Carbon footprint of unwanted data-use by smartphones

An analysis for the EU

CE Delft
Committed to the Environment

THE GREENS/EFA
in the European Parliament

Carbon footprint of unwanted data-use by smartphones

An analysis for the EU

This report was prepared by:
Meis Uijttewaal, Geert Bergsma, Thijs Scholten

Delft, CE Delft, July 2021

Publication code: 21.210166.101

Data / Use / Smarphones / Carbon dioxide / Footprint

Client: The Greens/EFA Group in the European Parliament, Kim van Sparrentak

Reference: M/2021/240

Publications of CE Delft are available from www.cedelft.eu

Further information on this study can be obtained from the contact person Geert Bergsma (CE Delft)

CE Delft
Committed to the Environment

Through its independent research and consultancy work CE Delft is helping build a sustainable world. In the fields of energy, transport and resources our expertise is leading-edge. With our wealth of know-how on technologies, policies and economic issues we support government agencies, ngo's and industries in pursuit of structural change. For 40 years now, the skills and enthusiasm of CE Delft's staff have been devoted to achieving this mission.

Content

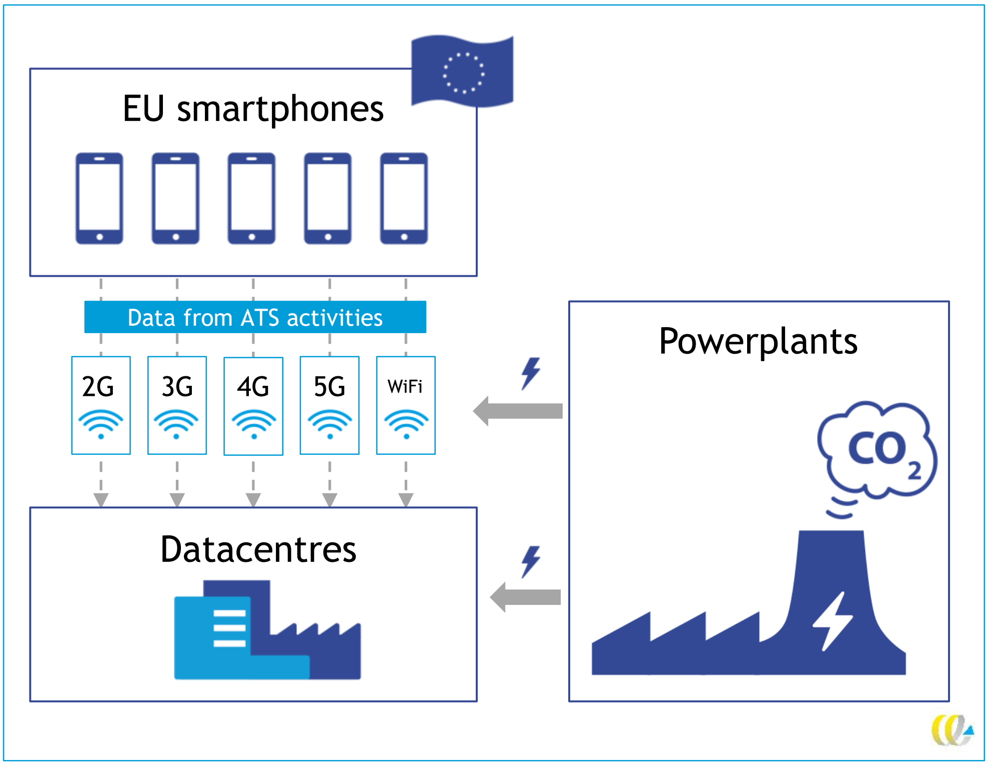
Summary

Recently, the European Commission has published their strategy on data (EC, 2020).
This strategy mainly focusses on the opportunities digital technologies and data sharing can create and the privacy risks associated with it. Smartphone apps collect more user data (also called tracking) than most consumers prefer. Besides privacy risks, the collection of user data also results in a carbon footprint as sending this user data to third parties and showing personalised advertisements consumes network data. When the user tracking is unwanted, also the consumption of network data for tracking is unwanted. Ideally, rules for smartphone companies to limit unwanted user tracking would also reduce this unwanted data-use and the accompanying carbon footprint. So far, however, it is unknown what the carbon footprint of this unwanted data-use is and what the potential carbon footprint reduction of limiting user tracking is. Therefore, the Green Party in the European Parliament has asked CE Delft to determine the carbon footprint of unwanted data-use by smartphone apps.

