The future carbon footprint of the ICT and E&M sectors

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ABSTRACT
In this paper, we forecast the future carbon footprint of the Information and Communication Technology (ICT) and Entertainment and Media (E&M) sectors in the year 2020 including the ICT and E&M related impact from a networked society, i.e. a society where both people and things are connected and communicate with each other. We also discuss sector boundaries, the full impact from the networked society, uncertainty, use of the Carbon Disclosure Project (CDP) as data source and important perspectives when assessing ICT.

Keywords
Carbon footprint, life cycle assessment (LCA), information and communication technology (ICT), entertainment & media (E&M), ICT sector

1. INTRODUCTION
The positive and negative environmental impacts of the ICT sector – i.e. ICT's own carbon footprint and how ICT can enable carbon footprint reductions in other sectors – have been studied and discussed by many stakeholders over the last few years. The focus of this paper is the future carbon footprint of the ICT sector itself. In addition, the enablement potential is addressed to some extent in the discussion part.

In 2010, the Centre for Sustainable Communications (CESC) at the Royal Institute of Technology (Stockholm, Sweden) together with the ICT vendor Ericsson and the telecom operator TeliaSonera, published a study entitled: "Greenhouse gas emissions and operational electricity use in the ICT and Entertainment & Media sectors" [1] (hereafter "the reference study").

In 2011, Ericsson and TeliaSonera continued the research, aiming to estimate the ICT and E&M sectors' energy use and carbon footprint until 2020. In addition to the reference study, the new study described in this paper also investigated historic and prognosticated changes over time related to number and types of devices, number of users and their generated data traffic, and also related to the changes in greenhouse gas (GHG) emissions for different types of equipment. It is anticipated that by 2020 machine-to-machine (M2M) communication is widely adopted i.e. full connectivity of all electronic devices applies and a high number of sensors that are expected to be integrated into various applications e.g. buildings, vehicles, infrastructure etc. This scenario, described in Section 3 and further discussed in Section 4.1, is hereafter referred to as the networked society and this study tries to embrace the related GHG impacts.

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The discussion part of this paper looks further into the ICT sector system boundary definition and especially relates the system boundaries of this study to the ICT sector definition of Organisation for Economic Co-operation and Development (OECD) [2]. It also looks into some important uncertainty sources. Additionally it elaborates on how the results of this study compares with those of other studies related to the ICT sector footprint, and also on implications of applying a sector perspective as such. Further the potential use of organizational reporting data as a source for sector studies is investigated.

2. METHODOLOGY
In this study the ICT sector footprint includes impacts from mobile and fixed telecommunication networks, enterprise data networks, data transport networks, data centers and all user equipment connected to the networks such as phones, PCs and modems. A more detailed discussion of the assessed ICT sector boundaries including further details regarding the ICT network and services is given in the reference study [1]. The reference study also includes a definition of the assessment boundaries for the entertainment and media sector, which in summary includes TVs and TV peripherals (including game consoles), a wide range of electronic "gadgets" (e.g. cameras, audio devices, car infotainment etc.), PC peripherals (e.g. audio, storage and gaming products, mainly used for entertainment and media and therefore included in E&M), optical discs and paper media. The boundary between the two sectors is not unambiguous and it is also changing over time. Further discussion on the selected system boundaries is therefore included in the discussion part. In particular a comparison is made between the sector boundaries used in this study and those defined by OECD [2].

A "carbon footprint" of a product is defined as the sum of all relevant GHG emissions which occur during its complete life cycle as determined by a life cycle assessment (LCA). See reference [3] for a more extensive definition and discussion about carbon footprints. A carbon footprint thus includes raw materials acquisition, production and transports of materials, components and the final assembly and transport of the product itself, as well as use and end-of-life treatment of the product. For ICT products a carbon footprint - interpreted as one single value used to represent the carbon emissions associated with a product - usually gives only limited information and could not capture the full impact from different use patterns and a dynamic and complex supply chain.

The carbon footprint of the ICT sector is principally the sum of the footprints of all individual ICT devices and network products, but it also includes overhead activities like operator activities needed to run the networks (offices, stores, service vehicles etc.).

The limitations of product carbon footprints are thus inherited so any life cycle based sector carbon footprint could only give a coarse indication of the real carbon emissions. Still such numbers are considered to be of interest to better understand the potential impact at a sector level.

For the production stage, which includes construction and manufacturing activities, a large number of LCAs have been reviewed and benchmarked in order to create representative averages for each product category and to see trends over time. This work started already in the reference study. Production data for antenna towers, cable deployment, shelters and other infrastructure were based on LCA studies performed by Ericsson and TeliaSonera, summarized in [4].

