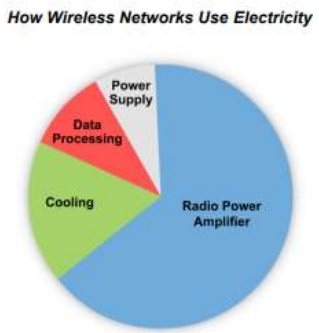
APPENDIX A

Summary of Wireless Electricity Usage

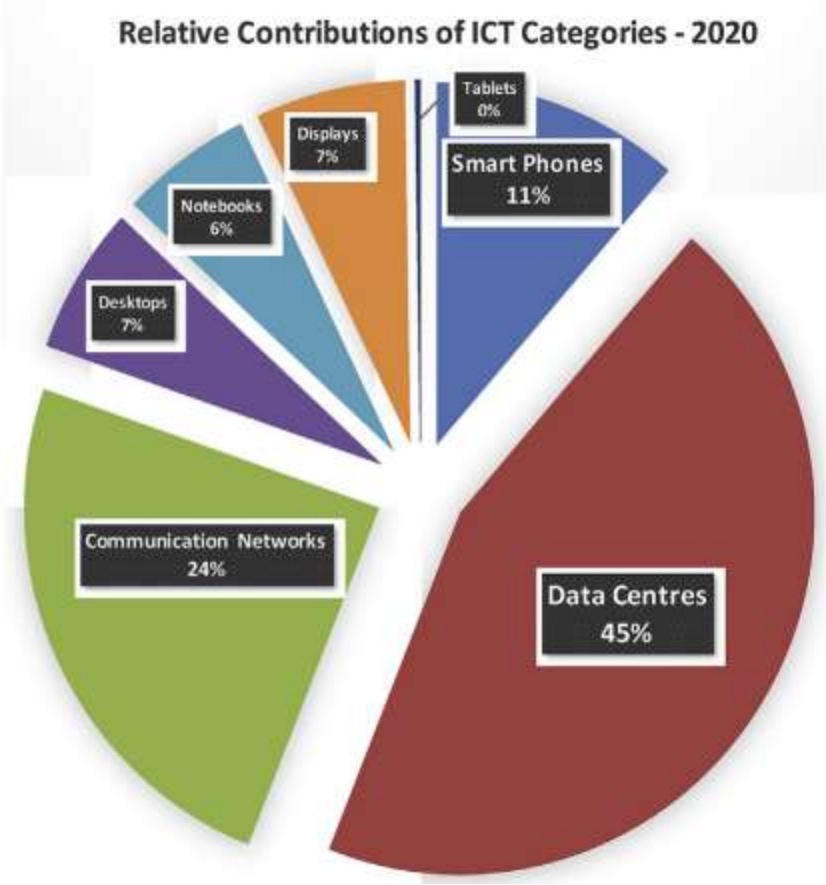
- The carbon footprint of a mobile phone is estimated to be 47 kg per year[1] by one source and by another source is estimated to be 60 kg for manufacturing alone and 122 kg per year for usage[2]
- Mobile phone CO2 emissions are expected to rise 55 million metric tons due to the increase in mobile communications by 2020 (Soonenschein et al, 2009)[3]
- Global communications consumed 1,815 TWh of electricity in 2012[4] – 8% of global electricity production[5]
- A wired connection (DSL, cable, fiber) is the most energy-efficient method to access the network. Wi-Fi slightly increases the energy use[6] [7]. 3G uses 15 times more energy than Wi-Fi and 4G uses 23 times more[8].
- Wireless access network technologies (Wi-Fi, 4G, LTE) comprise 90% of wireless cloud energy usage – 38.7 TWH or the equivalent of putting 5.6 million new cars on the road[9]
- At access rates greater than 10 Mb/s, wired access technologies are significantly more energy-efficient than wireless access technologies. Wireless technologies will continue to consume at least 10 times more power than wired technologies when providing comparable access rates and traffic volumes[10].
- Charging every cell phone on earth emits 35 million pounds of carbon dioxide[11]
- The electricity used by 170 million iPhone 5s could power 54,000 homes for a year[12]
- Using either a tablet or "smart phone" to watch an hour of video weekly consumes more energy in a year than 2 new refrigerators.[13]