In this study we define the unwanted data-use by smartphone apps as the network data (both cellular and Wi-Fi) used to transfer the data collected by third-party advertisement and tracking services (ATS) in smartphone apps to the third-party servers. As approximately 60% of the consumers indicate that they would turn off third-party tracking, 60% of the network data used by ATS is qualified as unwanted.

To determine the carbon footprint of unwanted data-use we have combined the information on the amount of network data used by ATS with the electricity consumption of the data network and the carbon footprint of electricity production, as shown in in Figure 1.

Figure 1 - Schematic overview of the system studied

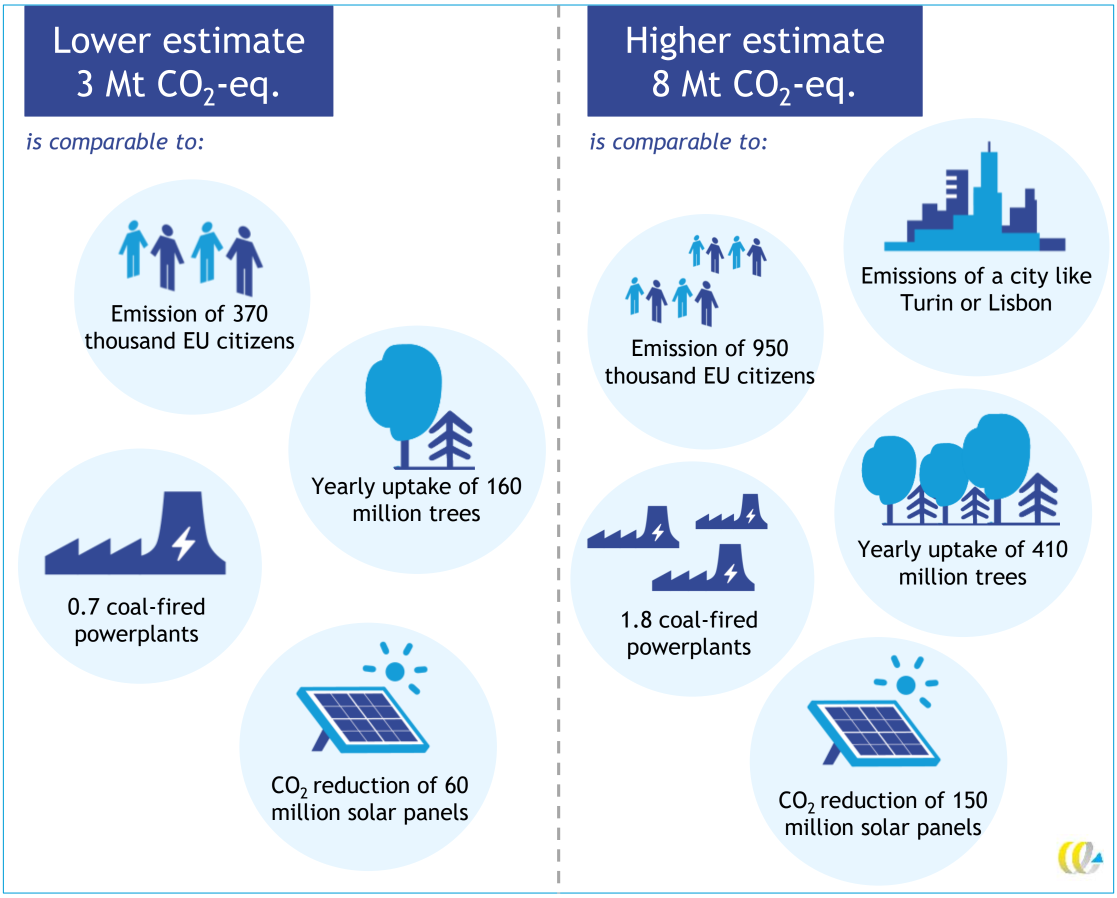


As the information on data-use by advertisement and tracking services is limited, the technology is developing at a fast rate and the electricity consumption of data networks is uncertain, this study only provides a first estimate of the carbon footprint of unwanted data-use by advertisement and tracking services. To arrive at more specific and certain carbon footprint, more research is needed.

This analysis results in an estimated **total carbon footprint of ATS data-use** in Europe of between 5 and 14 Mt CO_2-eq. per year. The **carbon footprint of unwanted data-use by ATS** is estimated to be between 3 and 8 Mt CO_2-eq. per year. This is comparable to the CO_2 emissions of 0.7 to 1.8 1,000 MW coal-fired powerplants, the CO_2 emissions of European cities such as Turin or Lisbon, or the CO_2 emissions of 370 to 950 thousand European citizens.

