Carbon footprint of package leaflets

A comparative study on greenhouse gas emissions of paper-based and digital package leaflets for pharmaceuticals – Part 1

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ABSTRACT

More than 1.5 billion package leaflets (PL) were dispensed or sold in Germany 2022. This paper summarises a study on related greenhouse gas (GHG) emissions and the potential reduction of GHG emissions by replacing a paper-based by an electronic PL. In close cooperation with industry a detailed carbon footprint study and a market analysis on printed leaflets per prescription status were established. On average a paper-based PL causes 7.0 g CO_2e and a reduction potential was estimated with 90 %. A calculator is available online (ePILCarbonCalculator.com).

KEY WORDS

- Package leaflet
- Carbon footprint
- Electronic patient information
- Carbon calculator

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1. Introduction, background of study

1.1 Motivation

Pharmaceutical companies aim at more sustainable solutions and products. Digitization advances and enables alternative flows of information such as providing the package leaflets (PL) required by law [1] in electronic formats such as pdf files on dedicated company websites or by pilot projects such as GI 4.0 [2].

The digitization of PL opens perspectives for innovative patient information integrated into electronic patient files or medication plans and overcoming limitations of printed PL such as language barriers, reading size or the timely provision of updates. It is assumed that providing the information electronically has considerable potential to reduce greenhouse gas (GHG) emissions caused by printing, assembly and distribution of paper-based PL. So far, this assumption has not been checked by a study comparing GHG emissions of paper-based and digital PL. This is the aim of this study.

A potential to considerably reduce GHG emissions by digital PL (ePL) may provide additional arguments for the transition from paper-based to ePL as currently tested in a number of European pilot tests in hospitals, e.g., in the Baltic States, Belgium and Luxemburg, Iceland as well as Spain, and proposed in upcoming European legislation [4].

1.2 Project team and setting

The project was realized by a team from IGES Institut GmbH and Fraunhofer IML. The former was responsible for communication to pharmaceutical companies and associations, data generation and methodology to estimate total PL sizes, weights and size distributions while the latter developed the GHG emission models, calculated the carbon footprints (CF) for PL and ePL and developed the carbon calculator.

2. Methodology of the study

A comprehensive understanding on which processes and resource uses contribute to the overall GHG emissions of dedicated products is however rare, information on the focussed PL even less available. Therefore, the study started with the detailed definition of the lifecycle of PL of pharmaceutical products and the identification of related processes and involved organisations, for both the paper-based PL (62 process steps of which 49 were relevant for the study) and the digital alternative. This has been established in close cooperation with 4 pharmaceutical companies by means of a workshop and consultations. The identified parties producing and handling the paper-based PL have been invited to support this study by sharing relevant process data within an industry survey and bilateral interviews. These have been

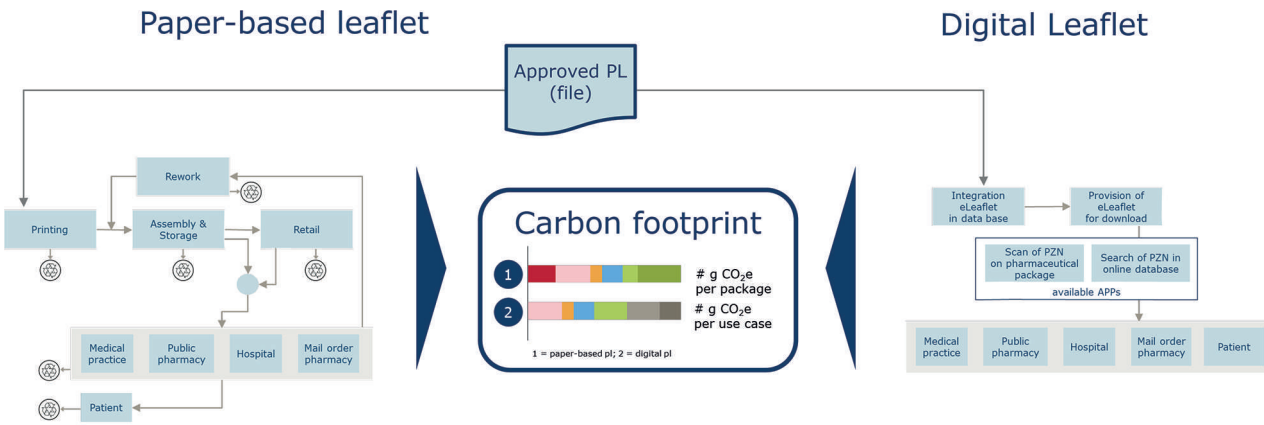

Figure 1: Scope of the study – lifecycle of both alternatives (all figures provided by the authors).