[1] https://www.theguardian.com/environment/green-living-blog/2010/jun/09/carbon-footprint-mobile-phone
[2] https://www.riverpublishers.com/journal_read_html_article.php?j=JGE/5/2/4
[3] https://www.riverpublishers.com/journal_read_html_article.php?j=JGE/5/2/4
[4] http://vmserver14.nuigalway.ie/xmlui/handle/10379/3563
[5] https://www.iea.org/publications/freepublications/publication/Electricitytrends.pdf
[6] https://www.energystar.gov/products/office_equipment/small_network_equipment/key_product_criteria
[7] http://publicationslist.org/data/lorenz.hilty/ref-229/2014_Coroama_Schien_Preist_Hilty_Energy_Intensity_Internet_Home_Access.pdf
[8] http://www.cs.columbia.edu/~lierranli/coms6998-7Spring2014/papers/rrclte_mobisys2012.pdf
[9] https://ceet.unimelb.edu.au/publications/ceet-white-paper-wireless-cloud.pdf
[10] https://people.eng.unimelb.edu.au/rtucker/publications/files/energy-wired-wireless.pdf
[11] https://visual.ly/community/Infographics/environment/environmental-impact-cell-phones
[12] https://lifehacker.com/how-much-energy-a-smartphone-uses-in-a-year-and-what-i-5948075
[13] https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf pg. 3/44



- [14]
- Landlines use less electricity since all the power comes from the central office. Wireless calls require power in a central office, at cell towers, and at the customer[15].
- The embodied energy of a smartphone is 70% to 90%, including battery recharges. The embodied energy of a refrigerator is only 4% of total lifecycle energy; for cars, only 20%[16].
- Wireless networks use the energy in 1 pound of coal to transport 1 GB[17].
- 80% of the energy consumption of cellular networks is by cell towers[18]
- The average LTE energy consumption per subscriber is 49 kWh/year[19]
- 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 Information & Communication Technology devices and their associated carbon footprint relative to that of the other economic sectors[20].

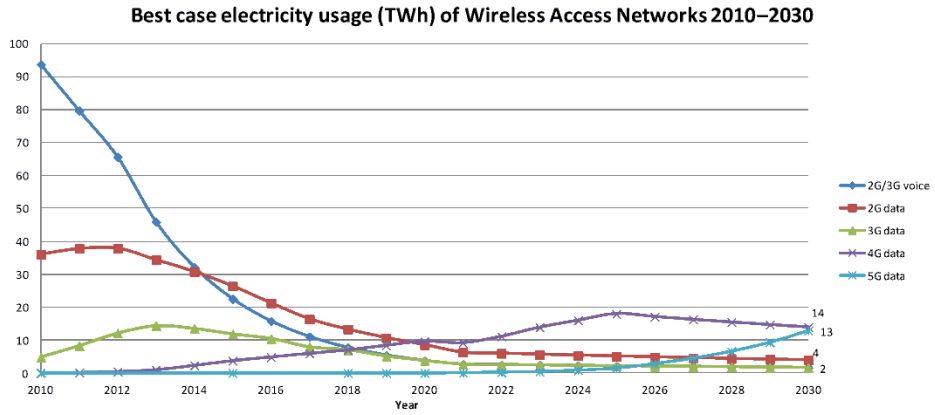
[14] https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf pg. 22
[15] https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf pg. 27
[16] https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf pg. 33
[17] https://www.tech-pundit.com/wp-content/uploads/2013/07/Cloud_Begins_With_Coal.pdf pg. 38
[18] http://epubs.surrey.ac.uk/44146/3/EARTH%20Com%20Mag%202011_E3F.pdf pg. 2
[19] http://epubs.surrey.ac.uk/44146/3/EARTH%20Com%20Mag%202011_E3F.pdf pg. 12
[20] https://www.sciencedirect.com/science/article/pii/S095965261733233X pg. 2



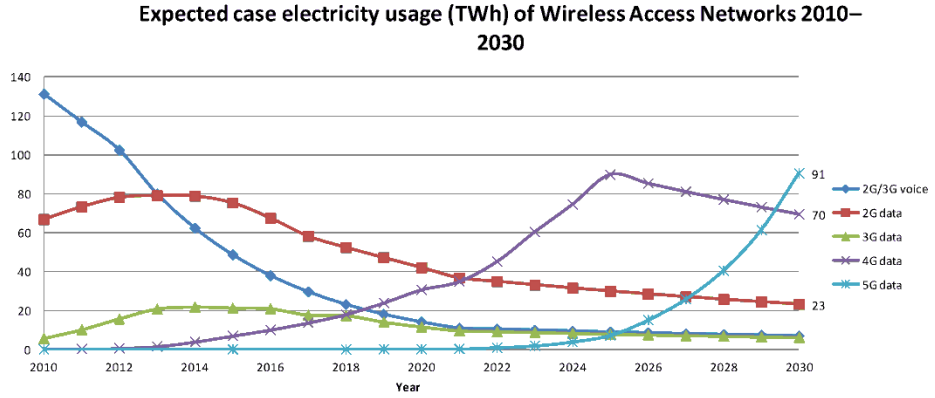
- [21]

