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Assessing ICT global emissions footprint: Trends to 2040 & recommendations

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ABSTRACT

In light of the concerted efforts to reduce global greenhouse gas emissions (GHGE) per the so-called Paris Agreement, the Information and Communication Industry (ICT) has received little attention as a significant contributor to GHGE and if anything is often highly praised for enabling efficiencies that help reduce other industry sectors footprint. In this paper, we aim at assessing the global carbon footprint of the overall ICT industry, including the contribution from the main consumer devices, the data centers and communication networks, and compare it with the to the total worldwide GHGE. We conduct a detailed and rigorous analysis of the ICT global carbon footprint, including both the production and the operational energy of ICT devices, as well as the operational energy for the supporting ICT infrastructure. We then compare this contribution to the global 2016-level GHGE. We have found that, if unchecked, ICT GHGE relative contribution could grow from roughly 1–1.6% in 2007 to exceed 14% of the 2016-level worldwide GHGE by 2040, accounting for more than half of the current relative contribution of the whole transportation sector. Our study also highlights the contribution of smart phones and shows that by 2020, the footprint of smart phones alone would surpass the individual contribution of desktops, laptops and displays. Finally, we offer some actionable recommendations on how to mitigate and curb the ICT explosive GHGE footprint, through a combination of renewable energy use, tax policies, managerial actions and alternative business models.

1. Introduction

Information and Communication Technology (ICT) devices and services have taken a central part in our lives and have fundamentally transformed the way we work, communicate, travel, and play in the last few decades. Indeed, while human population has only doubled in the last 50 years, the global consumption of electronic devices has grown six fold in that same time span (Wann, 2011). According to the cellphone manufacturer Ericsson, 6.1 billion cellphones will be smartphones by 2020 (Reuters, 2020).

The ICT industry has a rather positive image in the eyes of the sustainability community today as it has substantially transformed the way we communicate and work, uncovering opportunities to reduce the human impact on nature. As an example, e-commerce, tele-working, and video conferencing have reduced the worldwide travelling of both people and goods and hence the consumption of petroleum and the emission of greenhouse gases (Yi and Thomas, 2007). Furthermore, wireless sensors and monitoring technology has enabled us to develop the concept of so-called "smart grids", "smart homes" and "smart buildings" to better optimize energy management in those premises through monitoring of parameters such as temperature, humidity, and sun light (Gharavi and Ghafurian, 2011) (Paetz et al., 2012) (Chwieduk, 2003).

However, this is only one side of the coin to the ICT technology in our lives; the brighter side that is. The darker and more ominous side of the ICT industry is its exponentially growing energy consumption. As our reliance on ICT devices and services grows rapidly, so does our need for energy to manufacture and electricity to power these devices. The generation of this much-needed energy to make and operate all the ICT devices on the market today is a significant contributing cause towards the creation of carbon dioxide, a leading Green House Gas (GHG), as well as other global warming pollutants.

In recent years there has been more awareness around climate change and its potentially devastating effects. There are more climate change initiatives than ever with specific action plans and

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strategies intended to mitigate the negative effects of global warming on our environment. A chief example of a recent global initiative is the Paris Agreement that took place in December 2015, where 196 nations approved a landmark global plan to curb climate change in the years to come. The agreement placed strong commitments in place to limit global warming to below 2 °C (Stocker, 2014).

Global greenhouse emissions data shows that the major contributors to global emissions by economic sector in 2015 were electricity production (29%), transportation (27%), industry (21%), followed by commercial and residential (12%) and agriculture (9%) (U.S. Environmental Protection Agency, 2016). Based on these numbers alone, one might think that the ICT industry is not a contributing factor towards the global emissions of greenhouse gases. However, a closer look reveals that the energy consumption of computers, data centers, networking equipment, and other ICT devices (excluding smart phones) amounted to as much as 8% of total worldwide consumption, and is projected to reach 14% by 2020 (Pickavet et al., 2008a). What is even more surprising is the fact that these numbers and projections don't include the manufacturing contribution (Williams, 2004a), especially in light of the fact that ICT devices have a much shorter useful life (2–5 years) than any other piece of hardware. If we are to meet the goals of the Paris Agreement and mitigate the effects of climate change, it is imperative that we pay close attention to the rapid growth of ICT devices and their associated carbon footprint relative to that of the other economic sectors.

The increase in volume of ICT equipment has an associated increase in carbon footprint on our environment. However, there is spotty record in the literature of the global ICT carbon footprint as its environmental impact comes in different forms and from multiple sources. The emissions from the ICT devices and therefore their environmental impact come from energy consumption used both, in manufacturing these devices, as well as running them. In addition, mining for earth metals used in manufacturing of ICT devices and waste disposal are additional contributors to the total ICT industry CO_2 footprint. As such, there are several different methodologies that can be used to calculate the CO_2 footprint depending on which aspects are taken into account.

