Carbon footprint of package leaflets

A comparative study on greenhouse gas emissions of paper-based and digital package leaflets for pharmaceuticals – Part 2*)

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■ ABSTRACT

This article is divided into 2 separate parts. The first part described the background, scope and methods of the study. Results were presented regarding average weight, area and market share of package leaflets (PL) according to prescription status as well as total sizes and weights of PL and the size distribution of PL in Germany. Further on, the results for printing and supply of printed PL were depicted.

3.3 Distribution distances

The distribution of the pharmaceutical products to the market is modelled partly directly or indirectly via retail. Here, the transport leg to retail (indirect transport) or the direct transport is assumed to be realised by solo truck or truck trailer, with a share of 50 % each, and a load factor of 58 % or 28 % respectively. The transport distance varies between 362 km when indirect (producer to retail) and 207 km to 316 km when direct (producer to market, see details in fig. 4). At the retail sites, the product packs are repacked in multiple use boxes (weight 5 kg), containing approx. 50 packs and requiring 8 g plastic strap band each. The transport from retail to the market is realised by light duty vehicles over 175 km on average. In case of the transport from mail order pharmacy to the patient, a transport distance of 100 km is assumed. This transport is realised in boxes as described for the retail. In addition, in case of public pharmacies it was assumed that 3 % of the packs are delivered by car to the patient (home service) over an average distance of 5.5 km.

The above outlined distribution distances represent an average value to model the lifecycle of PL in Germany, referred to as "basic scenario" in this study. The industry survey however outlined that distances may vary decisively between companies and products. Therefore, a sensitivity analysis has been performed covering a variation of the assumed distribution distance. As examples, the alternative distances from producer to retail are 273 and 450 km (basic scenario 362 km), from retail to market are 50 and 500 km (basic scenario 175 km), or from producer to public pharmacy 281 and 350 km (basic scenario 316 km). All values are provided in fig. 4 (red numbers).

3.4 Distribution paths

The participating companies provided information on pharmaceutical products that have an average weight of 4.0856 g and a size of 0.0815 m^2 per PL and are distributed mainly to public pharmacies (71 %), mail order pharmacies (15 %) and hospitals (13 %). 60 % of the pharmaceutical products are transported indirectly via retail (see also fig. 5). These figures were used in the "basic scenario" of this study and further discussed in a sensitivity analysis covering a slightly adjusted share of distribution paths for public pharmacies (77 %) and hospitals (7 %), that was the outcome of the status quo analysis of PL (see section 3.1). This status-quo analysis confirms the industry-based information on PL size and distribution paths which supports in turn the conclusion of having realised a reasonable coverage of the German market by this industry survey.

3.5 Lifecycle of the digital package leaflet

The lifecycle of the digital package leaflet (ePL) examined in the study begins with the approved leaflet file, which is transmitted to a central database where it is stored or integrated and made available for download to private or professional end users (e.g., doctors, staff and/or patient). The download file can be accessed by scanning the PZN on the pharmaceutical pack or by searching for the PZN in an online database. In the context of this study only the search for the PZN in an online database was considered. For this purpose, an energy consumption of 0.3 Wh per search query (referencing to a Google search) was assumed [16].

The energy consumption values for transmission, storage and reading of the ePL on the respective user device were taken from the study by Oeko-Institut [5]. An energy consumption of 2.52e–10 Wh/kB was assumed for data transmission when using mobile internet and 5.2e–