To compensate for 3 to 8 Mt CO_2 emissions, 160 to 410 million trees need to grow for one year or between 60 and 150 million PV panels need to be installed to replace the average European electricity production.

Figure 2 – The carbon footprint of unwanted data-use by smartphones in the EU compared with other CO_2 emitters or CO_2 reduction options. (Each circle represents a CO_2 emitting or reducing activity which is comparable to 3 of 8 Mton CO_2)



1 Introduction

With the large amount of cookie consent notifications popping up on websites, almost all smartphone users are now aware that websites store cookies on their devices to track them and collect information about them. What is less visible to most consumers is that also smartphone apps collect user data with trackers installed in the software. And also adds (text, pictures video) which many consumers would like to see less lead to data transfer.

Awareness of the privacy risks associated with user tracking is increasing. The privacy risks, however, are not the only issue with user tracking in smartphone apps. The data is not stored on the smartphones themselves, but is sent to third parties over the data network and stored in datacentres. Both the data network and the datacentres consume electricity, which results in CO_2 emissions. Therefore, the data traffic generated by the trackers has a carbon footprint. In this project we investigated how large this carbon footprint is for all smartphones used in the EU.

Recently, the European Commission has published their strategy on data (EC, 2020). This strategy mainly focusses on the opportunities digital technologies and data sharing can create and the privacy risks associated with it. Smartphone apps collect more user data (also called tracking) than most consumers prefer. Besides privacy risks, the collection of user data also results in carbon footprint as sending this user data to third parties and showing personalised advertisements consumes network data. When the user tracking is unwanted, also the consumption of network data for tracking is unwanted. Ideally, rules for smartphone companies to limit user tracking would also reduce this unwanted data-use and the accompanying carbon footprint. So far, however, it is unknown what the carbon footprint of this unwanted data-use is and what the potential carbon footprint reduction of limiting user tracking is. Therefore, the Green Party in the European Parliament has asked CE Delft to determine the carbon footprint of unwanted data-use by smartphone apps.

To determine this carbon footprint we have to answer two questions:
1. What is the carbon footprint of the data-use of advertisement and tracker services in smartphone apps?
2. What amount of the data-use by advertisement and tracker services is unwanted by European consumers?

With the answers to these questions we can determine the carbon footprint of the unwanted data-use by advertisement and tracker services in smartphone apps.

2 Methodology

2.1 Goal

The goal of this study is to make an estimation of the carbon footprint of unwanted data-use by smartphones in the European Union. Furthermore, we would like to give insight in the effects of smartphone settings on this carbon footprint.

2.2 Scope

In this study we only look at the unwanted data-use by smartphones in the EU. Also on desktop computers, laptops, tablets and other devices connected to the internet unwanted data-use takes place, but these devices are not part of the scope of this study. This is a first analysis and data for other devices could later be added if interesting.

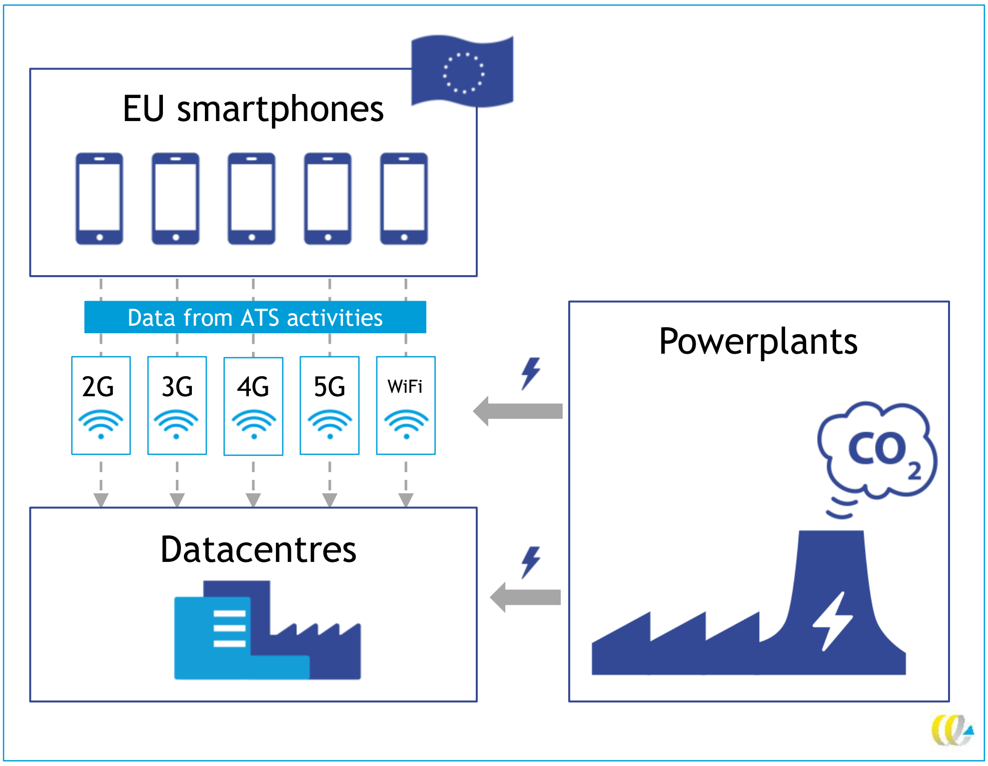
We define unwanted data-use as network data consumed by advertisements and trackers in smartphone apps of consumers who prefer not to be tracked and shown personalised advertisements. This data-use might not be unwanted by everyone, as some people experience benefits of the advertisements and trackers. The problem, however, is that the trackers and advertisements are part of smartphone apps and it is often not possible to (easily) switch them off or remove them. For a large part of the consumers the network data consumed by apps for trackers and advertisement is mostly unwanted. For these consumers the data-use would actually be lower if European law would state that new smartphones and operating systems should be sold to consumers with minimum tracking and advertisement settings.

