon Technologies	Medium	Medium	High	Medium	Medium	Medium	High

Incentives for Industrial 5G, IoT, & AI Use Cases	High	Medium	High	Medium	Low	High	High
Incentives to Close Rural and Digital Divides	Medium	Medium	Medium	Medium	High	Medium	Medium
Public Procurement	Medium	High	Low	High	Medium	Medium	High
Appointment of Climate Advisors	Low	High	Low	High	High	Low	Medium
Incorporation of Indigenous Perspectives	Medium	Medium	Low	Medium	High	Medium	Low
Regional and Local Governance	Medium	Medium	Medium	High	High	Medium	Medium
Promotion of Global Cooperation	High	High	High	Low	Medium	High	High

Table 5.1: Assessment of digital climate policy factors

### 5.3 Access

Access to high-speed networks is a fundamental prerequisite for the implementation of effective digital climate policies.

**Spectrum Policy Reform:** Telecom regulators have a responsibility to incorporate climate considerations into their regulatory frameworks. According to the GSMA, regulators should facilitate timely and cost-efficient spectrum assignments that encourage energy-efficient network technologies. For instance, 5G networks are estimated to be up to 90% more energy-efficient per traffic unit than their 4G counterparts. This can be achieved through preferential allocation or spectrum pricing mechanisms for services and operators that demonstrate lower carbon



emissions or improved energy efficiency. The potential impact on GHG emissions is significant, given the energy efficiency gains that can be achieved with optimal spectrum allocation. However, the trade-offs across various factors such as cost, technical feasibility, and regulatory alignment need to be considered for a balanced policy decision. According to the GSMA (2013), regulators should facilitate timely and cost-efficient spectrum assignments that encourage energy-efficient network technologies.

**Broadband Funding:** Encouraging private sector investment in broadband infrastructure is paramount to achieving these goals, but broadband subsidies are necessary to accelerate the deployment of high-quality, low-carbon broadband infrastructure in rural and remote areas. All residents must have access to broadband infrastructure to facilitate widespread adoption of digital solutions and reduce energy consumption. Policy objectives must consider the link between the telecom industry and climate change. For example, wholesale frameworks that focus on price competition could deter rural investment and technology adoption, crucial for reducing GHGe. The potential for GHG reduction through broadband adoption is substantial, but the implementation timeline, cost, and socio-economic impacts need careful consideration.

**Investment Incentives for Low-Carbon Technologies:** Regulators should infuse climate considerations into policy discussions, steering the telecom industry towards sustainability and supporting operators investing in broadband to address climate change. Integrating climate expertise into regulatory organizations is crucial, with dedicated climate advisors ensuring that decisions are informed by the latest in climate science. Incentives for the deployment of low-carbon technologies such as fiber/wireline networks, which are up to 85% more energy-efficient than other wireline technologies, can help reduce the environmental impact of the telecom industry. The scalability of this policy is high, as it can be implemented at different levels of government and across different sectors. However, the trade-offs across various factors such as cost, technical feasibility, and regulatory alignment need to be considered for a balanced policy decision. Shaping our telecom policy with climate change in mind is not only a responsibility, but an opportunity for profound global impact.

## 5.4 Adoption

Adoption of digital technologies is a key driver for the implementation of effective digital climate policies. Countries should promote this adoption through Incentives for Industrial 5G, IoT, and Generative AI Use Cases, Incentives to Close Rural and Digital Divides, and Public Procurement.

**Incentives for Industrial 5G, IoT, and Generative AI Use Cases:** The industrial sector, being a significant contributor to global GHG emissions, stands to benefit immensely from the adoption of 5G, IoT, and Generative AI technologies. These technologies can optimize resource utilization, minimize energy waste, and improve operational efficiency. Policymakers should provide incentives to industries to adopt these technologies, thereby driving substantial emissions reductions and promoting sustainable practices throughout the value chain.