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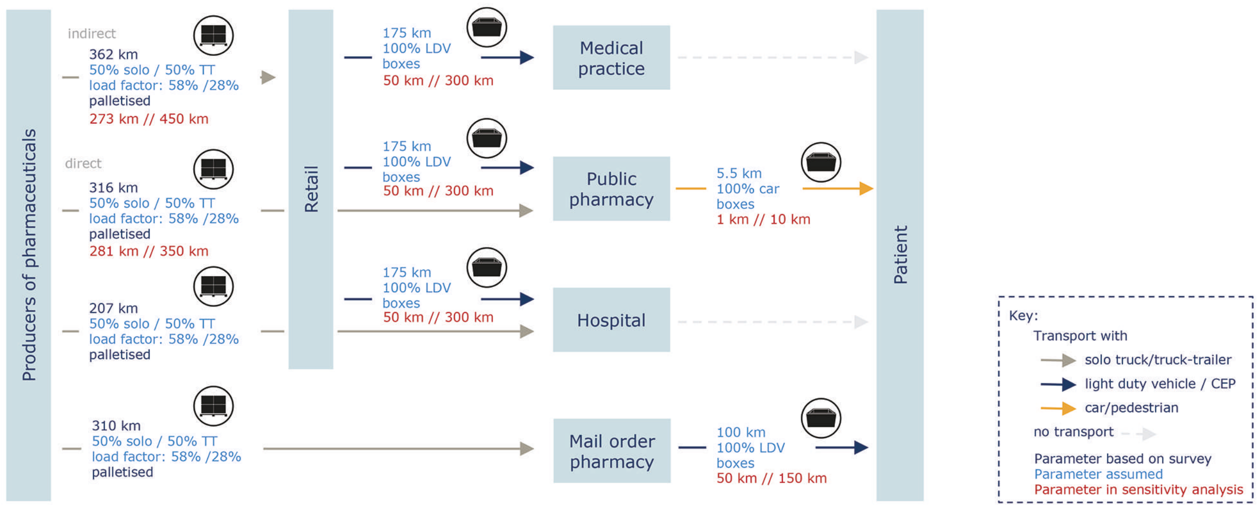

Figure 4: Distribution distances of pharmaceuticals (basic scenario).

11 Wh/kB for using wired internet. For ePL storage, an energy consumption of 0.3e–7 Wh/kB of the file to be stored was calculated. For the usage of individual devices for reading the downloaded leaflet, energy consumptions of 1.3 Wh for smartphones, 4.0 Wh for tablets, 13.0 Wh for laptops, and 87.0 Wh for desktop PCs with monitors were allocated to the assumed reading time.

4. Carbon footprint results

4.1 Carbon footprint of paper-based leaflet

The lifecycle of paper-based PL in Germany has been described in the previous chapters. As can be seen from the outlined data base gathered from the industry survey as well as statistical analyses, it is reasonable to advance a carbon footprint (CF) of PL by scenarios as well as sensitivity analyses.

4.1.1 Basic scenario and sensitivity analyses

The study therefore starts with a "basic scenario" representing average parameters derived from the industry survey. Due to the range of industry answers regarding selected parameters, the CF result of the basic scenario is discussed by means of 4 sensitivity analyses, that already have been introduced before.

In the lifecycle of paper-based PL in Germany, the main source for GHG emissions are upstream processes of the PL. 66 % of the total CF are caused due to paper production (61 %) and supply to printing companies (5 %). Another 16 % of the CF are caused by printing process, mainly influenced by the required electricity use. All other processes within the lifecycle, i.e., transport of PL to producers, producer processes, distribution, disposal of PL in the market and the surcharge due to rework, contribute by 3 % to 5 % each to the overall GHG emissions of a PL (see fig. 6). In total, approx. 7.2 g CO_2e are caused during the lifecycle of a paper-based PL in Germany.

In the model the total GHG emissions are influenced differently by assumed input parameters: firstly, some emissions are depending on the weight of PL, such as production or disposal of paper. Secondly, some process consumption and related emissions correspond to the area of PL, such as the production of ink or the electricity use for printing. Thirdly, all transport emissions relate to the tonne-kilometres required, which is the transport weight (including respective share of transport packaging) multiplied by the transport distance. Finally, some processes are covered by emissions per pack (i.e., per PL), such as file transmission to the printing company, surcharges due to discarded paper or electricity use at the sites of pharmaceutical companies.

Considering the outlined range of input parameters, the sensitivity analyses result in the following deviation compared to the basic scenario: (1) varying PL supply distances of 25 km or 450 km result in minus 1.7 % or plus 1.8 % emissions; (2) no transport between producer's sites in minus 0.1 % emissions; (3) adjusted distribution paths (hospital 7 %, public pharmacy 77 %) in plus 0.1 % emissions and (4) shorter or farther distribution in minus or plus 1.4 % emissions. In total, the calculated CF range between 7.0 and 7.5 g CO_2e per PL (i.e., minus 3.2 % to plus 3.3 %). This outlines, that the selected parameters sufficiently describe the lifecycle of paper-based PL in Germany. However, it is reasonable to adjust the values in case of company specific analyses.