Energy consumption of the smartphone itself when using data is left out of the scope of this study due to a lack of reliable and relevant information.

2.3 System description

The system which is the subject of this study is shown in Figure 3. Below the figure we will give a short description of each component of the system.

Figure 3 - System boundaries



Advertisement and tracking activities on smartphones

The apps on smartphones contain many functions which are useful for the user, such as social network integrations or crash and bug reporting. These functions are often not developed by the app developers themselves, but by third parties who provide these functions to app developers in the form of software development kits (SDKs). Sometimes these SDKs do not only provide a certain function, but they also track the app user by collecting information about him. This information is sent back to the developer of the SDK, which is a so-called third-party. This third-party can use this information to build a profile of the user, which is useful for targeted advertising.

Furthermore, to monetise their apps, app developers sell advertisement space in their apps to advertisers. This is usually done through ad networks, which connect app publishers to advertisers. The ad network tracks the app user and collects information about, for example, his location, age, gender and interests to be able to show targeted and personalised adds.

Data network and datacentres

The information collected by the trackers from third-party services are sent to the third parties over the data network. To send the information the smartphone connects to a antenna on a cell tower. The information is further transmitted by cables to the server of the third-party. The transmission of the information (data) from the smartphone to the antenna and further to the server requires electricity. The amount of electricity needed per unit of information sent, depends on the type of data network (2G, 3G, 4G, 5G and Wi-Fi).

The servers are usually stored in datacentres. These datacentres can be located anywhere in the world, but in this study we assume that all datacentres storing the information from European smartphones are located in Europe. These servers require electricity to keep running, but also the datacentres in which they are stored consume electricity, for example for cooling.

Electricity network

The electricity required by the data network and the datacentres is provided by the electricity network. Electricity is mostly generated in powerplants (by burning coal, gas or biomass or through nuclear reactions) or from hydro energy, wind energy or solar energy. The generation of electricity results in carbon dioxide emissions, either directly through the combustion of fossil fuels, or indirectly in the electricity production chain. In this study we take both the direct and indirect CO_2 emissions of electricity production into account.

We assumed that the electricity use is distributed all over Europe. In the calculation we used the actual European electricity grid mix from 2019.

3 Inventory

Amount of network data used by trackers and advertisements

Vallina-Rodriguez et al. (2016) have studied third-party advertising and tracking services (ATS) in 1,732 mobile apps at the traffic level. One of their findings is that in the 200 apps consuming most data, on average, 17% of app traffic is associated with ATS. There is a large variety in the amount of app traffic caused by ATS. The distribution of app traffic volume indicates that 70% of the analysed apps dedicate at least 10% of their traffic to advertising and tracking services and more than 7% of the apps have at least 90% of their network data consumption associated with ATS (Vallina-Rodriguez et al., 2016).

The results found by Vallina-Rodriguez et al., (2016) show that there is a large variety in data traffic associated with ATS for different apps. In determining the average of 17% they did not take into account how much the different apps are used by consumers. It is possible that apps contributing largely to the total European data traffic dedicate only a small percentage of their data traffic to ATS services, which would result in a lower average contribution of ATS data traffic to total data traffic. The opposite, often-used apps consuming large amounts of network data for ATS, is also possible.