With our ever-growing demand for ICT devices and the pressing matter of carbon emissions reduction, it is critical that (i) we fully and precisely assess the contribution of ICT to the global GHG emissions both today and in the future, and (ii) explore innovative solutions in the ICT industry that can meet our growing demand without undermining our reductions targets for CO_2 emissions.

2. Previous work

Quite surprisingly, while there have been many studies of the electricity consumption of ICT devices and infrastructure, ranging in scope from a single device or a single region to a broader scope, there is a relative dearth of peer-reviewed articles on the total carbon footprint impact of the overall ICT industry. Some of the early estimations of the global CO_2 emissions and energy use (Gartner, 2007) (Webb, 2008) were based on rough, unspecified and obsolete data, and lacked the necessary transparency required for peer-reviewed publications. More rigorous and recent studies by Malmodin et *al.* have focused mostly on the overall energy consumption of ICT. Results suggested that the ICT sector produced 1.3% of global GHG emissions in 2007 with a corresponding global electricity consumption of 3.9% (Malmodin et al., 2010). However, Malmodin *et* al. greatly underestimated the contribution of the manufacturing process to the total carbon footprint, as demonstrated by the detailed and transparent estimations of the contribution of manufacturing of ICT devices done initially by Williams (2004a) and corroborated more recently by Ciceri et al. (2010). Pickavet et al. have estimated the total power consumption of the ICT industry, including PC's, network equipment, data centers and other ICT equipment, such as audio equipment, telephone handsets, gaming consoles, printers, copiers and fax machines. They estimated the total power consumption in 2008 to amount to 168 GW, corresponding to a total energy consumption of 1470 TWh per year (Pickavet et al., 2008a). The authors also projected that this electricity consumption will grow to about 430 GW or 3766 TWh by 2020 representing a 156% increase in the span of 12 years. A somewhat similar exercise was done more recently by Van Heddeghem et *al.* who did a more detailed analysis of the electricity consumption by PC's, data centers and communication networks from 2007 to 2012. A comparison of their actual 2012 results with those of Pickavet et *al.* show that the actual and projected results are within 2–3% of each other (Van Heddeghem et al., 2014). Fehske et al. undertook one of the rare assessment of the global footprint of mobile communication (which included laptops in addition to smartphones and mobile phones), and projected a 3-fold increase in GHGE, from 86 in 2007 to 235 Mt–CO_2-e by 2020. The authors took into account and provided a breakdown of the individual contribution of the production and energy consumption of the devices, as well as that of the radio access network (Fehske et al., 2011) and other networking infrastructure. Their findings reveal that by 2020, the production of mobile devices, the operation of radio access networks, and the operation of data center and data transport will account for 30%, 29% and 19% of the total carbon footprint of mobile communications respectively.

The only two pertinent studies that directly addressed ICT global carbon footprint that we could find are those by Malmodin et al. who estimated the total ICT carbon contribution to reach 1.1 Gt–CO_2–e by 2020 (Malmodin et al., 2013), and another extensive study of the global electricity consumption by ICT, trending to 2030, was done by Andrae and Edler and published the carbon footprint in their supplemental material (Andraea. and Edler, 2015). Andrae and Edler presented three different scenarios (expected, best and worst cases), comprising the combined contribution of the electricity consumption of consumer devices, communication networks and data centers. Their devices scope included desktops, laptops, monitors, smartphones, ordinary mobile phones, tablets, phablets, TV's, and DVD players. Admittedly, the scope of this study is the broadest being considered to date and certainly broader than our study. However, Andrae and Edler relied on unsupported values of device lifetimes, underestimated the electricity intensity improvement of Fixed Access Networks, did not use a common baseline starting point for all scenarios for 2010, and likely overestimated the total global CO_{2}-e emissions and the total global electricity consumption. In sum, while the Andrae & Edler paper provides an extensive study of ICT devices, their study lacks somewhat in rigor and consistency. As expected, this leads to 2030 projections that exhibit as high as an order of magnitude difference between their best and worst case scenarios. For instance, their Fig. 7, shows the ICT total share of global electricity consumption ranging from 8% in best case scenario to 51% in worst case, with an expected baseline of 21%. Both baseline and worst case numbers are so high, that an extrapolation of even the baseline to 2040 will exceed 50% of the global electricity consumption, while an extrapolation of the worst case scenario will exceed 100% of total electricity consumption! Another example is their projections that Fixed Access Wired Networks will reach an expected scenario of 2641 TWh by 2030, but with a variance ranging from a minimum of 825 TWh to a max of 7912 TWh, or in other words an order of magnitude in variability (Fig. 2(a) of (Andraea. and Edler, 2015)). As such, we believe the