4.1.2 Germany and selected pharmaceutical scenarios

The basic scenario takes the average weight of 4.0856 g and 0.0815 m^2 per PL as starting point, that reflects the participating companies or their selected pharmaceutical products. The investigation of the quantity and size distribution of PL in Germany outlined that this lies very close to the German average value of 3.8986 g/PL and within the elaborated range of 1.8043 g/PL (general

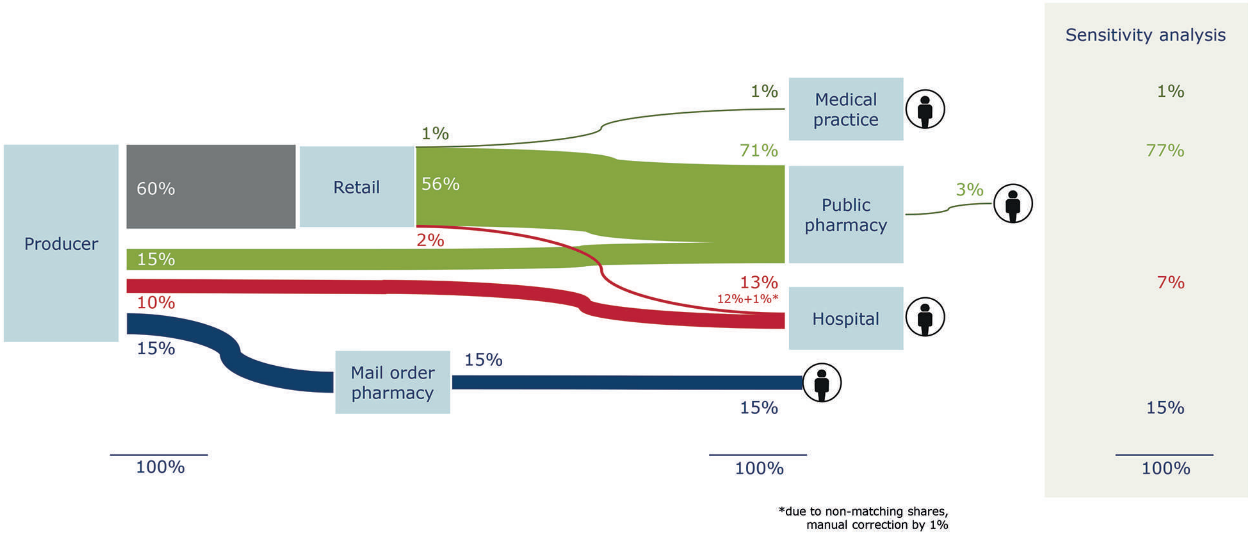

Figure 5: Share of distribution paths (basic scenario in Sankey-diagram, sensitivity analysis on the right).