For the use stage of user equipment, measurements have been prioritized over estimates, e.g. the unique measurements of electronic device use in 400 Swedish households over a whole year [5], was used as a main data source. For the use stage of networks, measurements by operators and service providers have been used as reported to CDP and in corporate reporting as well as other publically available technical data (e.g. number of lines and subscriptions). The global average electricity model described in the reference study [1] was reused.

Another important part of the methodology was to forecast type and number of all devices related to the ICT sector between now and 2020. Large industry analysts' market research and future market projections have been used as data sources, e.g. International Data Corporation (IDC) (PCs, servers) [6] and Display Search (TVs, monitors) [7]. Subscription information was based on prognoses from ITU [8]. For the mobile subsector's carbon footprint 2007-2020, a detailed previous study by the European Union (EU) research project EARTH [9] was used as a data source. The data traffic was based on Cisco's Visual Networking Index [10]. Other more specific studies like Koomey's studies of servers [11] and data centers energy consumption globally were also used as input. As these sources do not make prognosis as far ahead as 2020 extrapolations were made for the sake of the study.

3. RESULTS AND OBSERVATIONS

The global carbon footprint of the ICT sector in the reference study [1] in 2007 was estimated to 620 Mtonne CO_2e which is about 1.3% of the total global carbon footprint, 47 Gtonne CO_2e (the figure includes all CO_2 equivalent emissions and effects). Often, but less correctly, the ICT sector's footprint is related to global CO_2 emissions (31 Gtonne) which excludes other green house gases and effects, and would then equal 2%. The corresponding figures for the E&M sector were 1,7% and 2,6% respectively (excluding the uncertain forestry impact of paper media shown in Figure 1).

The future prognoses for the ICT sector indicates that the carbon footprint (in CO_2e) increases slightly (about 4%/year), and is estimated to increase by approximately 70% between 2007 and 2020, to a total of about 1100 Mtonne. This figure is expected to correspond to 1,9% of the global CO_2e emissions. The E&M sector's carbon footprint is estimated to increase to a level of 1300Mtonne (2,4% of global CO_2e emissions) or 1100 Mtonne and 2% if paper media is excluded. Use of paper media was not changed compared to the 2007 estimate in the reference study, due to the large uncertainties related to paper media production volumes observed in that study and to the uncertainty in market development. According to [12] this approach seems reasonable. In Figure 1, the total predicted carbon footprints for ICT and E&M (including paper media) sectors is presented based on the outcome of the reference study (2007 values) and this study (2020 values).

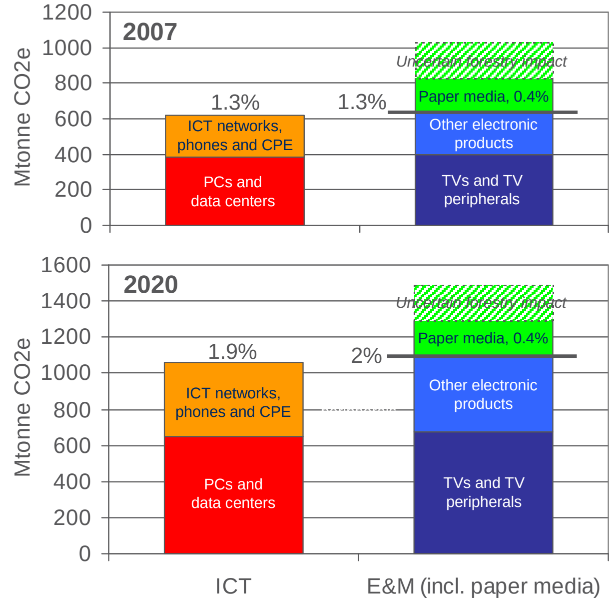

Figure 1. Total carbon footprint of the ICT and E&M sectors in 2007 (results from the reference study) and the forecasted impact of 2020.

The increase in number of devices, from about 6 to 12,5 billion, and thereby in subscriptions, is the main reason for ICT's increased carbon footprint. PCs and servers in data centers are the largest subsectors. At the same time there are other trends that have been considered for the modeling of end user and network equipment which are expected to limit the increase of the ICT sector impact beyond the predicted levels. Such trends are

- Energy efficiency improvements of network equipment in constant operation.
- Change from cathode ray tube screens to flat panels and from desktops to laptops for PCs give large reductions per PC.
- Better power management and lower stand-by power consumption of user equipment.
- Data center virtualizations and modernizations, including more efficiently used servers with better supporting infrastructure.
- Decrease in carbon footprint per device over time observed in LCA studies.

