The energy and carbon footprint of the global ICT and E&M sectors 2010-2015 - Supplementary material

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I.   ICT and E&M product (equipment / devices) data

The following table and data comes from [1], the same shipment data for 2015 is used in both studies.

Shipments	Shipments 2015 [million]	Est. weight per average unit [kg]	Est. total shipped weight [kt]	Notes and data sources (shipments 2015) Weights per average unit is based on former Ericsson publications [20]
Fixed phones (PSTN+VoIP)	200	0.2	40	Estimated based on telephony subscriptions (ITU)
Smartphones	**1 433**	0.15	215	Gartner, Worldwide Quarterly Device Shipments, https://www.gartner.com/newsroom/id/3187134
Other mobile phones	**537**	0.1	54	IDC, Worldwide Quarterly Mobile Phone Tracker https://www.idc.com/tracker/showproductinfo.jsp?prod_id=37
CPE (e.g. modems and gateways)	184	0.5	77	Future Source (see reference below)
Tablets	**208**	0.75	156	IDC, Worldwide Quarterly Personal Computing Device Tracker, https://www.idc.com/tracker/showproductinfo.jsp?prod_id=1541
Laptops	163	**1.75**	**285**	
Desktops	114	**7.5**	**855**	Gartner, Worldwide Quarterly Device Shipments, https://www.gartner.com/newsroom/id/3187134
Computer displays	130	**5**	**650**	IHS, https://technology.ihs.com/572224/desktop-monitor-market-tracker-q1-2016 (Desktop Monitor Market Tracker)
Computer peripherals (no HDDs)	(114)	(1)	114	Estimated based on PC shipments and common peripherals e.g. mouse and keyboard
Projectors	8	7.5	60	Future Source (see reference below)
Public displays	3.5	50	175	IHS, https://technology.ihs.com/572984/public-display-market-tracker-q1-2016 (Public Display Market Tracker)
Surveillance cameras	28	5	80	IHS, https://technology.ihs.com/Research-by-Market/551540/security-technology ()
Payment terminals	35	1	35	BI Intelligence, https://www.businessinsider.com.au/the-global-payment-terminal-market-2014-5
Wearables	46	0.15	7	IDC, Worldwide Quarterly Wearable Device Tracker, https://www.idc.com/tracker/showproductinfo.jsp?prod_id=962
Smart meters (only control units)	*40*	*0.15*	*6*	*Pike Research*
ICT sector user devices total:	**3 213.5**	**(~0.9 kg)**	**2 749**	

TVs	**235**	**15**	**3 525**	Digital TV Research, Digital TV World Data Book 2016 (May 2016) https://www.digitaltvresearch.com/products/product?id=142
STBs (Set-top boxes)	**265**	0.5	133	Future Source, https://www.futuresource-consulting.com/ One of the leading analyst for audio and camera products but also for CPEs (gateways, modems etc.), STBs and projectors, and also for optical and electronic media (discs, memory sticks/cards, printer consumables) See also: CES 2016, Global Tech Spending Update, Presentation at CES 2016 January 6-9 Las Vegas (media copy)
DVD/BD players	57	2	114	
Media players	50	1	50	
Home audio systems	79	**5**	**395**	
Portable media players	35	0.15	5	
Headphones	**320**	0.5	160	
Cameras, camcorders	58	0.25	15	
Game consoles	37	1.75	65	Jon Peddie Research, https://www.jonpeddie.com/press-releases/millions-of-android-gaming-consoles-on-the-horizon/ http://www.jonpeddie.com/publications/console-gaming-hardware-market-study/
Portable game consoles	18	0.5	9	
Arcade game machines	2.4	**200**	**480**	
Automotive (all display products)	75	0.75	56	IHS, https://technology.ihs.com/572824/small-medium-display-market-tracker-q1-2016 (Small / Medium Display Market Tracker)
E&M sector user devices total:	**1 231**	**(~4 kg)**	**5 006**	
Hardcopy devices[1]	103	10	1 030	IDC, Worldwide Quarterly Hardcopy Peripherals Tracker https://www.idc.com/tracker/showproductinfo.jsp?prod_id=3
Servers	11.1	5	55	IDC, Worldwide Quarterly Server Tracker https://www.idc.com/tracker/showproductinfo.jsp?prod_id=7
HDDs (additional)[2]	100	0.25	25	About 470 million in total (IDC), about 370 million estimated to be already included in ICT sector user devices above, e.g. PCs
Network equipment[3]	10		800	Ericsson estimate for node level based on [20]
Cables (additional/external)	na		1 000	Estimate[4]
Batteries (additional/external)	na		500	Estimate[5]
Memory cards/sticks, optical discs, inkjet and toner cartridges	7 000	**na**	340	Future Source (see reference above)
GRAND TOTAL:			**11 700**	
Retail product packaging total:	**na**		**2 500**	Estimate in this study based on RISI [6]
E&M paper consumption	*na*		*126 000*	RISI [6], paper used for media
ICT infrastructure materials (steel, concrete, gravel etc.)			*~20 000*	Ericsson estimate based on [20]