Vallina-Rodriguez et al., (2016) do not specify for which apps the ATS data traffic is high and for which it is low, but their analysis does reveal that news and social media apps contain the most ATS services. These apps, however, consume only between 10% and 20% of the total global mobile data traffic. Video apps, on the other hand, consume 66% of the global mobile data traffic (Statista, 2021a). As streaming videos itself requires large amounts of data traffic, it is likely that the contribution of ATS services to the data-use of video apps is limited. Therefore, we take the 17% of app traffic associated with ATS found by Vallina-Rodriguez et al., (2016) as an upper boundary, also because in some video apps lots of advertisements are shown, and as a lower boundary we assume 10%, to use a conservative range for the carbon footprint of unwanted data-use.

The Ericsson mobility report provides information on worldwide cellular mobile traffic specified per region (Ericsson, 2020). They make a distinction between Western Europe and Central and Eastern Europe. We assume that the numbers for Western Europe are representative for the EU as a whole. The cellular data traffic per smartphone in 2020 was 11.3 GB/month in Western Europe. These amounts do not included data traffic by Wi-Fi. Data from the US indicates that the ratio Wi-Fi to cellular data is approximately 3:1 (FierceWireless, 2018). Assuming that this ratio is the same in Europe, Wi-Fi data traffic will be 34 GB/month in the EU.

With an average of 1.22 mobile cellular subscriptions per person in the EU and 448 million EU citizens, there are in total 546 million subscriptions in the EU (Eurostat, 2020, The World Bank, 2019). Assuming that all of the data consumed by smartphones is used by apps and using the number of smartphone subscriptions we arrive at the total ATS data consumption specified in Table 1.

Table 1 - Total yearly data consumption by advertisement and tracking services (ATS) in the European Union when 10% of the data is used by ATS and when 17% of the data is used by ATS (in billion GB)

	10% ATS		17% ATS	
	Cellular data	Wi-Fi data	Cellular data	Wi-Fi data
ATS data consumption	7.4	22.2	12.6	37.8

Electricity consumption of data traffic

The electricity consumption of the mobile networks differs per type of network. The newer the technology the more energy efficient it is. The energy efficiencies of the different mobile networks are indicated in Table 2.

Table 2 - Energy efficiencies of mobile networks

Mobile network	Energy efficiency (kWh/GB)	Source
2G	19 ± 6	(CE Delft, 2020)
3G	1.5 ± 0.5	(CE Delft, 2020)
4G	0.35 ± 0.1	(CE Delft, 2020)
5G	0.05 ± 0.025	(CE Delft, 2020)
Wi-Fi	0.15	(The Shift Project, 2019)

The energy consumption of datacentres is 0.072 kWh/GB (CE Delft, 2020).

The EU average energy consumption of data traffic depends on the distribution of mobile networks used for cellular data traffic. The Ericsson mobility report also provides information on the type of smartphone subscription. This data is summarised in Table 3. We make the assumption that the distribution of the total data-use over the different mobile networks is the same.

Table 3 - Distribution of smartphone subscriptions in Europe (Ericsson, 2020)

Mobile network	Western Europe
2G	5%
3G	12%
4G	81%
5G	2%

Combining the energy efficiencies from Table 2 and the network distribution from Table 3 and including the energy use of data centres, results in an energy consumption of cellular data of **1.49 ± 0.44 kWh/GB**. For Wi-Fi data traffic, the energy consumption is **0.22 kWh/GB**, including the energy use of data centres.

Carbon footprint of electricity consumption

The carbon footprint of the European electricity mix is **0.42 kg CO_2-eq./kWh**. This carbon footprint has been calculated by analysing the Ecoinvent model "*Electricity, low voltage | market group for*" with the *IPCC 2013 GWP 100a V1.03* method in SimaPro. This model represents the European electricity mix in the year 2019.

4 Results & Discussion

4.1 The yearly carbon footprint of data-use by tracking is 5 to 14 Mt CO_2-eq.

Combining the data of the amount of network data used by trackers and advertisement services, the electricity consumption of the data network and the carbon footprint of electricity production presented in Chapter 3, we estimate that the yearly carbon footprint of data-use by advertising and tracking services in smartphone apps in Europe is between 5 and 14 Mt CO_2-eq. The uncertainty in this number is caused by the uncertainty in the energy consumption of data-use and the uncertainty in the data-use by ATS services. The upper limit of the estimation is derived from the scientific literature we could find. As the most important source is from 2016, we add a conservative lower estimate taking into account that network data consumption by video apps has increased since 2016 and the relative amount of data consumption by advertisements and tracking is likely to be lower in video apps.