processed on an anonymised level and average process parameters basing on primary data have been elaborated along the lifecycle (see section 3). In combination with an analysis on the German market for pharmaceutical products (see section 2.3 and 3.1) this work served the quantification of GHG emissions. Since the ePL is currently tested in pilots only (e.g. GI 4.0 [2] and initiatives such as dabeipackzettel [3] in Germany) and representative primary data is not available, the parameters for quantifying GHG emissions base on literature values in this study (see section 4.3).

2.1 Scope of the project

For comparing the impact of both alternatives, a similar scope of both leaflets needs to be defined, which has been realised as follows: Both lifecycles start with an officially approved file for the PL. For the paper-based PL, this file is transferred to the printing company, that is generally a sub-contracted partner. The printed PL are transported to the pharmaceutical company, that adds the leaflet to the relevant pharmaceutical product's packs during assembly. After final quality check and storage, the approved products are distributed to the relevant markets. This study differentiates 3 main distribution paths: (1) public pharmacies, (2) hospitals (including their pharmacies) and (3) mail order pharmacies. The distribution of pharmaceutical products via medical practices is covered as fourth distribution path, which is however of minor relevance; exemplary packs are not in the scope of this study.

The starting point for the ePL is also the officially approved file of the leaflet, that is transferred to a database for ePL. This database serves available applications for subsequent download and use by interested parties (e.g., doctors, staff and/or patient). This can be realised either by the scan of the pharmacy product code on the pharmaceutical packs or by the search of the pharmacy product code in an online database. The distribution paths are equivalent to the ones of the paper-based PL.

For calculating the CF of these alternative leaflet lifecycles, each of the outlined steps within the lifecycles needs to be further detailed by specific sub-processes and their relevant resource use, such as paper use, printing ink, electricity consumption during production or diesel use within transportation. With the help of so-called emission factors this resource use can be converted into GHG emissions. Any infrastructure, such as printing equipment, vehicles or IT hardware are excluded from the scope of this study as only very generic data is available and usually related emissions are of negligible impact to the overall CF.

2.2 Approach for data collection: survey & literature study

Regarding the paper-based PL, the study uses primary data from industry with the focus on the German market. In the following the structure and content of the industry survey is described, its detailed outcome and the data used for calculating the GHG emissions are provided in section 3. Data for describing the digital alternative were taken from literature publicly available (see 2.2.2).

2.2.1 Paper-based package leaflet

The industry data was collected by means of an Excel-based questionnaire starting with a general allocation of the company and its product to its main market segments. The questionnaire was circulated via the 3 associations of the pharmaceutical industry co-funding the study to their member companies. Here 2 different perspectives have been covered, that are (1) the market segment by distribution channel (medical practices, public pharmacies, hospitals, mail order pharmacy, retail store (e.g., drugstore)), and (2) the market segment by product status (e.g., active ingredient patent protected, patent-free, i.e., generic or branded generic). This information was accompanied by the selection of 5 representative pharmaceutical products to be specified in the following

questions. For these selected products the information on pharmacy product code (i.e., Pharmazentralnummer PZN), market segment, paper type, size and weight, finishing process (e.g., folded, glued), number of PL for this PZN, the annual quantity of PL of this PZN that need to be disposed due to changes of the PL as well as the total number of PL (all PZN) of the company was requested.

A second section of the questionnaire referred to information on the printing process. First, the questions referred to the type of paper (grammage, annual quantity) and ink (annual quantity) and average transport distances for paper or ink supply. Second, the process of printing and any further finishing step (e.g., binding) were described with information on annual electricity use or any other consumption of energy or material. Finally, information regarding the quantity (absolute or share) that is disposed annually due to processes scrap was collected.