More detailed distribution of results within the ICT sector is given in Figure 2.

In addition to the predicted amount of devices in 2020 for device categories in use today, this paper also includes additional new network equipment categories associated with the networked society which is further discussed in Section 4.1. Thus, in addition to 12,5 billion traditional ICT devices and 16 billion E&M devices, 1 billion new ICT devices were included in the assessment. These devices were modeled based on fixed broadband gateways, e.g. fixed wireless gateways connected through mobile broadband which enable connection possibilities for devices in a household and in other buildings/sites. Further the impact of connectivity of the 16 billion E&M devices were included in the E&M results.

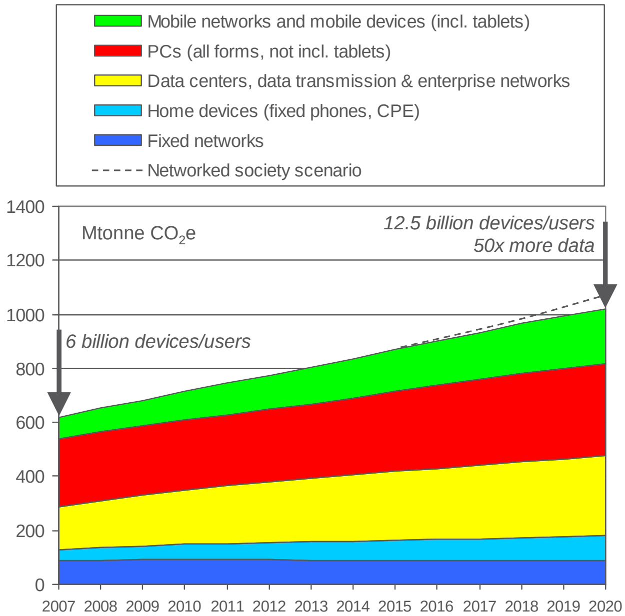

Figure 2. The carbon footprint development of the main ICT subsectors 2007-2020.

To put the overall sector results in context, they were also normalized based on number of users. This part of the results does not include the specific impact related to the networked society due to difficulties in modeling the machine-to-machine users. "Users" is here to be understood as number of mobile subscriptions (mobile devices), number of fixed subscriptions (fixed phones and Customer Premises Equipment (CPE) per fixed line) and number of PCs. This means that number of users nearly equals number of devices.

Based on an analysis of historic data for number of devices for example International Telecommunication Union (ITU) statistics of PCs in use and telephone lines [13], and earlier LCA studies performed by Ericsson and TeliaSonera, we found that the ICT sector's total carbon footprint per average user, including also impact from shared resources such as data centers and network equipment, has decreased from about 300 kg CO_2e/year in 1995 to about 100 kg in 2007 and is estimated to decrease further to about 80 kg in 2020, see Figure 3.

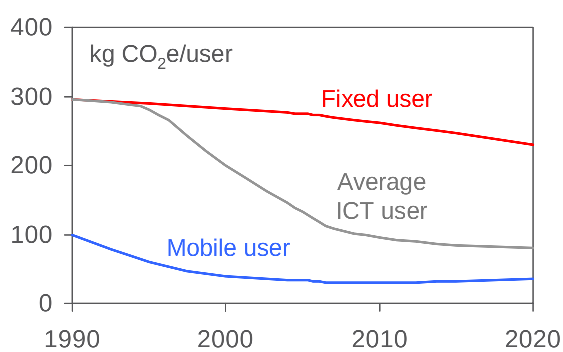

Figure 3. The ICT sector carbon footprint expressed per user.

For mobile users, the small increase 2010-2020 is due to the introduction of more advanced mobile phones and PCs.

The main reason for the decreased footprint per average ICT user, shown in Figure 3, is that more and more users use mobile devices and mobile access technologies which have lower footprints per user than fixed PCs and always on-devices like modems/routers. The reason for this is the higher energy efficiency of battery-operated mobile user devices. Fixed networks, on the other hand, have a lower impact per GByte (GB) as shown in Figure 4.

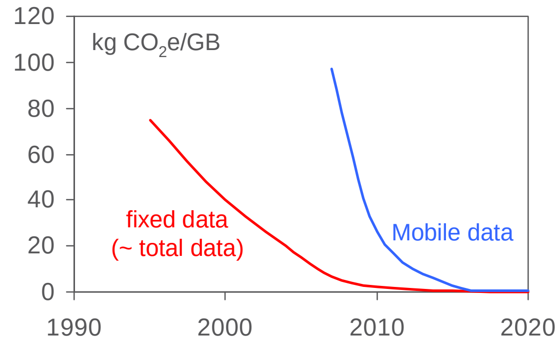

Figure 4. The carbon footprint per GB sent in access networks.