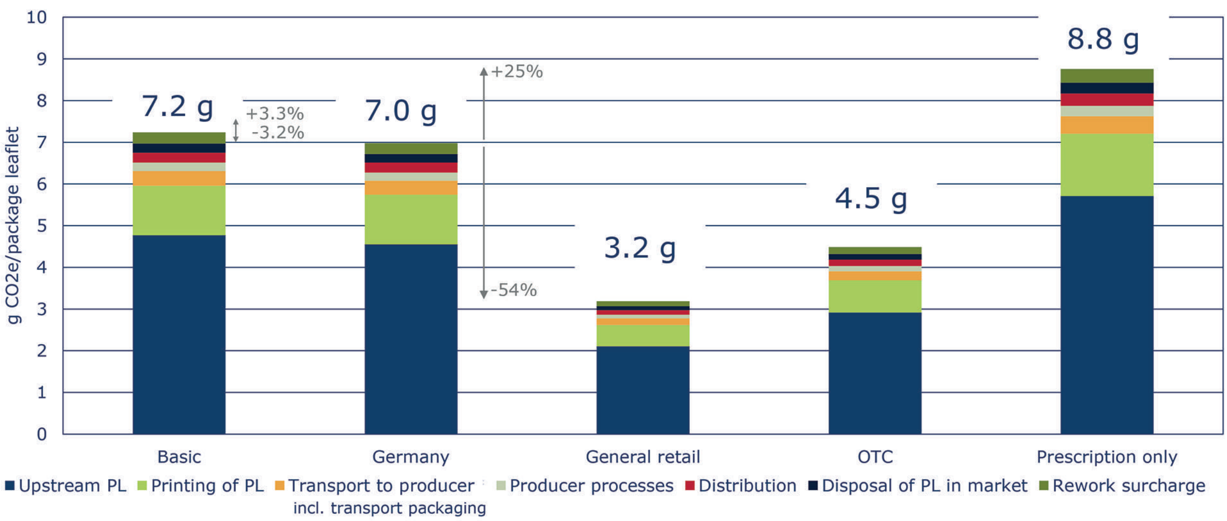

Figure 6: Carbon footprint results for scenarios of paper-based PL.

retail) to 4.8931 g/PL (prescription only) (see table 1 in section 3.1).

In fig. 6 the results for the additional scenarios of the study are presented. In the "Germany scenario" the German average weight of the PL is assumed (3.8986 g/PL, 0.0818 m^2/PL) as well as the adjusted market shares as indicated on the right in fig. 4. All other parameters are the same as described for the "basic scenario". For the additional 3 scenarios, that reflect the prescription status of the pharmaceutical products, the identified different average sizes and weights of each PL are used, all other parameters remain the same as in the "Germany scenario".

As one can see in fig. 6, the CF for the lifecycle of an average paper-based PL accounts for 7.0 g CO_2e per PL. The contributing shares of lifecycle phases remain comparable to the one described in more detail in the previous section, i.e., main emission sources are the paper production and supply as well as electricity use while printing. Therefore, the weight and size of a PL is directly influencing the related CF: the heaviest PL of average pharmaceutical prescription-only products result in the highest CF of 8.8 g CO_2e/PL; the smallest PL of average pharmaceutical products for general retail in the lowest of 3.2 g CO_2e/PL. Compared to the average CF, this means plus 25 % or minus 54 % respectively.

4.1.3 Carbon footprint of package leaflets in the German drug market

The elaborated parameter on an average CF of 7.0 g CO_2e per PL has been used for estimating the total CF caused by paper-based PL in Germany. Here, the underlying weight

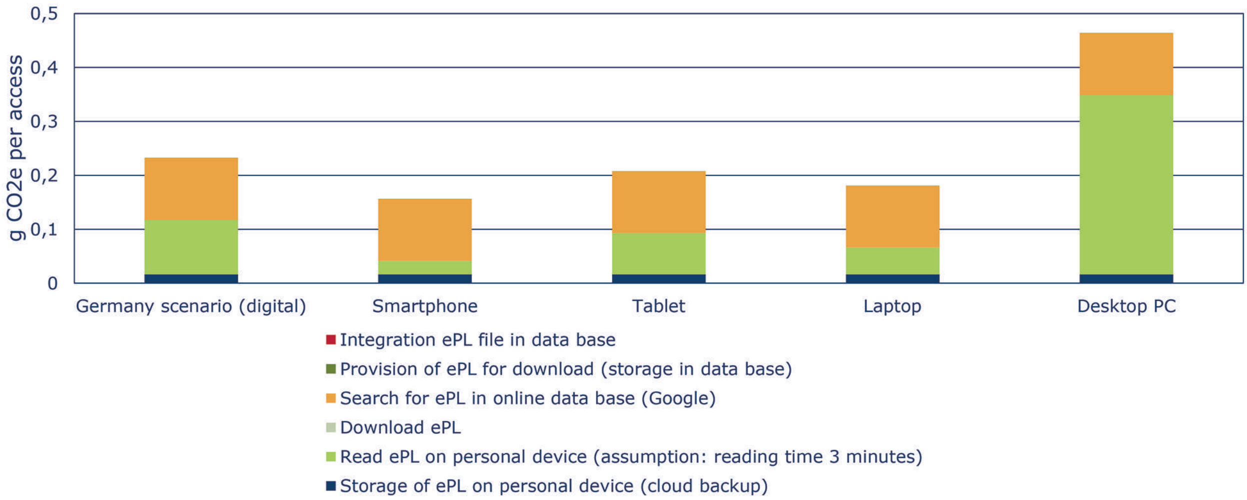

Figure 7: Carbon footprint results for ePL scenarios: Germany scenario (digital) vs. 100 % access to ePL via smartphone/tablet/laptop/desktop PC with monitor.