The third section of the questionnaire covered questions relating to specific PZN and was meant to be duplicated for additional PZN: Inbound transportation of printed PL (from external), incoming PL, assembly, storage, shipping, discarded PL (from receiving to shipping) and the distribution of the assembled pharmaceutical product units (outbound). Regarding transport processes (inbound and outbound) the information requested differentiated transport modes (e.g., road, rail), distances, quantities of related transport paths and the relevant shipping unit (e.g., palletised and relevant outer packaging and transport security used such as cardboard intermediate layers, plastic strapping or stretch film). At the site(s) of the producing companies, electricity consumption was described regarding handling, warehousing, processing (e.g., folding, assembly), or cooling and temperature control. In addition, discarded PL were asked to detail regarding the quantity (absolute or share) that is disposed annually due to processes scrap or due to changes of the PL or rework.

The data collection started end of Nov 2022 and final answers were received in Feb 2023. Various companies were interested in participating but could not hold the deadline for data submission that was set by the study contract. In total, 29 companies provided data for more than 70 different pharmaceutical products. The participating companies are evenly distributed between associations, all types and sizes of pharmaceutical companies. Most questionnaires were filled-in partially and were in a first step reviewed regarding data quality and plausibility. Partly, additional information was provided upon request. Overall, two third of the companies provided a good overall picture on supplied market segments. A detailed evaluation was performed covering the following: 6 companies specified the printing process, for 17 PZN the assembly process was detailed, and the distribution of the final pharmaceutical product packs was described by 8 companies for 11 PZN. This input data was, then, used to elaborate reference values for the assessment model for the paper-based PL (see section 3). The validation of the reference values bases on experience from previous projects by the project team: Here, some outliers have been identified and excluded as well as some further research and discussion with experts on e.g., share of distribution channels supported the completion of the data base.

Considerable basic interest and willingness to participate among companies can be stated. However, a broader time frame for detailed responding to the survey would have been beneficial for the data base. Some of the data requested is not available or cannot be collected in relation to a PL as functional unit for this study without great effort. Despite the size of the data base, the summarized input data can be considered as the best currently available data set for the project scope.

2.2.2 Digital package leaflet

Initially, it was planned to use primary data to calculate the carbon footprint of the ePL. In the course of the project, it emerged that it was not possible to collect the relevant data in the required level of detail and within the time frame of the project.

Alternatively, a literature search was conducted to identify adequate data on the resource consumptions of the processes considered in the lifecycle of ePL and its CF calculation. Resource consumptions for producing hardware as part of required IT infrastructure, e.g., servers for data storage and provision of computers, tablets and smartphones for the processing and use of the ePL, are excluded from the scope. The overall share of use of this hardware that could be attributed to an ePL was assumed to be negligible small. Instead, the search on data was focused on the energy consumption of the individual process steps.

Next to sources with data on very individual and specific use cases only one overarching study has been identified, that was evaluated as a good data source for the calculation of the CF of the ePL. This study [5] provides a good and comprehensive insight on the use and energy consumption of digital applications and products. The data presented in the study is based on literature research by Oeko-Institut (e.g., lifecycle assessments of individual technical products), calculations based on this, and educated guesses. For individual further values (e.g., the total number of accesses to an ePL in the central database, the average reading time per access to an ePL, and the share of user devices used for this purpose), additional sources were used [6,7,8].

2.3 Investigation of the quantity and size distribution of PL in Germany

To determine the CF of paper-based PL in Germany an estimation of the total number of produced and dis-

pensed PL and their resource consumption measured in paper weight and dimensions (area in square meters) are indispensable prerequisites. The weight of a PL and the total weight of all PL is a parameter to measure resources consumed to produce and transport PL while the area is corresponding to the information stored on a PL and associated printing resources needed.

While data concerning the number of dispensed printed PL in the non-hospital market are available from commercial market data providers, information about their weight and dimensions (width, height, and area in square meters) are not. Therefore, a method to analyse weight and dimensions of PL in Germany had to be developed.

The 8 digit "Pharmazentralnummer" (PZN) is the national unambiguous identification key for pharmaceuticals and the key to trade name, pharmaceutical entrepreneur, dosage form, drug potency and pack size according to § 300 and § 131 of the German social code (SGB V) [10]. The PZN is issued by the "Informationsstelle für Arzneispezialitäten IFA GmbH" (IFA), which also provides the IFA database with a multitude of additional information about products such as product type, regulatory status, prescription status, reimbursement and pricing information.

"ABDA-Artikelstamm" with "Plus X Modul" (status Nov 2022) was used to download all available PL in digital format as pdf files. The pdf files were extracted using a software developed inhouse and 16 parameters per pdf were determined, among them the number of characters, the number of words and the size of the data file in kilobytes per pdf. 24,687 downloaded ePL corresponded to 65,578 PZN as one PL may supply a number of PZN with e.g., different pack sizes. All data storage, handling and analysis steps were performed in Excel 365 with analysis Toolpak plugin installed.

