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The status of corporate greenhouse gas emissions reporting in the food sector: An evaluation of food and beverage manufacturers

Alexander Damkær Hansen [a,1], Takeshi Kuramochi [a,b], Birka Wicke [a,c,*]

[a] Utrecht University, Utrecht, the Netherlands
[b] New Climate Institute, Cologne, Germany
[c] Radboud University, Netherlands

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ABSTRACT

The global food system is a key contributor to anthropogenic greenhouse gas emissions. Companies can play an important role in reducing these emissions but doing so effectively requires accurate emissions data. This study assessed the status and quality of corporate emissions reporting and target setting in the food system mainly through a survey of the public emission reports for 2018 to the CDP by the largest 50 food and beverage manufacturers worldwide.

In total, these companies reported 0.9 Gt CO_2-eq. per year, although 7 companies did not publicly report emissions and many other companies provided incomplete reports of emissions. Direct emissions (Scope 1) comprised 8% of total reported emissions, and indirect emissions of purchased energy (Scope 2) 4% and of the value chain (Scope 3) 88%.

Despite the large proportion of Scope 3 emissions, reporting for this scope was often incomplete and inconsistent. For example, land-use change emissions are key for the food system but they are only explicitly covered by 10% of the companies. In addition, more than a third of reported Scope 3 emissions were not covered by emissions reduction targets of the companies. Based on a first order approximation, we estimated that the 50 companies are associated with 1.9–3.8 Gt CO_2-eq. per year, indicating that between 53 and 77% of emissions go under-reported.

Together with the relatively poor reporting of Scope 3 emissions, our findings suggest that the food and beverages industry needs to urgently improve their GHG emissions reporting and management if they are serious about mitigating their impact on climate change. For more accurate emission reporting of companies in the food system, sector-specific guidance for Scope 3 is needed that prioritizes the most significant scope 3 categories, includes a dedicated category for emissions from land-use change and provides clear, easily applicable methods to determine the emissions from these high priority categories.

1. Introduction

The growing threat of climate change has created an urgent need for reductions in greenhouse gas (GHG) emissions from all sectors across the economy. The food system contributes approximately 34% of all annual anthropogenic GHG emissions (Crippa et al., 2021). These emissions are so substantial that, even if the use of fossil fuels were immediately halted, the goals of the Paris Agreement could still not be achieved; this is only possible if changes are also made in the food system (Clark et al., 2020).

The role of companies contributing to climate change and its mitigation is increasingly being scrutinized (Black et al., 2021; Kuramochi et al., 2020). Corporate emission data and reduction targets are relevant for better understanding current and expected future emissions from an industry sector. This can help define the complementary role companies can play in emissions reductions (Kuramochi et al., 2020). Despite its relevance, corporate emissions reporting has been criticized for its lack of standardization (Busch et al., 2020b; Doda et al., 2016) and reports are often either incomplete or completely missing (GRAIN, 2018; Liesen et al., 2015; Richards, 2018). Moreover, there is large gap in academic

* Corresponding author. Radboud University, Netherlands.
E-mail address: birka.wicke@ru.nl (B. Wicke).
[1] Alexander Damkær Hansen is currently a student in the Environmental Biology master at Utrecht University. He can be contacted at. alexanderdamkaer@gmail.com

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literature on value chains of individual corporations (Goldstein and Newell, 2019).

Also companies in the food system, for example supermarket chains or food and beverage manufacturer, receive increasing attention in the climate change debate (Ghadge et al., 2020; Tidy et al., 2016). Not only do companies in the food sector cause the emissions or are associated with emissions through their value chain, the agricultural sector is also one of the most vulnerable to climate change because of its effects on crop yields (Myers et al., 2017; Wheeler and von Braun, 2013). Furthermore, corporate emission reduction programmes can also provide short-term economic benefits for companies, as such programmes can increase resource efficiency, lower costs and help to secure investments from increasingly environmentally minded investors (Busch et al., 2020a; Solomon et al., 2011).