4.2 Potential carbon footprint reduction of stopping unwanted data-use of trackers and advertisements

The biggest carbon footprint reduction could be achieved by banning all third-party advertisement and tracking services from smartphone apps. This would then result in a carbon footprint reduction of between 5 and 14 Mt CO_2-eq. per year.

However, some people might prefer the advertisement and tracker services in apps to be activated, as this allows for more personalised advertisements. Furthermore, the high effectiveness of personalised advertisements made possible by tracking makes it possible to offer the apps for free.

Therefore, it is more likely that consumers are offered the choice to be tracked in smartphone apps. This has recently also become the case in Apples latest iOS 14.5 update, which includes a new feature called App Tracking Transparency, that requires apps to ask permission if they want to track users (Apple, 2021). The potential carbon footprint reduction then depends on consumer behaviour.

According to a survey of 600 Americans 61.5% of the consumers will not allow apps to track them, whereas the other 38.5% of the consumers would allow app tracking (Koetsier, 2021). A survey in Germany on personalised adds (for which tracking is needed) show similar results. 60-70% of the respondents indicate that they find personalised adds annoying. On the other hand, 30-40% of the respondents find personalised adds useful (Statista, 2021b). If the results from these surveys apply to Europeans in general and approximately 60% of the Europeans would block advertisement and trackers services in their apps, this could result in an estimated carbon footprint reduction of between 3 and 8 Mt CO_2-eq. per year.

4.3 The carbon footprint of unwanted data-use in perspective

The greenhouse gas emission per capita in the European Union was 8.7 ton CO_2-eq. in 2018 (Eurostat, 2021). This means that the carbon footprint of the unwanted data-use (between 3 and 8 Mt CO_2-eq. as mentioned above) is equal to the carbon footprint of between 370 and 950 thousand EU citizens.

The higher estimate of the carbon footprint of unwanted data-use (8 Mt CO_2-eq.) is comparable to the carbon footprint of Turin or Lisbon (Moran et al., 2018).
These city carbon footprints are based on data on population, purchasing power and available subnational carbon footprints[1].

Furthermore, the lower estimate of the carbon footprint of unwanted data-use is comparable to 70% of the yearly CO_2 emissions of the Uniper coal-fired powerplant in the Netherlands. This is a powerplant with a capacity of 1070 MW (WISE, 2020).
The higher estimate of 8 Mt CO_2-eq. is equal to the emissions of 1.8 such powerplants.

To compensate for 1 ton of CO_2-eq., approximately 50 trees need to grow for one year (Climate Neutral Group, ongoing). This means that to compensate for the yearly carbon footprint of the unwanted data-use, between 160 million and 410 million trees need to grow for one year.

To compensate 3 to 8 Mton CO_2 emissions each year European citizens could also place 60 to 150 million 360 kWp PV panels, respectively. This calculation is based on the assumption that the electricity from a PV panel replaces the average European electricity mix. The CO_2 emission of PV-electricity is 0.1 kg CO_2-eq./kWh[2], the CO_2 emission of the European electricity mix is 0.42 kg CO_2-eq./kWh. The electricity yield of a PV panel is 480 kWh/kWp in the Netherlands, we assume that is representative for the average European PV panel (Sonnenertrag.eu, 2021). For a 360 kWp PV panel, the electricity yield is then 173 kWh/per year.