Analysed parameters per PZN were transferred to the IFA Database with status from Oct 2022 (courtesy of Rote Liste Service GmbH) in Excel format and filtered according to product status "pharmaceutical product" and "actively marketed product" to eliminate downloaded PL of medical products and analyse the current market situation only.

Artefacts such as files containing more than one PL in one pdf or files where the content was stored as picture and could therefore not be appropriately analysed were removed, which reduced the dataset to 20,630 PL corresponding to 49,254 PZN.

As the provision of ePL is not compulsory these downloads do not represent the total of all PL in the market but provide the largest available sample of ePL in Germany. The sample included 35,651 prescription-only PZN (roughly 60 % of all prescription-only PZN), 12,213 PZN of over-the-counter (OTC) products (roughly 15 % of the total market) and 1,390 PZN of general retail pharmaceuticals (roughly 72 %).

The heights and widths of electronically analysed pdf PL were among the 16 determined parameters but could not be used, as for the majority of pdf the paper format was converted to DIN A4 to enable printing. The dimensions were therefore massively deviating from the dimensions of the paper format used in real life PL within the packs. Weight data were not available from this analysis. Therefore, data from electronic analyses had to be correlated to real life PL data, that is their actual weight and area in square meters calculated from width and height.

A sample of 324 PL corresponding to 842 PZN was created from data for 182 PL provided by industry (see 2.2.1) and additional own measurements of further 142 PL using a precision balance (KERN TGD 50-3C-A, resolution 1 mg). For these measurements the weight of each of 142 PL was determined 4 times and the average calculated as well as height and width measured by a ruler and the area calculated.

Using the IFA database, the prescription status of these products was determined: 194 were PL for prescription-only drugs, 114 were PL for OTC products, 16 general retail drugs. For every PL with a given prescription status unit parameters were calculated, combining data from the electronic analysis of PL and physical data: the area in square meters per character and per word and the weight per character and per word.

For every prescription status the arithmetic mean for every unit parameter was calculated. For prescription-only drugs the 95 % confidence levels of the average unit parameters varied between plus/minus 4.6 and 5.2 % of the mean, for OTC drugs between plus/minus 5.1 and 5.4 % of the mean. Due to the small sample for general retail drugs the variance of the average was between plus/minus 16.2 and 18.3 % for these products.

From this dataset arithmetic mean values for average weight and area in square meters for prescription-only, OTC and general retail PL were calculated.

The 49,254 PZN for which electronic analyses of the number of words and characters were available were filtered according to their prescription status. Using the mean unit parameters in (1) square meters per character and per word and (2) weight per character and per word, the area and weight for every PZN was calculated by multiplying the mean unit parameters with the respective number of characters or words per PZN. The resulting area per PL and weight per PL (2 values each as calculated via the number of characters and the number of words) was then multiplied with the number of packs of the given PZN dispensed or sold in 2022, resulting in 2 values for the total area or weight per PZN in 2022.

Market data of dispensed packs per PZN were acquired from Insight Health GmbH. The 49,254 PZN available for analysis corresponded to 1,142 billion packs in 2022 or 82 % of all packs (88 % for prescription-only packs, 78 % for OTC packs).

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For every prescription status both values for the areas and weights for all PZN were summed up resulting in a total area and total weight, calculated via the number of characters and in parallel the number of words. Total area and weight calculated by both methods varied by about 1 %. The arithmetic mean for both methods was calculated for area and weight and used for further calculations.

Results were extrapolated to the total number of packs. Results for prescription-only drugs were increased by an estimated number of 110 Mio. hospital only packs and 19.9 Mio. packs to account for parallel imports, resulting in a total of 910.7 Mio. packs. For OTC products for the extrapolation the number of general retail drug packs was added due to their comparatively small number (5.3 % of the number of OTC packs) and the large variance of unit parameters for general retail drugs caused by the small sample of available real-life PL. For OTC drugs the number of packs added up to 611 Mio. packs.

A comparison of total pack numbers from the detailed dataset acquired from Insight Health and publicly available total numbers of IQViA Commercial GmbH & Co. OHG (IQViA) revealed that these were as expected nearly identical for prescription-only drugs. But there was a considerable difference between Insight Health and IQViA total pack numbers for non-prescription drugs. This turned out to be caused by different definitions of the market segment [9]. As total pack numbers of both data providers are used in the market it was decided to provide extrapolations to both total numbers (table 2).