Another metric of carbon footprint intensity is thus the carbon footprint per amount of data (including voice) which has already been reduced from about 75 kg/GB 1995 down to about 7 kg/GB in 2007 due to the technical development and high increase in amount of data. This metric is predicted to further decrease by a factor of 35 by 2020, based on Cisco's [10] prognosis for data traffic growth up to 2015 which was extrapolated to 2020 for this study. This source was chosen as it is a well recognized source for data traffic numbers and also as it transparently describes its methodology although its background data is not available.

Note that all user equipment (phones, PCs, etc), network components such as Internet Protocol (IP) core network and transmission networks such as fiber communication, copper networks and all data services (servers / data centers) are included in the data related to Figure 4. Thus the results are more comprehensive than what is seen in other studies that only look at the IP core network parts, such as [14], and are therefore not directly comparable to such studies.

Based on described data sources and future prognoses, the ICT sector in 2020 compared to 1995 is estimated to have:

- Increased number of users about 10 times to about 12,5 billion PCs, phones, etc.
- Increased total data traffic volumes (including voice) about 1000 times. It is to be noted that in 1995 voice was dominating the total data traffic). The mobile data traffic is estimated to show the same increase, 1000 times, between 2007 and 2010, i.e. during a considerably shorter time frame than the fixed traffic.
- Increased its total absolute carbon footprint by a factor of about 3, but will remain a continued reasonably low relative footprint, less than 2% of the total global carbon footprint (CO_2e) The increase in absolute numbers is due to dramatic increase in number of capabilities and users, especially in the developing countries, and a foreseen additional impact from new devices associated with a networked society.

- Decreased the footprint per average ICT user by about 70% - mainly because the share of mobile users grows from about 5% to about 60%.

Although an intensity metric based on data volumes is interesting in combination with other results related to sustainability impact it is not seen as the best metric on its own, as it has a low correlation to the impact per user and may be regarded as a metric intended to diminish the importance of ICT due to the rapid development of data traffic.

4. DISCUSSION

4.1 System Boundaries of the ICT and E&M Sectors

Applicable boundaries for the ICT sector are not obvious and they are therefore a subject for discussion. The most widely acknowledged definition of the ICT sector is perhaps that of OECD [2]. The OECD definition takes a quite inclusive approach and includes both the ICT and the E&M elements of the reference study as well as well as sub-elements beyond what was used in that study.

This study therefore tried to adopt the OECD definition but found it hard to apply directly for life cycle based environmental assessments. As an example both components and final products were part of the scope which would lead to double-counting effects if added together. Also the boundaries towards other sectors could be discussed. For example is a writer's original manuscript, or a music studio a part of E&M or rather a part of the cultural sector? Further, some of the categories covered by OECD could alternatively be seen as "other electronics" which is examined in the next chapter.

Another drawback of applying the OECD definition in this study would be that the alignment with older (pre-OECD definition) studies would be reduced - especially the allocation between ICT and E&M was different between the reference study and the OECD definition and was kept for comparability reasons. For example TVs, TV peripherals, hard copy equipment (printers, copiers etc) and paper media were in our studies allocated to E&M.

Table 1 and 2 tries to cross-connect the system boundaries of this study and those of OECD

Table 1. Cross reference table relating the system boundaries for ICT to the OECD ICT sector definition

OECD category	Coverage in this study
Communication equipment	*High coverage of related GHG emissions*. Alarms etc: excluded as being associated with Safety and security sector Television cameras: excluded Telephone sets: based on LCA.
Telecommunications services	*High coverage of related GHG emissions.* *Included. As the services are based on the usage of above product categories double-counting effects have been handled.*
Computers and peripheral equipment	*High coverage of related GHG emissions.* Computers (PC and workstations): included based on LCA. Mouses and keyboards mainly based on economic input-output (EIO) data. Scanners and printers: based on LCA but allocated to E&M. Monitors and memory devices: based on LCA and EIO respectively. Specific equipment for dedicated tasks: excluded as expected to be replaced by generic ICT products (smart phones/tablets) Other data processing machines: No major products identified
Consumer electronic equipment	*High coverage of related GHG emissions.* Consumer electronics gadgets: based on EIO. The category includes all cameras, audio equipment including radio, and home-theatre-in-a-box (TV etc). Consumer products are covered but not professional recording devices (low volumes)
Miscellaneous ICT components and goods	*High coverage of related GHG emissions.* Discs and optical media allocated to E&M sector Other components included to the same extent as final products and the components for non-ICT products is integrated into the category "other electronics" (not part of ICT sector
Manufacturing services for ICT equipment	*High coverage of related GHG emissions.* As the study is LCA based manufacturing processes are included for all included final products
Business and productivity software and licensing services	*High coverage of related GHG emissions.* Equipment use stage included. Manufacturing to some extent (discs and PC software included based on EIO)
Information technology consultancy and services	*Moderate coverage of related GHG emissions.* Partly included (equipment use stage and life cycle included). Business activities for data centers included. Retail and software development included only to a limited extent
Leasing and rental services for Telecom equipment	*Moderate coverage of related GHG emissions.* Partly included (equipment use stage and life cycle included). Business activities for data centers included. Retail and software development included only to a limited extent