and size are 3.8986 g/PL and 0.0818 m^2/PL respectively. As outlined in section 3.1, the total weight of PL in Germany accounts for 6,507 t (OTC definition A) or 7,651 t (OTC definition B) and the total area 137 km^2 (OTC definition A) or 161 km^2 (OTC definition B).

Using the weight related approach, the total CF of paper-based PL accounts for 11,600 t CO_2e (OTC definition A) or 13,700 t CO_2e (OTC definition B). Alternatively, the area related results are 11,700 t CO_2e (OTC definition A) or 13,700 t CO_2e (OTC definition B).

Taking the average annual GHG emissions caused by a German inhabitant of 10.8 t per capita, as published by the German Ministry for the Environment [17], this equals the annual emissions of almost 1,100 to 1,300 Germans.

4.2 Carbon Footprint of digital package leaflet

As for the paper-based PL, different scenarios were calculated for the lifecycle of ePL in order to analyse how different influencing factors (e.g., user behaviour, used hardware) affect the CF. In order to establish the best possible comparability with the CF of paper-based PL, a Germany scenario (digital) was modelled for the ePL based on data on PL file sizes and internet usage specifically for Germany. The relevant influencing factors and scenarios are explained in the following.

The file size of the ePL affects the energy consumption of transmission and storage processes. Based on an analysis of the file sizes of 20,630 PL available as pdf files for the German market, an average pdf file size and a total storage capacity demand for all ePL for the German market were calculated. This resulted in an average pdf file size of 320 kB and a total storage capacity in a central database of 47.55 GB. For example, for the structured transfer of data to web servers, the machine-readable xml format is used instead of pdf. Xml files are significantly more compact than pdf files. It was assumed for the Germany scenario (digital) that 50 % of the ePL are processed in pdf and 50 % in xml format with a file size of 5 kB (own assumption). In Germany, the information for use of pharmaceutical products must be made available until at least 5 years after the pharmaceutical product has been withdrawn from the market. It was therefore assumed that the ePL is stored in a central database for 15 years.

For the transfer of the ePL file to the central database and from there to the end user's device, different transmission paths (mobile or wired internet) and end devices (smartphone, tablet, laptop, desktop PC with monitor) can be used. As described in section 4.3, these show significant differences in terms of their energy consumption. For the modelling of the Germany scenario (digital), it was assumed that the transmission of the approved PL file to the central database as well as the access of end users using a laptop or a desktop PC with monitor takes place via a wired internet connection. For access via smartphone or tablet, the use of a mobile internet connection was assumed (own assumptions).

Based on a Statista study on internet usage in Germany by device in 2022, the access to an ePL is modelled with the following shares in the Germany scenario (digital): 37 % via smartphone, 15 % via tablet, 28 % via laptop and 20 % via desktop PC [8]. The energy consumption of laptops and desktop PCs is significantly higher compared to smartphones and tablets, which leads to a correspondingly higher CF (fig. 7). Laptops and desktop PCs usually have a higher processing performance than smartphones and tablets, which is not utilised to 100 % by accessing and reading an ePL. It is assumed that reading ePL on laptop and desktop PC only claims 20 % of the total device performance and accordingly only one fifth of the energy consumption of these end devices was attributed to reading ePL in the CF calculation. The value of approx. 20 % share of the total processor utilisation was recorded when accessing and reading an ePL in pdf format on a laptop or desktop PC in the Windows task manager. Based on 2 studies on use of pharmaceutical PL [6,7] adapted to the German market it