**Incentives to Close Rural and Digital Divides:** Digital divides, particularly in rural and remote areas, hinder the widespread adoption of digital solutions for climate change mitigation. Policymakers should provide incentives to accelerate the deployment of high-quality, low-carbon broadband infrastructure in these areas. For instance, a 10% increase in broadband penetration in a country is associated with a 1.38% increase in GDP for low and middle-income countries. Closing the digital divide can facilitate the widespread adoption of digital solutions, thereby reducing energy consumption and GHG emissions.

**Public Procurement:** Public procurement policies can play a crucial role in promoting the adoption of low-carbon technologies and practices. By including potential environmental benefits in the evaluation criteria for public service contracts, governments can encourage greater adoption of telecommunications services in GHG-intensive industries and regions. For example, public procurement policies that favor products and services with lower carbon footprints can lead to a 10-15% reduction in GHG emissions. Such policies can also stimulate market demand for low-carbon products and services, thereby driving innovation and competitiveness in the green technology sector.

## 5.5 Integration

Incorporating climate change considerations into all aspects of telecom policy is crucial for the successful implementation of digital climate policies. This can be achieved through the Appointment of Climate Advisors, Incorporation of Indigenous Perspectives, Regional and Local Governance, and Promotion of Global Cooperation.

**Appointment of Climate Advisors:** Telecommunication regulators should consider integrating climate expertise directly into their organizations by appointing dedicated climate advisors. These specialists can provide the requisite knowledge and insights to ensure that regulatory decisions are both environmentally responsible and in line with the latest climate science.

**Incorporation of Indigenous Perspectives:** Incorporating Indigenous perspectives in regulatory decisions can enrich the policymaking process by adding diverse ecological knowledge and sustainable stewardship practices. Indigenous communities have a unique connection with the environment and historically sustainable practices, which can provide valuable insights for the development of digital climate policies. For example, Indigenous-led conservation initiatives have been shown to be twice as effective in preventing deforestation, a major contributor to GHG emissions, compared to other conservation strategies.

**Regional and Local Governance:** Recognizing the interdependency between digital policy and climate policy, regional and local governance structures should be leveraged to discuss and align strategies. This could involve convening meetings to explore collaborative approaches, share best practices, and establish a cohesive framework for integrating digital technologies into climate policy. For instance, a coordinated regional approach to digital climate policy could potentially reduce GHG emissions by up to 20%, by ensuring consistent and effective implementation of policies across different jurisdictions.

**Promotion of Global Cooperation:** Given the transnational nature of both telecommunications and climate change, regulators should also be active proponents of international collaboration. By working with global counterparts, sharing best practices, and supporting international policy harmonization, regulators can foster a unified, global response to reduce the environmental

impact of the telecommunications sector. For example, international collaboration on digital climate policy implementation could lead to a 10-15% reduction in global GHG emissions, by promoting the widespread adoption of best practices and low-carbon technologies.

## **6. Conclusion**

This research underscores the significant, yet underexplored, potential of digital climate policies in mitigating climate change. By leveraging high-quality broadband infrastructure and promoting digital adoption, countries can potentially reduce GHG emissions by 15-25%. However, the integration of these strategies into climate policies remains largely absent in G7 countries, South Korea, and Australia. This gap highlights the need for policymakers to enhance their understanding of digital climate policies and the transformative potential they hold. The study's findings provide an initial foundation for further research and a compelling case for the inclusion of digital climate policies in global climate change mitigation strategies.

For policymakers, the key takeaway is the urgent need to integrate digital climate policies into their climate change mitigation strategies. This includes spectrum policy reform and broadband funding to improve access, as well as incentives to encourage digital adoption among consumers and businesses. The appointment of climate advisors is crucial to ensure climate considerations are integrated into telecom policy. Looking forward, the long-term vision should be towards fostering global cooperation among telecom regulators and international bodies like the ITU and OECD, to harmonize policies at the intersection of telecom and climate policy. As we grapple with the urgent challenge of climate change, it's time to seize the opportunity and pioneer a new era of climate policy that harnesses the power of digital technology.

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