OECD category	Coverage in this study
Other ICT services	*Moderate coverage of related GHG emissions.* Partly included (equipment use stage and life cycle included). Business activities for data centers included. Retail and software development included only to a limited extent

Table 2. Cross reference table relating the system boundaries for E&M to the OECD ICT sector definition

OECD category	Coverage in this study
Printed and other text-based content on physical media, and related services	*Low-Moderate coverage of related GHG emission.* Paper included Use of ICT included, other aspects of content production excluded. All optical disks included. Advertising mainly excluded.
Motion picture, video, television and radio content, and related services	*Moderate coverage of related GHG emissions.* Discs and use of ICT equipment: included Business activities for content production and distribution excluded.
Music content and related services	
Games software	
On-line content and related services	
Other content and related services	*Moderate coverage of related GHG emissions.* Discs and use of ICT equipment: included Business activities for content production and distribution excluded. Licensing services for the right to use entertainment, literary or artistic originals not included except for use of ICT and to some extent business activities.

In general a main observation is that this study has a product/hardware perspective but include use of services to the extent that they are associated with ICT equipment. Thus other aspects of services such as development, retail and distribution is only included to a limited extent. To fully capture the impacts from services would be a subject for a paper by itself. Based on our analysis of software services, the additional impact from production and distribution of services is expected to give only a limited impact. Another main observation is that the focus of this study is on the ICT devices as such. Consequently they are analyzed in a more detailed way than related accessories that are considered and included, but based on less accurate data.

4.2 The Impact of the Networked Society Scenario

When predicting the future impact of the ICT industry it is important to consider that in the future not only everyone but also everything is expected to be connected and communicating. Although the technical solutions for this networked society are not fully known at this stage we have tried to model the associated impacts in our study to get an indication on its importance for the ICT footprint. It could be argued that it would be better not to include technical solutions which are yet to be developed but the rational to model these impacts is that also a coarse model will lend more relevant results than leaving this impact out.

Thus, when applying a sector perspective in Section 3, the ICT and E&M related impacts from a networked society scenario were taken into consideration. These impacts were associated with new ICT devices (1 billion) and the connectivity of the E&M sector (16 billion devices) as described in that section.

In addition, a networked society scenario also needs to consider effects in other sectors. Thus, to fully capture the networked society, this study also looked into the anticipated 2020 impact from the connectivity of another 12 billion devices representing electronic devices in other sectors. These connectivity components (as well as those of the E&M sector) were modeled based on the mobile connectivity devices for PCs. The connected electronic devices are expected to be found in e.g. vehicles, home appliances, HVACs (Heating, Ventilation and Air Condition), meters, production machinery, payment, medical and security products etc. In addition, this study also considers impact from 500 billion sensors and tags which are expected to be used by all industry sectors.

When considering also these aspects of the networked society scenario, it turns out that according to our scenario the largest additional impact comes from ICT connectivity components while the sensors and tags gives a relatively low impact in spite of the very high volume assumed due to their small size and, when batteries are used, efficient battery operation. The corresponding total additional life cycle impact in terms of CO_2e emissions for the scenario applied for the networked society is shown in Figure 5 and equals 185 Mtonne CO_2e in total, which includes also the impact on ICT and E&M sectors already accounted for in the sector results presented in Section 3.

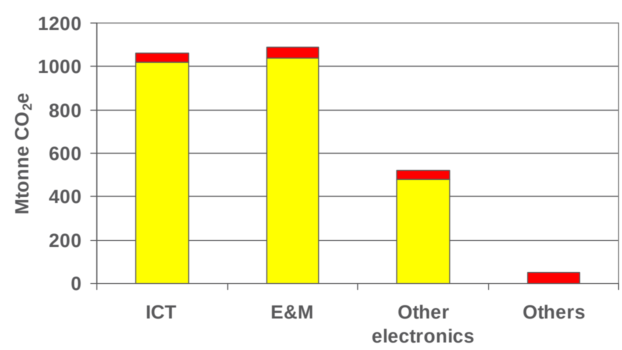

Figure 5. Additional impact (red) from the networked society scenario shown together with a business as usual scenario (yellow). Note that the paper media part of E&M sector is not included in this figure.