Effectively reducing corporate emissions requires data on where emission sources are located in the company's production, including direct emissions from its own facilities and indirect emissions from its value chain. For the food sector, it is not currently known how well companies report emissions associated with their production, especially with regard to agricultural and land-use emissions from agricultural commodity production. Accounting of these indirect emissions is particularly important for companies for better assessing the most significant emission sources and targeting the most cost-effective mitigation first, thereby prioritizing limited resources where they will have the greatest effect (Blanco et al., 2016; Hertwich and Wood, 2018; Li et al., 2019; Matthews et al., 2008). This is because previous studies, not specific to the food system, have estimated that the majority (approximately 75%) of an average company's emissions are related to upstream and downstream activities in the value chain (Downie and Stubbs, 2013; Huang et al., 2009b). However, this proportion differs highly between different industry sectors (Blanco et al., 2016; Huang et al., 2009b). For companies in the food system, it is likely that these indirect emissions represent a large fraction of total emissions, as significant emissions related to agriculture and land-use change (LUC) arise upstream in the value chain of the purchased agricultural commodities (Poore and Nemecek, 2018). Nevertheless, it remains unclear how well these indirect emissions are covered in corporate emission reports and emission reduction targets.

Given the knowledge gaps identified above, our study aims to assesses the current status and quality of corporate emissions reporting and reduction target setting in the food sector. To do so, we first analyse the coverage of reported emissions from companies' production and full value chain. Given incomplete reporting of especially the indirect emissions associated with agricultural commodities by many companies, we then estimate unreported emissions. Finally, we evaluate the extent of setting emissions reduction targets. Our analysis focuses specifically on the 50 largest global food and beverage manufacturers because within the food sector they in particular can play an important role in reducing these emissions. This is because there are 7 billion consumers and 1.5 billion food producers globally, but only 500 food and beverage manufacturers that control 70% of the world's food choice (Hoffman, 2013). This gives these companies a substantial influence over the sustainability of food production as compared to the individual food producers or consumers. Food and beverage manufacturers are also typically the most visible part of the agricultural value chain, meaning that consumers wishing to make sustainable choices may do so based on the reputations of these companies (Hoffman, 2013).

2. Material and methods

2.1. Selection and categorization of companies

The 50 largest food and beverage manufacturers in the world, measured by revenue, were selected from Food Engineering Magazines annual top 100 list for the year 2019 (Scully, 2019). To better understand trends in company reporting and potential factors that influence the reporting level and emissions, the companies were then characterized by four different company categories:

i. *Annual company revenue*: Within the global top 50 food and beverage manufacturer, there is a large difference between earnings of the companies. Companies were divided into five revenue categories, i.e. top 1–10, 11–20, 21–30, 31–40 and 41–50 based on company revenue for the year 2019 (Scully, 2019).
ii. *Headquarters location*: The surveyed companies span the globe and companies were therefore categorized by location to elucidate any differences in business cultures. Company headquarter locations were determined based on information available on the target company's website or from its emissions report. Since most of the companies operate in many countries and on nearly every continent, only headquarters were chosen as location.
iii. *Product groups*: Companies within the food and beverage manufacturing sector can be very diverse with some producing all kinds of products while others only focus on some food products only. Therefore, six product groups are considered: Food, Beverage, Food and Beverage, Meat, Dairy, and Agricultural Raw Materials. Companies are distinguished here based on the product group which provides the primary source of revenue for the company. While there may be overlap between product groups, e.g. a company categorized in *Food* may also produce meat, this distinction is still useful. This is because of the large differences in emission dynamics underlying the product groups, particularly between meat, dairy, and agricultural crops.
iv. *Company ownership model*: Companies differ in their ownership model, which has implications for reporting requirements. For example, in Europe, stock-traded companies are required to disclose non-financial aspects, increasingly including also sustainability aspects and in the future detailed greenhouse gas emissions, such as indirect emissions of the value chain (Maas and Sampers, 2020). We distinguish here between publicly traded and privately owned companies.