Table 1: ICT and E&M product shipments, weight estimates and shipment data sources
[1] Includes printers, copiers, faxes and combo-devices, office and home devices
[2] Additional HDDs not already included in PC and server shipments
[3] Includes mobile base station, fixed access and IP data transmission and core network equipment and internal cabling, includes also data center cabinets but servers listed exclusively, [4] About 500 kt external cables estimated to already be included in ICT and E&M user devices, the remaining (this estimate) covers network cables (note that new network cables are not needed at the same pace as network equipment)., [5] Most small batteries estimated to be "consumed" by ICT and E&M user devices, the remaining (this estimate) covers back-up batteries (mainly lead types)

The starting point for modeling the user devices footprints have been market statistics from leading market analysts like IDC, Gartner and IHS, e.g. total number of shipped devices in 2015 and historical shipment data to be able to estimate the total number of device in operation in 2015 (installed base). There are other ways to estimate the total number of units in operation, e.g. number of active mobile

subscriptions that give a very accurate estimate on the total number of smartphones and other mobile phones in operation. Likewise, number of fixed broadband subscriptions and TV subscriptions can be used to estimate CPE (customer premises equipment, e.g. modems / gateways), STB's TV's (and TV peripherals).

ICT sector	Shipments 2015 [million]	Est. embodied CF/unit [kg CO_2e]	Est. total embodied CF [Mt CO_2e]	Est. total units in operation[1] [million]	Est. OEC per unit [kWh]	Est. total OEC[2] [TWh]	Est. total OEC[2] CF[3] [Mt CO_2e]
Fixed phones (PSTN + VoIP)	200	20	4	**1 650**	20	28	16.8
Smartphones	**1 433**	**45**	**64.5**	**3 700**	3	11.1	6.7
Other mobile phones	**537**	25	13.4	**3 400**	1.5	5.1	3.1
CPE (modems, gateways)	184	50	7.7	975	**100**	83.5	**50.1**
Tablets	**208**	75	15.6	700	7	4.9	3
Laptops	163	**200**	**32.6**	970	**35**	**34**	**20.4**
Desktops	114	**250**	**28.5**	730	**150**	109.5	65.7
Computer displays	130	100	13	1 000	30	30	18
Computer peripherals	(114)	50	5.7	na.	na	na.	na.
Projectors	8	200	1.6	50	150	7.5	4.5
Public displays	3.5	400	1.8	25	300	7.5	4.5
Surveillance cameras	28	100	2.8	140	70	8.4	5
Payment terminals	35	50	1.8	150	30	4.5	2.7
Wearables	46	20	0.9	100	1	0.1	0.06
Smart meters (only control units)	*40*	*20*	*0.8**	*400*	*20*	*8**	*4.8**
ICT sector total:	**3 213.5**	**(61)**	**196**	**14 170**	**(24)**	**342**	**205**
E&M sector	Shipments 2015 [million]	Est. embodied CF/unit [kg CO_2e]	Est. total embodied CF [Mt CO_2e]	Est. total in operation[1] [million]	Est. OEC per unit [kWh]	Est. total OEC[2] [TWh]	Est. total OEC[2] CF[3] [Mt CO_2e]
TVs	**235**	**300**	**70.5**	**1 900**	**140**	**266**	**160**
STBs (Set-top boxes)	**265**	30	**8**	**890**	**100**	**89**	**53.4**
DVD/BD players	57	50	2.9	400	50	20	12
Media players	50	30	1.5	200	20	4	2.4
Home audio systems	79	**50**	4	**800**	**50**	**40**	**24**
Portable media players	35	20	0.7	130	1	0.13	0.08
Headphones	**320**	10	3.2	na.	Na	na.	na.
Cameras	35	50	1.8	500	1	0.5	0.3
Camcorders	23	50	1.2	200	1	0.2	0.12
Game consoles	37	150	**5.6**	250	100	25	15
Portable game consoles	18	75	1.4	100	15	1.5	0.9
Arcade game machines	2.4	**2 000**	4.8	25	750	18.8	11.3
Automotive (displays)	75	50	3.8	400	na	na.	~2
E&M sector total:	**1 231**	**(89)**	**109**	**5 795**	**(81)**	**467**	**280**
Paper media (E&M)							
Hardcopy devices	103	200	10.3	500	150	75	45
GRAND TOTAL:	**4 548**	**(67)**	**295**	**20 465**	**(43)**	**884**	**430**

Table 2: User devices: shipments, total number of units in operation, OEC and resulting CF's
[1] Estimated total number of devices in operation are <u>per mid-year</u> and not *end-of-year*. [2] OEC = Operational Electricity Consumption. [3] CF = Carbon Footprint.