Due to modeling difficulties and lack of data the network impact from a networked society scenario was not included in this figure but was tested in the sensitivity analysis as described in next section.

4.3 Uncertainty and Sensitivity

It is obvious that a study which tries to forecast the future impact of a complete industry sector is associated with a high degree of uncertainty. The uncertainties associated with the system boundary setting were discussed in Section 4.1. Since the uncertainties associated with defining the future scenario are so high it was concluded that a detailed assessment of parameter uncertainty would not give any further understanding of the results.

For scenario uncertainty it is clear that the predicted number of devices and their assumed energy consumption have a strong impact on the results. The main effort in terms of sensitivity analysis was therefore focused on the additional impact associated with a networked society scenario to understand if the conclusion was robust, so that assumptions associated with such impact would only marginally impact the overall final result.

The parameters tested were number of ICT connectivity components, number of sensors, number of new ICT devices and impact from the use of networks due to increased traffic associated with the networked society scenario.

This sensitivity analysis revealed that the numerical value of the sector impact would be affected but to a marginal extent that would not contradict the conclusion that the networked society scenario would add but marginally to the overall sector impact. Although the conclusion seems robust and indicates that the networking of society has a limited cost in terms of CO_2e it is obvious that it is necessary to monitor the technology development related to the networked society to get a more thorough understanding of its impacts.

Another aspect that needs additional consideration is the use of intensity metrics. For intensity metrics like CO_2/user the definition of a user has a significant impact. As the number of users is not directly measurable, number of subscriptions and number of devices are used as proxy data when modeling this figure. The definition described in Section 3 which was developed for [1] and reused here worked well in a situation (2007) when the number of PC's with access to broadband was limited.

It can be argued that for 2020, when calculating the number of PC and the number of broadband and mobile connections, the number of users is double counted. On the other hand subscriptions related to other devises related to M2M communication are not included in the number of users used in Section 3. Another issue is to understand the impact of users with double subscription and how subscriptions are shared between users, e.g. it is not clear how to model fixed PSTN subscriptions which are normally shared by a number of users, e.g. in a household, as the available data is generally referring to subscriptions not to users.

In our continued research the aim is to refine the methodology to consider these aspects to understand how such effects impact the intensity results.

Another issue worth considering is the importance of the electricity mix. This study did not take into account that the electricity mix could significantly change towards lower carbon impact or the contrary within the 2020 timeframe.

4.4 Comparison with the Smart 2020 Report

The Global e-Sustainability Initiative (GeSI) Smart 2020 study from 2008 [15] (hereafter "Smart 2020") is perhaps the most frequently cited study regarding ICT sector impact and is therefore interesting to analyze further. Compared to the results of the reference study, Smart 2020 estimated a 34% higher absolute carbon footprint for the ICT sector in 2007 (830 Mtonne CO_2e e)[1].

The system boundaries between Smart 2020 and the reference study were different as the reference study allocated printers to the E&M sector. However, this difference does not explain the substantial difference in results. One important reason for the difference in results is instead that Smart 2020 estimated the mobile telecom subsector to 245 Mtonne CO_2e in 2007 which is about 100 Mtonne CO_2e higher than the corresponding figure in this study. The main difference seems to be that Smart 2020 used old data that was based on old fixed networks to estimate mobile networks which lead to an overestimation of its impact. It was also noticed that the estimated carbon footprint per PC was higher as far ahead as 2020, also due to use of old desktop PC data as a basis for extrapolation. These two differences together explains why Smart 2020 ended up in higher impact estimates for 2020 and indicates that the estimate of our study gives a more realistic prognosis for 2020.

4.5 Analysis of CDP Data

A major issue when performing a sector level study is to find good data sources. This section discusses that organizational GHG data for scope 1 and 2 emissions may be a useful data source while scope 3 emissions are harder to use to understand sector level impacts.

An interesting example is the Carbon Disclosure Project (CDP) [16]. CDP request all major companies in the world to report their organizational carbon footprints which results in an extensive data set of interest for sector level studies. .