In a further analysis size distributions for PL according to their prescription status were determined. The 49,254 PZN available for electronic analysis were filtered according to their prescription status. For every prescription status PL were grouped into size classes depending on the parameter analysed (number of characters or words). Classes for the number of characters were arranged in 2,000-character steps (>0 to 2,000, 2,000 to 4,000 characters, …), for the number of words in 750-word steps. Then the number of PZN and the number of packs per size class were determined and depicted as histograms (see fig. 2).

Further analyses (not shown) revealed that no correlation between the number of characters and words of a PL and its file size in kilobytes could be found as file sizes vary enormously independently from the number of characters and words. As expected, a linear relationship was found between the number of words and characters (correlation coefficient 0.98).

2.4 Carbon footprinting – some background information of this study

As CF results strongly depend on underlying methodological decisions, some background information is given in the following. Basing on this and using the lifecycle data described in section 3, the overall CF results are presented and further discussed (see section 5).

As outlined before, a comparable assessment scope for both, the lifecycle of the printed PL and the ePL has been chosen. It starts with the approved file for the PL and ends with either the end-of-life processes of wastepaper or the read file stored in the private backup of the end appliance for one year.

The functional unit for this study is defined as one PL ready to be read by the patient (or any other person), and one ePL, that means available (e.g., downloaded) file for the digital alternative. In case of the digital alternative, different options (e.g., end user appliances) for establishing the availability have been identified. Therefore, the term "use case" has been introduced for describing the functional unit (see further details in sections 3.2 and 4.3).

With the help of so-called emission factors, the collected data on resource use can be converted into GHG emissions. The calculated GHG emissions are expressed in terms of carbon dioxide equivalents (CO_2e), covering next to carbon dioxide also other GHG such as methane, nitrous oxide, that are converted by so-called global warming potential of each gas as published in the Assessment reports of the Intergovernmental Panel for Climate Change (IPCC).

The sources for emission factors applied in this study were taken from licensed and publicly available sources as follows: Diesel consumption for road transport for inbound processes of printing companies, the supply of printed PL to the pharmaceutical companies as well as the distribution of the final pharmaceutical products into the market has been modelled with data taken from the "Handbuch Emissionsfaktoren des Straßenverkehrs" [11] . Conversion factors for diesel have been taken from ISO/FDIS 14083 on the quantification and reporting of GHG emissions arising from transport chain operations [12]. Any electricity used in the assessment scope has been converted to GHG emissions by using the German electricity mix and related emissions as published by the Umweltbundesamt for the year 2020 [13]. For all other processes, emission factors of the lifecycle analysis database ecoinvent (version 3.7, cut-off approach) [14] have been taken, using the assessment method ReCiPe Midpoint (H) V1.13 – climate change, GWP100.

3. Results on leaflets

3.1 Quantity and Size distribution of PL in Germany

The examination of PL supplied with packs differentiated according to their prescription status based on data provided by pharmaceutical companies and measurements of PL by the authors revealed distinct differ-

Table 1

Average weight, area and German market share of PL according to prescription status.

Prescription status	Weight [g]	Area [m^2]	Share in DE market [15]
Prescription only	4.89310	0.1026	58.7 %
OTC	2.50002	0.0531	38.6 %
General retail	1.80433	0.0351	2.7 %
Average	**3.89856**	**0.0818**	**100 %**

ences in averages of weight and area. A clear tendency of increasing weight and area was found from general retail drugs over OTC products to prescription-only pharmaceuticals. As area and weight determine the size and therefore the storage capacity for information this is a clear indication, that the amount of information carried by PL is increasing with product type.

While data for OTC and prescription-only drugs with 95 % confidence intervals of plus/minus 5 % of the average are quite robust and based on samples of 114 and 194 PL respectively, data for general retail drugs are based on a small sample and therefore less robust. As prescription-only and OTC pharmaceuticals account for the vast majority of packs on the market (97.3 %) at least these 2 market segments have to be analysed separately to determine the quantity of PL.

The results of the extrapolation of total printing and paper sizes and the total weight of all PL in Germany to estimate their total quantity are presented in table 2. The total printing size I describes the total size which is used to print information on, corresponding to the front and back of each PL. Print margins were neglected and the full paper size calculated.