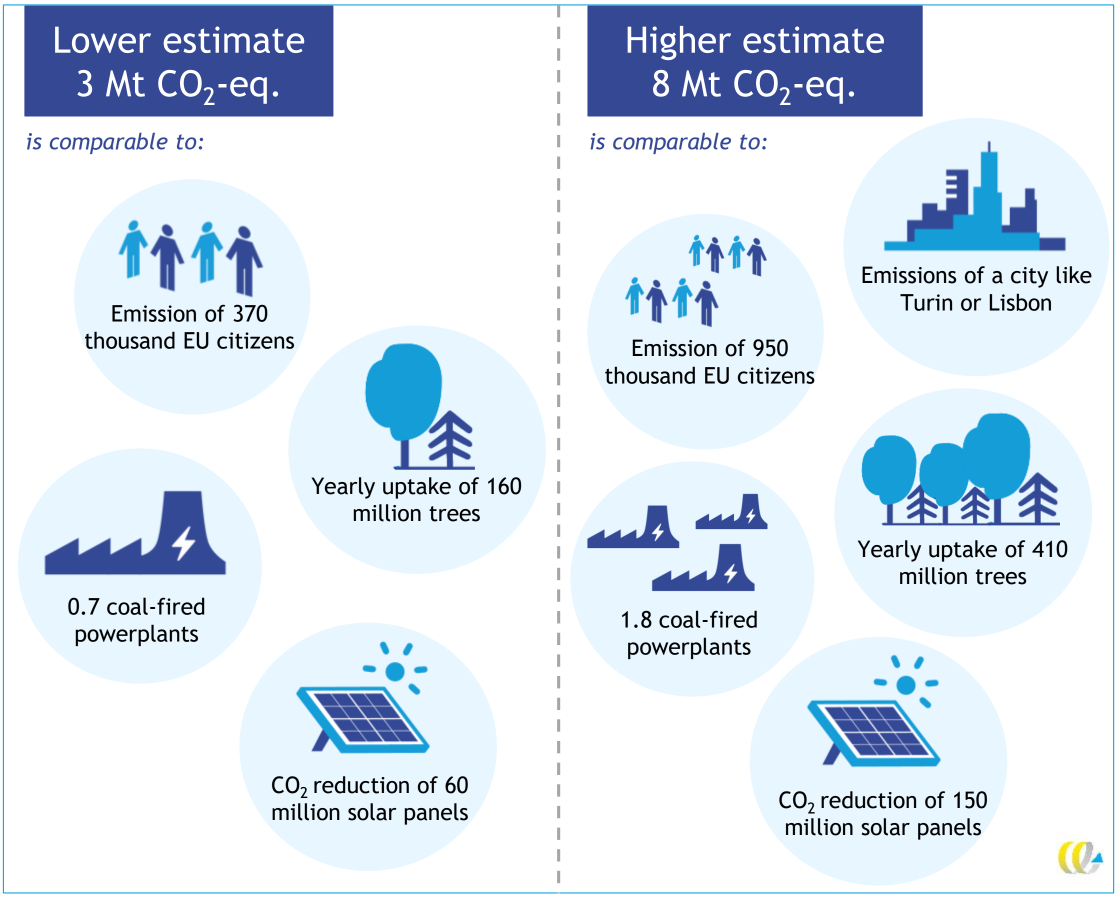
With a total EU ban on third-party advertisement and tracker services in smartphone apps, the yearly emission of 5 to 14 Mt CO_2-eq. would be prevented. This equals the installation of 90 to 260 million solar panels.

---

1 The carbon footprint of Turin is 7.5 ± 4.5 Mt CO_2-eq., the carbon footprint of Lisbon is 8.3 ± 3.7 Mt CO_2-eq. (Citycarbonfootprints, 2018). These city carbon footprints were determined using per capita footprints.

2 Ecoinvent v3.6: Electricity, low voltage {NL}| electricity production, photovoltaic, 3 kWp slanted-roof installation, single-Si, panel, mounted | Cut-off.

Figure 4 - The carbon footprint of unwanted data-use by smartphones in the EU compared with other CO_2 emitters or CO_2 reduction options (Each circle represents a CO_2 emitting or reducing activity which is comparable to 3 or 8 Mton CO_2)



4.4 Discussion

The results presented above are a rough estimation of the carbon footprint of unwanted data-use. As it is difficult to identify the use of advertising and tracker services in smartphone apps, limited research into this subject is available. Most studies focus on cookies in internet browsers. The studies that do look into trackers in apps, mostly report the amount of trackers, but provide no information on the amount of network data consumed by the trackers.

The study by Vallina-Rodriguez et al., (2016) on which the results presented above are based is from 2016. Considering the speed of innovation and development in the field of ICT, the results found by Vallina-Rodriguez et al., (2016) might already be outdated. Whether the developments have resulted in an increase or decrease is hard to estimate. To be conservative we concentrated on the increase of video which probably has reduced the percentage of ATS.

Another uncertainty in the results is caused by the generality of the findings of Vallina-Rodriguez et al., (2016). The average data traffic by ATS services of 17% they report is not a weighted average and does not take into account the popularity of the apps. It might be the case that popular apps contain more trackers with more data traffic, which results in a higher total carbon footprint of advertisement and tracker services. However, the opposite might also be the case.

The carbon footprint presented above represents the average carbon footprint of advertisement and tracker services on smartphones. The carbon footprint of these services for individual consumers might be much higher or lower than the average carbon footprint and depends on many factors, such as the type of phone, the number of apps installed, the user behaviour, the type of network subscription, the country of residence, etc.

5 Conclusion

We estimate that the **total carbon footprint** of data-use by tracker and advertisement services in apps on European smartphones is between 5 and 14 Mt CO_2-eq. per year.