CDP re-uses the definitions of scope 1, 2 and 3 emissions defined by the GHG protocol [17]. Scope 1+2 emissions give very good insights to the emissions of an organization or a sector, but do not give a full understanding of an organization's total impact as most transports, travel and, not least, the use phase of products and services are not included. All those emissions are defined as scope 3. The full reporting of scope 3 emissions is so far only done by a minority of companies. The reporting is many times incomplete and not consistent with LCAs, and not performed in a standardized way since scope 3 related standards have barely been published. As an example, telecom operators experiences difficulties in covering end-user products in a comprehensive way without in-depth analysis of user habits and patterns. Scope 3 data is thus difficult to use and to understand. Apart from scope 3 data often being incomplete, one company's scope 1+2 emissions can be another company's scope 3 emissions, and scope 3 emissions are therefore not well suited for aggregations due to double-counting effects.

In 2010, seventeen of the world's largest ICT suppliers (manufacturing and service providers) reported 210 Mtonne CO_2e emissions and the majority of the emissions was scope 3

[1] As GeSI is currently updating Smart2020 its second edition may be available when this paper is presented and may better align with the forecasts made here

(175 Mtonne CO_2e). Fourteen of the world's largest ICT operators reported 51 Mtonne CO_2e emissions in total of which only 3 Mtonne CO_2e was scope 3 emissions. However, it is noted that only about 50% of the operators are reporting scope 3 emissions.

The scope 1 and 2 emissions reported by ICT operators to CDP are examples of usable data in assessments of the carbon footprint of the ICT sector. In this study CDP data was used as a data source to calculate the telecom operators' carbon footprint. The data was validated and complemented based on operators' corporate social responsibility reports and other publically available technical data (e.g. number of lines and subscriptions) after necessary adjustments to make the data comparable. As an example of such adjustments, the data sources needed alignment as operators in general do not include their use of diesel in the CDP reporting.

Based on this procedure the total carbon footprint for telecom networks operation was estimated to be 104 Mtonne CO_2e for scope 1 and 2[2].

To transfer the operator data to a sector level using average impacts for reporting operators as a proxy for non-reporting operators, the scope 1 and 2 emissions were extrapolated by revenue and by number of subscriptions yielding results in the range 90-140 Mtonne CO_2e. Although the uncertainty of such figures is substantial this kind of extrapolations was found useful to overcome data gaps.

4.6 Some Reflections on the Sector Perspective

There is an interest in society to understand where the greenhouse gases originate from. Today much focus is put on the industry sectors as such to understand how emissions are distributed, not least in the European context.

According to [1] the ICT industry was 2007 responsible for approximately 1.3% of the global CO_2e emissions and this figure, as well as the results of this study, shows that the ICT industry needs to work to reduce its own impact.

It is clearly of interest to make proper estimates of the environmental impact per sector and to use such data as a tool to identify the improvement potential per sector. There is however a risk that focus on the carbon footprints of individual sectors and not on the impact of the technologies they offer, may lead to lost opportunities in identifying activities/technologies which could reduce carbon emissions If applying a sector perspective only, focus is on efficiency activities in the sector itself, and not on its technology. Consequently, for sectors with a relatively low contribution to the overall emissions, and a substantial abatement potential there is a risk that the latter is not leveraged. For ICT, several stakeholders, e.g.an EU FP7 funded research project [9] and GeSI [15], indicate a saving potential of approximately 15% if implementing already existing ICT solutions in other sectors, especially to reduce physical transports and travels with virtual solutions.

It is obvious that ICT, as all sectors, should economize its use of energy and its emissions, but for the total global emissions such improvements would only have a limited impact as its footprint is relatively small. Used wisely for dematerialization, optimization, etc. it may impact the overall global emissions considerably and we therefore propose that a technology perspective may be as important as a sector perspective to reduce global warming.

Based on previous experiences it could be expected that the results of this paper will be used for sector-to-sector comparisons. However, since the data quality as well as scope differs between sector estimates a superficial comparison of results might become misleading and may lead to wrong conclusions and prioritizations.

If such comparisons are made it is thus important that they, as all comparisons between LCA based results, are performed in a fair and correct way

Over the last years the carbon footprint of the ICT industry has been compared to other industry emissions, particularly to those emerging from the air industry and the two sectors have been claimed to have equal footprints [18]. There are several aspects to consider when making such comparison.

To understand the impact of a sector a life cycle perspective seems relevant, but historically that has not always been considered in sector-to-sector comparisons While the carbon footprint figure of the ICT sector discussed in this paper covers all substantial life cycle CO_2e emissions of all ICT devices and networks, the carbon footprint of the aviation sector as calculated in [18][3] is only including the direct CO_2 (not CO_2e) emissions that occurs during operation i.e. when flying. To calculate a life cycle based aviation sector carbon footprint, also the extraction, production and distribution of jet fuel, as well as construction and manufacturing of airports and aircrafts, and further all ground travel (transfers), need to be included. If all CO_2e emissions and effects related to operation of air planes are considered, the aviation sector's share of the global carbon footprint for 2009 was around 3,5%[4,5] [19], a figure which was about two times larger than the corresponding figure for the ICT sector [1].