The total paper size I corresponds to the size of the front side only and describes the area which would be necessary, if all printed PL are laid out one beside the other. Sizes II take production losses into account and therefore describe the total sizes needed to produce the PL which are brought to the market.

The results of distinct differences of the characteristics of PL in relationship to their prescription status are confirmed by a more detailed analysis based on electronic PL. A size distribution analysis was executed to determine the number of PZN or packs in relationship to size classes of PL (range of number of characters or word per PL), fig. 2.

Figure 2.1.1. depicts the overall size distribution in the number of PZN per size class of number of characters per PZN, showing 2 maxima with appr. 3,600 PZN having between 4,000 and 6,000 characters and appr. 4,000 PZN having between 22,000 and 24,000 characters.

An analysis differentiated according to prescription status reveals that this distribution is the result of the 3 prescription types adding up (fig. 2.2.1–2.2.3). Differentiating them reveals that the peak at 4,000 to 6,000 characters is caused by OTC drugs (appr. 3,400 of 3,600 PZN) while the second peak is nearly totally caused by prescription-only drugs. Some PZN have considerable sizes in terms of characters reaching more than 60,000 characters. The distribution of OTC drugs is shifted considerably to smaller numbers of characters per PL and this trend is even stronger for general retail drugs.

If the same analyses are being made for the number of PL (based on the number of packs sold or dispensed and assuming one PL per pack) the distributions change. Prescription-only drugs show a maximum of appr.

Table 2

Sizes and weights of PL in Germany.

Prescription Status		Total Printing Size [km^2] (Front and Back)	Total Paper Size [km^2] (Front only)	Total Weight [t]
Prescription only (R_X)		195 95 % CI [186, 204]	98 95 % CI [93, 102]	4,639 95 % CI [4,407, 4,872]
OTC Definition A[1)]		78 [74, 82]	39 [37, 41]	1,867 [1,769, 1,965]
OTC Definition B[2)]		126 [119, 133]	63 [60, 66]	3,011 [2,854, 3,169]
Total I (Sum of R_X and OTC)	OTC Def. A	273 [260, 286]	137 [130, 143]	6,507 [6,176, 6,837]
	OTC Def. B	321 [305, 337]	161 [153, 168]	7,651 [7,260, 8,041]
Total II (Total I & Production Waste[3)])	OTC Def. A	320 [305, 336]	160 [152, 168]	7,622 [7,235, 8,010]
	OTC Def. B	376 [358, 395]	188 [179, 197]	8,963 [8,506, 9,420]

[1)] OTC products, narrow definition of Insight Health GmbH, medicinal products only, [2)] OTC products according to non-prescription market definition of IQViA, [3)] Production waste as determined by industry survey, 3 % for rework, 12 % for printing.