When 60% of the consumers label these services as undesirable, the carbon footprint of the **unwanted data-use** by tracker and advertisement services on European smartphones is estimated to be between 3 Mt and 8 Mt CO_2-eq. per year.

Enabling users to turn-off these tracking activities could then prevent between 3 and 8 Mt of CO_2 emissions per year, which equals the CO_2 emissions of 0.7 to 1.8 1,000 MW coal-fired powerplants, the CO_2 emissions of European cities such as Turin or Lisbon or the CO_2 emissions of 370 to 950 thousand European citizens.

To compensate for 3 to 8 Mt CO_2 emissions, 160 to 410 million trees need to grow for one year or between 60 and 150 million PV panels need to be installed to replace the average European electricity production.

6 References

Apple. 2021. *User Privacy and Data Use* [Online]. Available: https://developer.apple.com/app-store/user-privacy-and-data-use/ [Accessed May 2021].

CE Delft. 2020. *Energiegebruik 5G-netwerk* [Online]. Delft: CE Delft. Available: https://ceproject.cedelft.eu/projecten/200122/Documents/CE_Delft_200122_Energieverbruik_5G-netwerk_Def.pdf [Accessed].

Citycarbonfootprints. 2018. *Global Gridded Model of Carbon Footprints* [Online]. Available: http://citycarbonfootprints.info/ [Accessed 29 June 2021].

Climate Neutral Group. lopend. *Insights: Wat is 1 ton CO_2* [Online]. Available: https://www.climateneutralgroup.com/nieuws/wat-is-1-ton-co2/ [Accessed May 2021].

EC, 2020. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A European strategy for data COM (2020)66 final. Brussels, European Commission (EC).

Ericsson, 2020. Ericsson Mobility Report. Stockholm, Erisson.

Eurostat. 2020. *EU population in 2020: almost 448 million* [Online]. [Accessed July 7 2021].

Eurostat. 2021. *Greenhouse gas emissions per capita ; Tonnes of CO_2 equivalent per capita* [Online]. Euorstat. Available: https://ec.europa.eu/eurostat/databrowser/view/t2020_rd300/default/table?lang=en [Accessed May 2021].

FierceWireless. 2018. *How much data we're using, by network, operator and service plan* [Online]. Available: https://www.fiercewireless.com/wireless/how-much-data-we-re-using-by-network-operator-and-service-plan [Accessed 28 June 2021].

Koetsier. 2021. *IDFA survey: 62% of consumers will not allow app tracking in iOS 14* [Online]. Available: https://www.singular.net/blog/idfa-survey/ [Accessed May 2021].

Moran, Kanemoto, Jiborn, Wood, Többen & Seto, 2018. Global Gridded Model of Carbon Footprints (GGMCF). *Environmental Research Letters,* 13.

Sonnenertrag.eu. 2021. *Landenvergelijking* [Online]. Available: http://www.zonnestroomopbrengst.eu/photovoltaic-plants-comparison.html [Accessed July 5 2021].

Statista. 2021a. *Distribution of global monthly mobile data volume as of January 2021, by category*` [Online]. Available: https://www.statista.com/statistics/383715/global-mobile-data-traffic-share/#statisticContainer [Accessed June 25 2021].

Statista. 2021b. *Welche Einstellung haben Sie gegenüber personalisierter Werbung?* [Online]. Available: https://de.statista.com/statistik/daten/studie/986552/umfrage/einstellung-gegenueber-personalisierter-werbung-in-deutschland/ [Accessed June 29 2021].

The Shift Project. 2019. *Lean ICT Materials* [Online]. Available: https://theshiftproject.org/wp-content/uploads/2019/10/Lean-ICT-Materials-Liens-%C3%A0-t%C3%A9l%C3%A9charger-r%C3%A9par%C3%A9-le-29-10-2019.pdf [Accessed May 2021].

The World Bank. 2019. *Mobile cellular subscriptions (per 100 people) - European Union* [Online]. Available: https://data.worldbank.org/indicator/IT.CEL.SETS.P2?locations=EU [Accessed July 7 2021].

Vallina-Rodriguez, Sundaresan, Razaghpanah, Nithyanand, Allman, Kreibich & Gill. 2016. *Tracking the Trackers: Towards Understanding the Mobile Advertising and Tracking Ecosystem* [Online]. Available: https://arxiv.org/pdf/1609.07190.pdf [Accessed].

WISE. 2020. *Kolen* [Online]. Available: https://wisenederland.nl/artikel/kolen [Accessed May 2021].