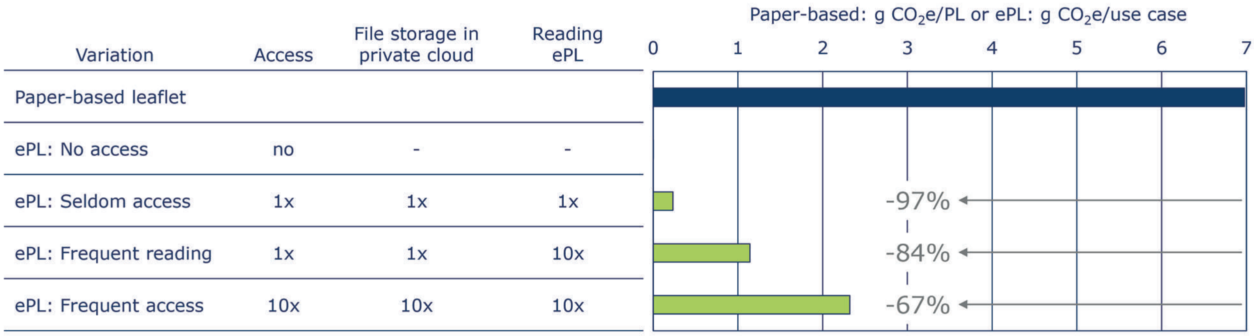

Figure 8: Carbon footprint PL vs. different ePL use cases.

is assumed, that the total number of accesses per ePL in central data base is 650.4 Mio.

This affects the share of energy consumption for the central provision of the ePL that is attributed to a single access to the ePL. According to research results from the GI 4.0 project [2], the average reading time for prescription-only pharmaceuticals is 1.5 min. In this study, a reading time of 3 min was assumed in order to have a conservative calculation.

Using the data from the literature described in section 4.3 and the assumptions made, a CF of 0.2 g CO_2e per ePL access in the Germany scenario (digital) was calculated. The largest share of this is accounted to the search of the ePL in the online database (49 %) and reading on the user device (44 %). Depending on individual user behaviour in terms of reading time, reading frequency, and storage settings, the CF caused by the use of ePL can therefore differ significantly.

4.3 The digital leaflet in comparison to the paper-based leaflet

The overall objective of the study is to quantify the greenhouse gas emissions of a paper-based and an ePL during their lifecycle. After having outlined the 2 different CF of the related "Germany scenario", i.e., 7.0 g CO_2e/PL (paper-based) and 0.2 g CO_2e/use case (ePL), they are further discussed in the following.

The CF of the paper-based PL is caused independently of the later actual use, i.e., reading the information on the pharmaceutical product and other content of the PL. Once it reaches the final addressee of the pharmaceutical pack, it can be directly wasted or read multiple times, without any impact of the calculated CF.

This is different in case of the digital alternative: The above stated CF of the ePL refers to a use where the ePL is accessed, stored in a private cloud, and read once by the patient or any other user, referred to as "Seldom access" in fig. 8. Comparing both leaflet types with these assumptions, the ePL is – with view to GHG emissions – 30 times or 97 % better than the paper-based PL.

Having in mind, that the information on a PL can be accessed and read very differently, further use cases are compared with the paper-based PL. They range from (1) "No access", which means the file is stored in a database, but no one accesses it, (2) a "Seldom access", which means the file is accessed, stored and read once, (3) "Frequent reading", which means that the file is read 10 times, up to (4) an unrealistic case with "Frequent access", where access, storage and reading is assumed to occur 10 times each. One can see that even under unrealistic assumptions, the ePL causes decisively less emissions than the PL.

4.4 Discussion

The authors of the study aimed at a realistic description of the lifecycles of the 2 alternatives of PL. The paper-based PL was modelled with primary data of the German pharmaceutical industry, still, some data gaps have been identified where assumptions needed to replace primary data, such as the electricity consumption at the production company of pharmaceutical products (assumed with 10 % share of the printing process) or the actual rework effort, i.e., wasted PL not having reached the market (assumed with 4 % surcharge in this study). Even if these assumptions are too high, the overall GHG emissions benefits of the ePL compared to the paper-based PL will not change considerably.