II.   ICT network operators public data (2015)

In addition to the ICT network operator data collected in [2], Table 2 below lists all public data collected from ICT network operator reports for the year 2015.

Company	Home country	Revenue B$	Empl.	Subs M	Electricity GWh	CF kt CO₂e	Notes and data sources (CSR reports 2015)
AT&T	US	147	281 450	180	14 800	8 746	
Verizon	US	132	177 700	137	11 000	5 939	
China Mobile	China	108	438 645	830	20 090	15 701	
NTT	Japan	94	240 000	215	8 950	5 080	
DT	Germany	77	226 000	203	7 422	3 468	
Softbank	Japan	75		~30*	1 357	766	
Vodafone	UK	65	101 443	446	5 853	2 800	
América Móvil	Mexico	56	195 475	349	4 356	~4 500*	
China Telecom	China	53	291 526	439	~15 000*	11 840	
Telefonica	Spain	53	129 890	322	5 997	2 004	
Orange	France	45	156 000	263	~4 500*	1 462	
China Unicom	China	43	231 300	436	14 575	5 468	
KDDI	Japan	37	28 172	52	1 873	1 044	
British Telecom	UK	27	102 500	40	2 256	223	
Telecom Italia	Italy	21	66 950	124	2 635	237	
Telstra	Australia	26	36 000	26	1 449	1 571	
BCE	Canada		49 950	18	1 871	365	
Telenor	Norway	15	38 000	188	1 923	1 060	
Vimpel com	Holland	9.6	59 000	217[A]	2 624	1 150	
Axiata	Malaysia	5.1	25 000	101[A]	564	435	
Singtel	Singapore	12.5	19 000	16[A]	781	579	
SK Telecom	Korea		4 046	29	1 453	686	
Bharti Airtel	India		16 000	244	~2 500*	1 910	
Bharti Airtel	Rest of World			95	~1 000*	853	
MTN	South Africa			230	~3 000*	1 590	
TRAI[1] (excl. Airtel)	India			792	~15 000*[1]	16 690	
Total:		**1 100**	**2 914 047**	**5 992**	**152 829**	**96 167**	

Table 3: ICT network operators public data (2015)
[1] Number of subscriptions are <u>per mid-year</u> and not *end-of-year*. [2] CF = Carbon Footprint.

III. ICT and E&M manufacturing companies public data (2015)

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Company	Home country	Revenue B$	Empl.	Electricity GWh	CF kt CO$_2$e	Categoty	Notes and data sources (CSR reports 2015)
Apple	US	234	110 000	996	211	Assembly	
Samsung	Korea	177	325 677	40 980	10 192	Display, IC, Assembly	
Foxconn	Taiwan	141	1 060 000	7 800	5 000	X-Assembly	
HP	US	103	287 000	3 500	1 432	Assembly+	
IBM	US	83	379 592	4 190	1 776	Assembly+	
Dell	US	74	140 000	675	358	Assembly	
Sony	Japan	68	131 700	6 390	1 368	Assembly	
Panasonic	Japan	63	254 084	3 800	3 280	Assembly	
Huawei	China	63	170 000	1 347	1 273	Assembly	
Intel	US	55	106 700	5 200	2 000	IC	
LG Electronics	Korea	50	77 000	1 237	1 110	Assembly	
Lenovo	US	46	50 348	216	558	Assembly	
Cisco	US	43	71 833	1 629	351	Assembly	
Fujitsu	Japan	41	156 000	1 714	1 132	Assembly	
Pegatron	Taiwan	38	123 000	568	513	X-Assembly	
Quanta Computer	Taiwan	35	81 135	594	528	X-Assembly	
China Electronics	China		129 000	1 236	862	X-Assembly	
Canon	Japan		192 000	2 002	1 563	Assembly	
Ericsson	Sweden	30	118 000	759	676	Assembly+	
TSMC	Taiwan	27	45 272	8 460	6 671	IC	
NEC	Japan	26	102 000	1 580	410	Assembly	
LG Display	Korea	26	50 000	18 700	8 024	Display	
Compal	Taiwan	26	66 000	251	221	X-Assembly	
Flextronics	US	24	180 750	~2 000*	1 197	X-Assembly	
Micron	US	16	30000	4 966	3 170	IC	
SK Hynix	Korea	15	26 900	13 433	4 947	IC	
TI	US	13	30000	2 484	2 400	IC	
Innolux	Taiwan	12	80348	4 955	3 261	Display	
AUO	Taiwan	11	42 000	4 234	3 000	Display	
BEO	China	8	42837	5 168	3 500	Display	
JDI	Japan	7	16 000	1 317	807	Display	
Total:		**1 555**	**4 675 176**	**152 381**	**71 791**		