- The big surprise however in our findings is the disproportionate impact of smart phones by 2020, and its vertiginous growth from 4% in 2010 to 11% in 2020 in relative terms. In absolute terms, the GHGE emissions of smart phones grew from about 17 MteCO2-e in 2010 to 125 MteCO2-e in 2020, representing a 730% increase in the span of 10 years. This impact is clearly driven by the fact that the production energy makes up 85e95% of its lifecycle annual footprint, driven by the short average useful life of smart phones of 2 years, which is driven by the telecom membership business model. Clearly this business model, while highly profitable to the smart phone manufacturers and the telecom industry, is unsustainable and quite detrimental to the global efforts in GHGE reductions[22].

[21] https://www.sciencedirect.com/science/article/pii/S095965261733233X pg. 10
[22] https://www.sciencedirect.com/science/article/pii/S095965261733233X pg. 11



(a)



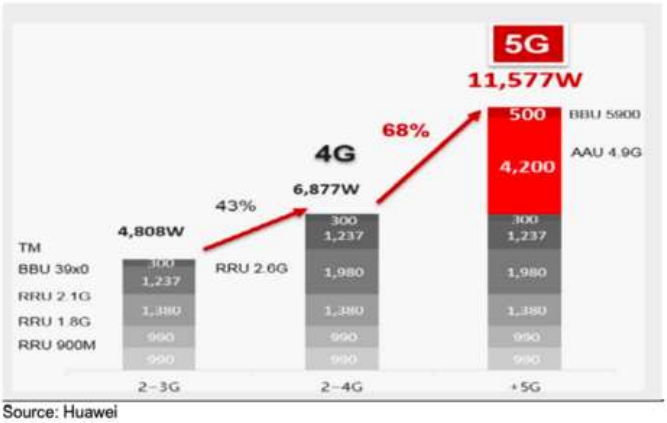
(b)

- [23]

- One way to view this figure of 812 TWh/yr is to consider it as an upper bound on electricity consumption for the network infrastructure deployed in 2012. It also tells us that a communications network that uses LTE, or equivalent wireless technology exclusively for its access infrastructure can consumer up to 2.2 times as much energy compared with a network where the primary access is via wired connections.[24]
- 5G will increase electricity usage of base stations by 70%[25]

[23] https://www.mdpi.com/2078-1547/6/1/117/htm
[24] https://aran.library.nuigalway.ie/bitstream/handle/10379/3563/CA_MainArticle14_all-v02.pdf pg. 25
[25] https://www.fiercewireless.com/tech/5g-base-stations-use-a-lot-more-energy-than-4g-base-stations-says-mtn

Figure 5: Site power requirements, 2G, 2-4G, and 5G (per Huawei)



Source: Huawei [26]

- Some studies have suggested that up to 50% of current network energy costs are due to the wireless portion of the network.[27]
- An Ethernet switch emits 10.8 kg of CO2 per year, compared to 14.83 kg by a Wi-Fi access point (37% less energy).[28]

Summary of Landline Electricity Usage

- A telephone uses -48V volts at 30 milliamps[29]
  - At 48 volts and 30 milliamps, the power is 1.44 W[30]
  - At 1.44 W, a phone uses 0.00144 kW[31]
  - 236g per kWh[32]
- A DMS-100 switch uses 500 A[33] when idle, 600-650 A at max capacity at -48 V
  - Capacity: 100,000 lines maximum
  - 24 kW
  - 24 x 236 = 5667 g CO2 per hour
  - 40.8g per line (split across 100,000 lines)
- Average subscriber, assuming ~3 hours usage per day = 34 x 90/100 = 30.6 g CO2 per month
- Total: 30.6 g + 40.8 g = 71.4 g per phone line (3 hours daily usage) CO2 per month or 0.857 kg per year

[26] https://www.fiercewireless.com/tech/5g-base-stations-use-a-lot-more-energy-than-4g-base-stations-says-mtn
[27] https://aran.library.nuigalway.ie/bitstream/handle/10379/3563/CA_MainArticle14_all-v02.pdf pg. 42
[28] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6490245 pg. 6
[29] https://electronics.howstuffworks.com/question62.htm
[30] https://www.rapidtables.com/calc/electric/Amp_to_Watt_Calculator.html
[31] https://www.rapidtables.com/calc/electric/watt-to-kwh-calculator.html
[32] https://www.rensmart.com/Calculators/KWH-to-CO2
[33] Winter Park, FL CenturyLink technician