The estimation of the total size and weight of PL in Germany is based on primary data provided by industry and additional data for real life PL collected by authors and the analysis of a large number of available electronic PL. The sample of electronic PL covers roughly 82 % of all packs sold or dispensed in Germany and therefore provides a sound statistical basis. The sample of real-life data for 324 PL in terms of size and weight was much smaller but the fact that 95 % confidence intervals varied by plus minus 5 % of the average for pivotal parameters is indicative for sufficient statistical robustness at least for prescription-only and OTC drugs. A broader data basis would be beneficial, nevertheless despite the restrictions the results provide the best currently available estimation for the quantity of paper-based PL in Germany.

As the sizes of PL had to be analysed to estimate the quantity of PL, size distributions resulted as a byproduct of the study providing insights into the amount of information and its distribution in relationship to their prescription status. They not unexpectedly revealed that the amount of information increases from general retail over OTC to prescription-only drugs and showed distinct size distributions for every prescription status. To the authors' knowledge, no comparable analysis has been published so far giving insights into size distributions of PL from a drug information perspective.

In the study, a national electricity mix has been applied, causing 382 g CO_2e per kWh [13]. Individual companies within the pharmaceutical industry may have already changed their electricity supply to more renewable energy carriers or even have a 100 percent replacement. The use of electricity accounts for approx. 15 % of the total CF calculated in this study for the paper-based PL. Since the focus of the study was on the average German market and not individual cases, the choice of the national electricity mix is reasonable and often applied in studies and standards on carbon footprints.

The developed CF model itself could easily be adjusted if company case studies with e.g., renewable energy strategies are of interest. Likewise, studies with other geographical scope can use the German model as a good starting point. Variations, that need to be reviewed regarding possible adjustment may cover e.g., size and quantity of PL, distances to be covered between the companies, or share of distribution channels.

When looking at the model for the ePL, an enhanced data base would be interesting. This should include e.g., experiences gained in the context of ongoing pilots on ePL. There exists a lot of literature about readability and memorability of PL. However, the study faced a lack of knowledge about real use of PL such as how often or how long the information is read. This would help to advance the model on the ePL as well as the definition of evidence-based use cases.

5. Summary and outlook

The comparative study on greenhouse gas emissions of paper-based and digital package leaflets for pharmaceuticals revealed that in 2022 roughly 1.5 (1.9) billion PL were dispensed or sold in Germany. Values are calculated based on data for pack numbers with a strict definition for OTC products including pharmaceuticals only while values in brackets are calculated based on pack numbers based on a broader definition of non-reimbursed products.

The printed area amounted to 270 (320) km^2 which is roughly equivalent to 37,815 (44,818) soccer fields. The paper area (one sided) is half of these values and still amounts to 135 (160) km^2.

The GHG emissions of the average paper-based PL is 7.0 g CO_2e per PL. Differentiated according to prescription status it amounts to 3.2 g CO_2e for general retail, 4.5 g CO_2e for OTC and 8.8 g CO_2e for prescription-only pharmaceuticals.

Total emissions amount to 11,600 (13,700) t CO_2e. The potential reduction of greenhouse gas emissions by replacing a paper-based PL by an ePL exceeds 90 %.

To combat climate change caused by GHG emissions countless processes and products have to be changed in short time. The transition to digital patient information has the potential not only to improve patient information by improved functionalities and presentation of information but to combine this improvement with a reduction of GHG emissions of 90 % and above. Even more so, if renewable energy sources are used to provide electricity.

Outlook: The detailed model described in this article has been transferred to a "carbon calculator" that will be available as online tool published by Rote Liste Service GmbH in due course. It provides a simplified calculation of company specific scenarios for PL based on the study's outcomes. Pharmaceutical companies may e.g., specify their individual paper leaflets (i.e., size, weight, total number of annual packs), choose between local, regional, and national supply of printed PL or distribution of pharmaceutical packs or define individual distribution paths' shares and distances. The carbon calculator provides the total carbon footprint of the scenario as well as the results on PL's specific emissions and a comparison to the ePL. Thus, companies may learn about the impact of their package leaflets regarding GHG emissions and related processes along the lifecycle.