Table 4: ICT and E&M manufacturing companies public data (2015)
[1] CF = Carbon Footprint.

IV. The importance of lifetime and allocation when estimating the life cycle of Smartphones

The actual usage of smartphones is of great importance when it comes to estimating the actual embedded footprint. The main reasons are:
- These end-user terminals are the key devices to access data / Internet.
- The users have until now due to better hardware and frequent software version updates been pushed to replace them with quite high frequency (= every 2-3 years)
- Smartphones are considered as part of their user's personal brand, especially by the younger generation.

The trends are however shifting and due to that new practices arise; practices that can be identified when assessing recycling statistics and take back data. This supplement is an attempt to summarize and consolidate what is known regarding mobile waste collection and recycling including established mobile take back systems based on the situation in Sweden 2017. Since Sweden is ranking high in ICT maturity it can be expected that similar trends identified in Sweden, will be seen also on other markets, but slightly delayed.

Several commercial studies exist, focusing on the financial effects of an extended usage of reconditioned mobile phones globally (Deloitte 2018, Gartner 2015 etc). However, there is little information available based on reported figures and for local markets.

Producer responsibility and e-waste collection

Sweden, that is one of the most IT mature countries in the world [Ref 1], have since the end of the 1990ies had a producer responsibility for Mobile phones. As a start it was just a voluntary program for among some mobile phone suppliers but since 2005 this has been part of the legal framework due to EU's WEEE legislation. As a reaction to the new legislation the electronic producers in Sweden created a membership-owned organization, Elkretsen, with the single task to collect and recycle the e-waste that their business members have produced or delivered in an economic, efficient and environmental friendly manner. There are other private collecting schemes in Sweden as well, but they have so far been quite small in comparison with Elkretsen. The cost for this e-waste collection and administration work is paid by a small fee that is added to the price of each product sold on the Swedish market. In practice the fee is paid by the producer or the supplier on the Swedish market and by that the consumer price increases with a certain percentage.

Except for the fact that the Swedish e-waste recycling figures are the highest in the world per capita where one reason is this "single source of electronic waste handling", this setup has also generated a good statistic foundation on electronic waste for different waste categories. In some cases and for specialized categories even more detailed data assessments have been performed, such as for mobile phones and Smartphones.

Study: Mobilephone and smartphone recycling in Sweden 2017

Pick and sorting studies are performed on an approximately regular basis. Due to the increased interest and discussion on the mobile phones life cycle a pick study was initiated and performed in 2017 by Elkretsen [2] to evaluate the numbers, types, status and quality of the collected phones. The collected phones have been sorted and classified as waste, i.e. the phones are in majority of cases broken (screens, connectors, covers). Phones that can be reconditioned and reused are not in general part of this waste flow.

The study and the result shows:
- In Sweden approximately 1 million mobile phones annually are recycled (collected and sorted as e-waste) equal to 100 000 kg of weight.
- This could be compared with the 4 million phones that are put on the market annually.
- Of the collected waste mobile phones, 250 000 are classified as "smart phones".
- The median age of a recycled phone (independent whether it's a smartphone or a regular one) is 5 year, but the variance is wide (2-11 years).

Conclusions:

- 1 million recycled mobile phones is a rather low figure compared to the annual sales volume of 4 million phones.
- The mean figure of 5 year of age figure is not "active age" of the recycled phone but more an indication of how long time the phone has been stored after it was broken and until it was delivered to the recycler.

Operators and suppliers mobile take back schemes

A majority of the mobile operators on the Swedish market has since 2016 had some kind of take back program for mobile phones, some more advanced than others. In some cases the program addresses only private consumers, in other cases it is also offered to business customers as a part of a service agreement (for instance in a mobility as a service model where the mobile phone/hardware is rented). Business examples existing on the Swedish market include:

- A possibility for the annual subscriber to update their hardware replacing the old one with a new model without any changes in the prize.
- Mobility as a service: Hardware and service included in a fixed subscription prize, as a part of a B2B offerings.
- An offer for customers to bring their old phone which are assessed/valuated and that value can be used to cover the cost to purchase a new mobile phone.
- An offer to customers to bring their old phones independent of age and condition, and just donate it to the operator/supplier which then will donate a fixed sum per collected/recycled phone as a voluntary contribution to a suitable NGO organization, for instance Plan international.