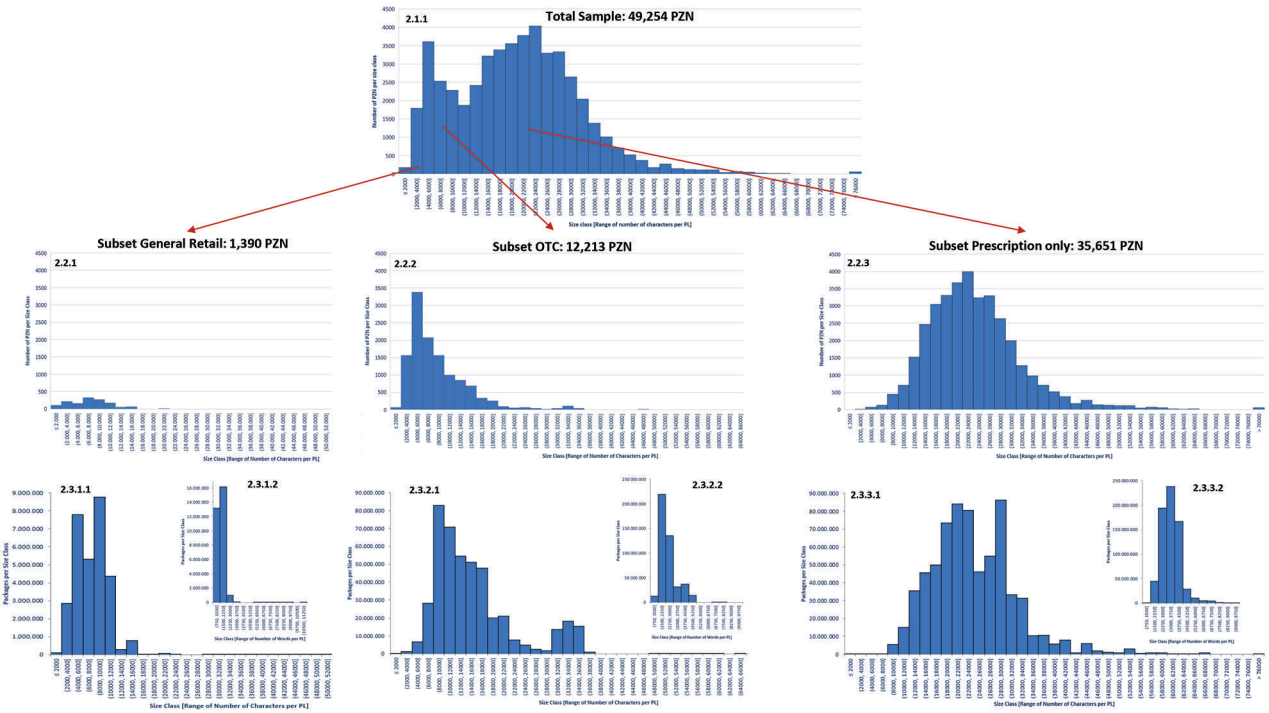

Figure 2: Size distribution of PL in Germany. 2.1.1. Number of PZN vs. size class of number of characters per PL, total sample of 49,254 PZN. 2.2.1. to 2.2.3. Same depiction for subsets of PL for general retail, OTC and prescription-only pharmaceuticals. 2.3.1.1. to 2.3.3.1: Number of sold/dispensed PL (one per pack) vs. size class of number of characters per PL. 2.3.1.2 to 2.3.3.2: number of sold/dispensed PL (one per pack) vs. size class of number of words per PL.

90 Mio. dispensed packs for the PL size class between 28,000 and 30,000 characters, indicating that pharmaceuticals with great significance for drug supply are part of this size class (fig. 2.3.3.1). These analyses were also carried out for the number of packs versus size classes defined as number of words per size class (fig. 2.3.1.2–2.3.3.2). These depictions are comparable to results obtained with characters but narrower, as the size classes correspond to a larger number of characters (roundabout 8.8 characters per word).

3.2 Lifecycle: from paper supply to approved pharmaceutical product pack

Using the input data of the industry survey, the average PL weighs 4.086 g and has a size of 0.0815 m^2 which results in a specific paper weight of 50.11 g/m^2. The companies outlined that due to the high technical demands generally no recycling paper is used for PL. Therefore, the paper production was modelled considering woodfree, uncoated paper, produced with equal share at integrated and at non-integrated mills in Europe. For the printing process, 0.034 kWh/m^2 of electricity and 0.33 g/m^2 printing ink is required. Regarding the ink production, the following ecoinvent module has been selected: European printing ink production, offset, product in 47.5 % solution state. Since no information on glue or other resource consumption has been specified by the participating companies, this has been neglected in this study. The approved file of the PL is transmitted, requiring an estimated electricity consumption of 52e–11 Wh/kB [5]. The analysed pdf files for PL (see section 2.3) outlined an average size of 320 kB. With the assumption of the use of 50 % pdf files and 50 % xml files with 5 kB, an overall average size of 163 kB per PL is used in this study. The paper and printing ink is supplied by truck transport (solo truck >12–14 t Euro-V EGR) with an average load factor of 80 % (own assumption) over an inbound distance of 653 km (paper) and 272 km (ink). For printing the PL 0.034 kWh electricity and 0.33 g ink per m^2 PL is required on average. The companies outlined that a share of 12 % of the paper is discarded due to cutting or during the start-up of the machines etc.