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REFERENCES

[1] Europe. Directive 2001/83/EC of the European Parliament and of the Council of 6 Nov 2001 on the Community code relating to medicinal products for human use [Internet]. Official Journal of the European Communities; 2001:Art. 58. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0083

[2] GI 4.0 Gebrauchsinformation [Internet]. Frankfurt am Main: Rote Liste Service GmbH. Available from: https://www.gebrauchsinformation4-0.de

[3] dabeipackzettel - der digitale Beipackzettel für deine Medikamente [Internet]. Hallstadt: dabeipackzettel GmbH. Available from: https://dabeipackzettel.de/

[4] Proposal for a Directive of the European Parliament and of the Council on the Union code relating to medicinal products for human use, and repealing Directive 2001/83/EC and Directive 2009/35/EC [Internet]. Brussles: European Commission; 2023:article 63. Available from: https://eur-lex.europa.eu/resource.html?uri=cellar:bfcb9e00-e437-11ed-a05c-01aa75ed71a1.0001.02/DOC_1&format=PDF

[5] Gröger J. Digitaler CO_2-Fußabdruck. Datensammlung zur Abschätzung von Herstellungsaufwand, Energieverbrauch und Nutzung digitaler Endgeräte und Dienste [Internet]. Berlin: Öko-Institut e. V.; 2020. Available from: https://www.oeko.de/fileadmin/oekodoc/Digitaler-CO2-Fussabdruck.pdf

[6] Raynor DK, Silcock J, Knapp P, Edmondson H.: How do patients use medicine information leaflets in the UK? IJPP 2007 Sep; 15(3):209–218. DOI 10.1211/ijpp.15.3.0008

[7] Lauruschkus F, Buhnar K. Arzneimittelverbrauch im Spannungsfeld des demografischen Wandels [Internet]. Berlin: civity Management Consultants commissioned by BDEW 2017. Available from: https://civity.de/de/publikationen/arzneimittelverbrauch-im-spannungsfeld-des-demografischen-wandels/

[8] Internetnutzer in Deutschland nach Endgeräten der Internetnutzung im Jahr 2022. Hamburg: Statista GmbH; 2021.

[9] IQVIA: IQViA Marktbericht classic. Entwicklung des deutschen Pharmamarktes im Jahr 2022 [Internet]. Frankfurt am Main: IQVIA Commercial GmbH & Co. OHG; 2023. Available from: https://www.iqvia.com/-/media/iqvia/pdfs/germany/library/publications/iqvia-pharma-marktbericht-classic-_das_jahr-2022.pdf

[10] Sozialgesetzbuch (SGB) Fünftes Buch (V) – Gesetzliche Krankenversicherung - (Artikel 1 des Gesetzes v. 20. Dezember 1988, BGBl. I S. 2477). Berlin: Bundesministerium der Justiz and Bundesamt für Justiz; 1988: § 300 and § 131 Available from: https://www.gesetze-im-internet.de/sgb_5/

[11] Handbuch Emissionsfaktoren des Straßenverkehrs (HBEFA). Version 4.2. Bern: INFRAS; 02/2022

[12] ISO 14083:2022. Greenhouse gases – Quantification and reporting of greenhouse gas emissions arising from transport chain operations. Vernier, Geneva: International Organization for Standardization; 2023

[13] Spezifische Emissionsfaktoren für den deutschen Strommix [Internet]. Berlin: Umweltbundesamt; 2022. Available from: https://www.umweltbundesamt.de/themen/luft/emissionen-von-luftschadstoffen/spezifische-emissionsfaktoren-fuer-den-deutschen

[14] ecoinvent Database [Internet]. Zurich: Ecoinvent. Available from: https://ecoinvent.org/the-ecoinvent-database/

[15] German Pharmacies Figures · Data · Facts 2022 [Internet]. Berlin: ABDA – Federal Union of German Associations of Pharmacists; 2022:87. Available from: https://www.abda.de/fileadmin/user_upload/assets/ZDF/ZDF22/ABDA_ZDF_2022_Brosch_english.pdf

[16] Powering a Google search [Internet]. Google; 2009. Available from: https://googleblog.blogspot.com/2009/01/powering-google-search.html

[17] Kohlenstoffdioxid-Fußabdruck pro Kopf in Deutschland [Internet]. Berlin: Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV): 2023. Available from: https://www.bmuv.de/media/kohlenstoffdioxid-fussabdruck-pro-kopf-in-Deutschland

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