There is very little information publicly available related to the collected volumes of mobile phones via the operators until now but some information has been collected from companies that's involved in the mobile reconditioning process in Sweden and Nordics. Due to that the information is seen as company internal information the actual sources can't be revealed [3].

- The average collected mobile phone age is 2 years. It can be assumed that this figure represents the mobile phones "active age" since the value of the phone when purchased is very much connected to how long time that has passed since it was used and the value is a driver for not letting a not used phone be stored as a spare phone for too long time.
  Still, when business customers are offered the possibility to replace their older professional used phone and have it reconditioned it is not unusual that these might be somewhere between 2-4 years old.
- Premium phones from premium brands have a longer usage life than low-price models. According to information received from reconditioning firms there is a clear difference between phones collected in wealthy countries where premium branded phones are dominating the market and where the actual life time for these phones might be much longer than for less wealthy countries where simpler and cheaper phones are used to a much larger extent with a shorter life span as a result.
- The actual reconditioning/reuse potential or outcome is much higher for phones from wealthier markets such as the Nordic region (Sweden, Norway, Denmark and Finland) where the reusability factor can be as high as 95-98%. The residual is recycled according to best practice.
- In markets where non-premium models and brands have a larger sales volume the reuse factor is lower according to the same source but no actual figures are available.
- The collected volume of phones that was estimated to have been collected via the operators collecting scheme in Sweden was in the range of 250 000 – 300 000 for Sweden 2017. In addition to this there is an additional volume of reused phones that is privately reconditioned but no quantitative data exists.
- The market of reused phones has increased rapidly the last couple of years from almost nothing and it is expected to increase further when the sharing economy approach expands. Not least due to the fact that the price for a reused but not old premium phone will be more reasonable, especially in countries with a limited economy or for the younger generation.
- The reconditioned phones are put on the secondhand market, either locally or sold to traders that normally operates via Hong Kong.

- Regarding the reusability of older phones concerns has been raised by security experts and others that if the operative system is not updated there is a risk for security breaches. It might even be so that some functionality might be not available due to this problem if older phones are used and this might become a serious problem especially in IT-mature countries if not the phone manufactures increases their time for operation program support.

Discussion and conclusions regarding mobile phone usage and actual age

There is a knowledge gap related to the whereabouts of mobile phones and the difference between the 4 million phones sold in Sweden 2017 and
- the collected volume of recycled phones (Elkretsen, about 1 million)
- the collected and reconditioned phones via different mobile collecting schemes. Four major different collection and reconditioning schemes have been identified in Sweden representing roughly 250 000 – 300 000 [2] collected phones.
- in total roughly 1,3 million phones were collected and reconditioned in 2017 and provided to the secondhand market or recycled.

Overall, knowledge of the destiny of 2,7 million phones is lacking. But there are certain factors that needs to be considered:
- People might have more than one phone and they might be used for certain activities or seasons.
- Phones are reconditioned and reused within families or among friends and by that bias the reuse statistics.
- Older phones are left in drawers when new phones are purchased as back up if something happens. Normally nothing happens and the old phone is forgotten or just handed over to the children to play with.

The actual life time for a mobile phone is hard to asses but it is at least 2 years. If the phone is reconditioned the median time life span can probably be expanded up to at least 4-5 years, especially for more expensive and premium branded phones.

However, the older the phone, the more important the software program version will be. Will the phone manufactures be willing to invest in updating the programs in outdated mobile phones? If not, what will the consequences be for security, privacy and the potential to increase the phones functionality by downloading new apps? In the worst case it might hamper the market development.

References

[1] [1]: Malmodin, J., Lundén, D. (2016). The energy and carbon footprint of the ICT and E&M sector in Sweden 1990-2015 and beyond. ICT for Sustainability (ICT4S), Amsterdam, Netherlands, 30-31 August 2016. <https://www.atlantis-press.com/proceedings/ict4s-16/25860385 >

[2]: Elkretsen (2017): Sammanfattning av projekt:Mobiltelefoner. S-2017–3.5. 2017-06-01

[3]: The consolidated range of figures are based on data received from representatives from the reconditioning business in Sweden (April 2017). No publicly information available.

V.   ICT network operators questionnaire