The printed PL are transported on single-use Euro pallets, with ca. 94,000 leaflets per pallet and using additional 13.4 kg cardboard (boxes and intermediate layers) and 400 g LDPE foil for transport security. As an average transport, 230 km truck transport (solo truck >12–14 t Euro-V EGR) with an average load factor of 80 % (own assumption) has been modelled. The industry survey outlined that this transport distance may vary between companies, some purchasing the printed PL locally (25 km), some from farther away (450 km). The study covers a sensitivity analysis that considers this variation. In addition, some companies outlined, that the PL are

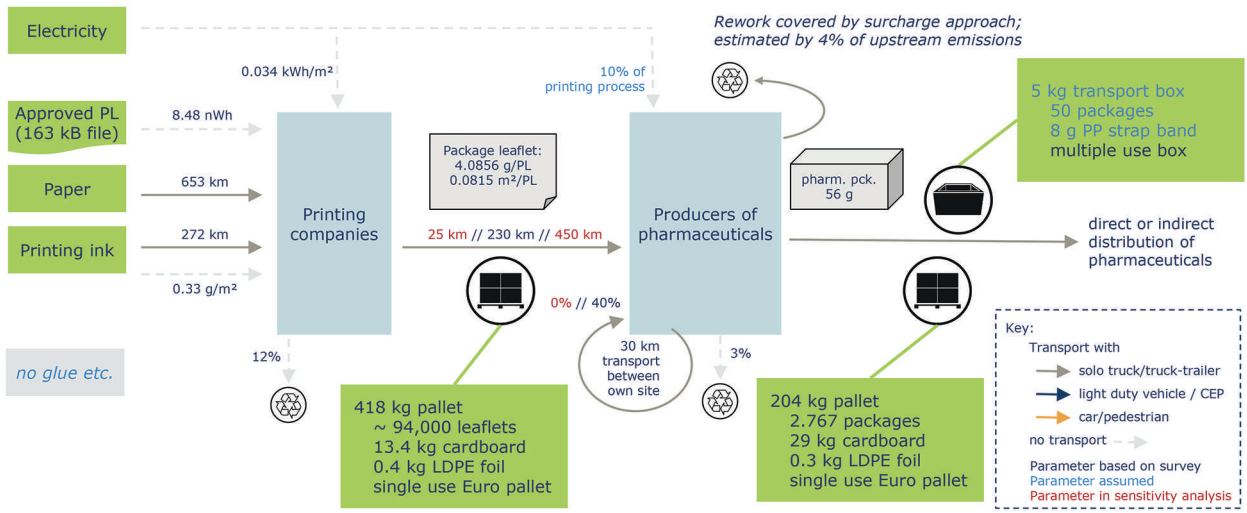

Figure 3: Printing and supply of printed PL.

supplied to one central destination and additional transport is required between sites of the pharmaceutical company. Therefore, it was assumed that 40 % of the PL require an additional transport (same type as inbound) over 30 km on average. Again, this share has been set to null to outline the impact on the overall GHG result for those companies, that do not have any transport of printed PL between sites (see discussion on sensitivity analysis in section 5.1).

Data on resource use at the producers' sites was difficult to obtain. For example, only very few was available regarding the assembly process, when the pharmaceutical product together with the PL is packed into to the product pack. Due to this data gap, an electricity use for assembly of 10 % of the electricity consumption outlined to be needed for printing a PL was assumed (3.4 Wh). 3 % of the printed PL are disposed at the sites of the pharmaceutical companies.

The finished and approved pharmaceutical product packs are generally packed on single-use Euro pallets, with ca. 2,767 packs per pallet and using additional 29 kg cardboard (boxes and intermediate layers) and 300 g LDPE foil for transport security.

For modelling the production of all material used for transport packaging, ecoinvent modules have been applied: EUR-flat pallet, packaging LDPE film, corrugated board box and PP strap band, extruded; all with regional focus in Europe. The end-of-life of these materials as well as the paper-based PL itself have been modelled with ecoinvent data as well, using German market-modules for waste graphical paper, untreated wood, paperboard and polyethylene and polypropylene.

Regarding the disposal of printed PL due to an update of the content, no detailed information could be gathered. However, the companies outlined, that the potentially disposed PL mostly only refer to those PL that have not been distributed, i.e., up to the point of the producer's warehouse for finished products. Therefore, in this study this rework was covered by a surcharge approach: all emissions caused by a PL upstream (i.e., before distribution into the market) is surcharged by a share of 4 % of PL.

Outlook to part 2:

This article is divided into 2 separate parts. The second part will outline remaining lifecycle results on the paper-based PL, such as the distribution of the pharmaceutical products and the lifecycle of the ePL. In addition, the calculated carbon footprint results of both PL alternatives are outlined and discussed as well as an outlook on e.g., the planned online calculator is provided.

Part 2 of this article (incl. the references) will be published in issue 1/2024.

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