Another aspect to consider when trying to identify carbon efficient activities is the impact per user. Already in 2007 the number of ICT users (6 billion) in the world was 89% of the number of inhabitants (6.7 billion [20]). Although the user concept as used here is only a proxy for actual number of users (see Section 4.3) it indicates that the ICT footprint is shared by a major part of the world´s population.

For the air industry, data available for 2005 [21] shows that there were 0.7 billion travelers, i.e. 11% of the population that

[2] The reported scope 3 emissions, which were not used, added an additional 38 Mtonne CO_2e. The scope 3 emissions represented operator activities as well as construction and manufacturing of network infrastructure and equipment.

[3] As in the case of ICT sector boundaries can be discussed. [18] takes a quite narrow approach by including only commercial passenger traffic, i.e. military, goods and private air transports are excluded.

[4] This figure includes nitrogen oxides. If the effect of induced cirrus is also taken into account, an impact of 4,9% has been proposed [19]. It is to be noted that the uncertainties related to these effects are large.

[5] Further background data is available in [19] and [21] which cover an extensive research of the carbon footprint of aviation.

made about 2 billion air trips (i.e 4 billion air port passenger movements) [22].

Comparing these numbers shows that the footprint per user is much lower for ICT usage than for air travelling although it may be hard to directly compare the numbers as the “user” concept is complex and also definitions differs between the sectors. More research in this area would be of interest as emissions per user seem to be a relevant ground for comparisons

5. CONCLUSIONS

This paper describes the methodology and data sources used for assessing the GHG emissions of the ICT and E&M sectors.

The ICT sector’s carbon footprint, where also the impact from the networked society is taken into account, is prognosticated to increase slightly year by year, in total by 70% compared to 2007, to about 1000 Mtonne CO_2e in 2020, which equals 1,9% of the estimated total global CO_2e in 2020. The carbon footprint of the E&M sector (with paper media included) is prognosticated to be 1300 Mtonne CO_2e and is thus expected to represent about 2,4% of the overall global CO_2e emissions.[6].

The carbon footprint per average ICT user and per amount of data decreases over time, both for fixed and mobile users. The carbon footprint per average ICT user is estimated to decrease from about 100 kg CO_2e in 2007 to about 80 kg CO_2e in 2020. Similarly, the carbon footprint per average GB of data is reduced by a factor of 35.

The results presented in this report clearly depends on the growth expectancy of the sector, but the study shows that although the scenario used corresponds to a quite high growth, the sector contribution to the overall carbon emissions is kept at a fairly low level well below its abatement potential. In addition, it is implied that the additional emissions related to the assessed networked society scenario do not impact the sector footprint but marginally.

It becomes evident when assessing the carbon footprint of the complex ICT sector that system boundaries can and should be discussed, and there is no such thing as one true value of future ICT impact. This study is mainly reusing the system boundaries of [1] and a cross reference table towards the OECD sector definition and the reasons for not applying that definition is given in the discussion part. Additionally it is proposed that future studies could focus more on software services.

The potential use of organizational data such as those reported by CDP (Carbon Disclosure Project) as data sources for studies like this was discussed and scope 1 and 2 CO_2e emissions reported by ICT operators were found to be usable data sources.

It was also discussed that, to identify substantial GHG emission savings, it may be as important to apply a technology perspective as a sector perspective, especially for sectors with a relatively small footprint compared to its abatement potential. Also sector-to-sector comparisons were discussed. It was indicated that the carbon footprints of the ICT and the aviation sectors are not equal, but the aviation sector’s footprint is roughly two times larger than that of ICT, in spite of the difference in numbers of users. This study also proposes that the carbon footprint per average user may be a relevant way to compare technologies of different sectors.

Based on the findings, it is recommended that – although the ICT industry as all sectors shall make sure to increase its own carbon efficiency and decrease emissions - the main efforts of the industry and of policy makers should be focused on how to best leverage the abatement potential of the ICT sector to support the shift towards a low carbon society. This paper clearly indicates that, - due to its limited footprint, - only when used for transformative changes could ICT make a real difference to the overall global GHG emission level.

6 If the ICT sector, in accordance with OECD adds impact from both ICT and E&M (including paper media and content) the total figures sum up to 2300 Mtonne CO_2e or 4,3% of the anticipated global emissions.

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