These four categorizations were easily defined for most companies from company reports or websites. However, the product group was harder to define for some companies. This is because most of the surveyed companies have a diverse portfolio of products, including even products which are not relevant to the food system. For example, a company may produce food and beverages, but also have considerable revenue from soap, beauty products and personal care. As these products are not relevant to the food system, the company was classified in the Food and Beverage product group. Emissions associated with non-food products cannot be distinguished based on the current level of detail of company reports. Therefore, some of the reported emissions included in our study are not directly related to the food system.

2.2. Collection of corporate GHG emissions data

Several voluntary reporting initiatives for corporate GHG emissions have been developed. One of the most comprehensive is the CDP (formerly named the Carbon Disclosure Project) where 6251 companies reported their emissions in 2018 through the CDP climate change questionnaire (CDP Worldwide, 2019). For our assessment, we used this database as the majority of the companies we surveyed also reported to the CDP. Our analysis covered only the public responses available in March 2020 (CDP Worldwide, n.d.). If the company in question did not report to the CDP or if any one piece of the desired data was missing, we first consulted corporate social responsibility (CSR) reports and then annual reports of these companies, which were available on the company's websites. If data were still missing at this step, the company's website itself was searched. For 37 of the 50 surveyed companies all emissions and methodology data were found in company CDP reports,

for three companies data were obtained from CSR reports, for two companies the data were found in annual reports and for one company data were found on the company website. In total, GHG emission data were collected for 43 companies. For the remaining seven companies no emissions could be found, and it was assumed that they do not (at least publicly) report emissions. To verify this, these companies were contacted by email, but no additional information could be obtained.

The newest available company reports at the time of the survey (March 2020) were collected. Most of the reporting companies (23) reported data for the year 2018. Eight companies reported data that was newer than 2018, nine reported data that was half a year older, two reported data from 2017 and one company reported data older than 2017 (Oct. 2016–Oct. 2017). For readability purposes, we refer to year 2018 in the remainder of the paper, acknowledging some reports refer to other years and that there is likely some annual variation. All data extracted from the CDP or from companies reports and websites that are used in this analysis are available upon request from the authors.

Company emission data was extracted from the emissions reports by scope for Scope 1 (direct emissions) and Scope 2 (indirect emissions from use of electricity and heat), and by category for Scope 3 (other value chain indirect emissions). [2] These emission categories as used for corporate emission reporting are different than the sector-based categories used for national GHG inventories (e.g. electricity supply, transport, buildings, industrial processes or land use). Total reported emissions were also recorded; for a few companies, this was the only reported emission data point. For Scope 2, there are two methods for determining emissions, i.e. market-based or location-based allocation (WBCSD, 2004). Companies generally reported emissions for both methods. However, the location-based method has been estimated to be the most accurate (Brander et al., 2018), and the data for this method were more complete than for the market-based method. Therefore, for Scope 2, we used emission from the location-based method for further calculations. For Scope 3, companies generally did not report a single overall number but rather individual values for each Scope 3 category. We summed these up to derive total Scope 3 emissions for each company.

As defined above, indirect emissions from the value chain, i.e. Scope 3, and particularly the purchased goods and services (PG&S) category are likely the most significant source of emissions for food and beverage manufacturers. PG&S comprises emissions associated with producing agricultural commodities. It also includes potentially significant land-use emissions associated with commodity production (Clark et al., 2020; Poore and Nemecek, 2018). We therefore specifically assessed whether companies reported land-use emissions that are associated with the use of agricultural commodities and their production. Land-use emissions are not a separate category required by the GHG Protocol or CDP questionnaire, and only few companies reported or mentioned these. Therefore, the CDP reports, CSR reports, annual reports and websites of each company were searched for any mention of the keywords “land-use change”, “land use”, “LUC”, and “deforestation”, to find out whether and how these emissions are included in the reporting.

Emissions data were measured in metric tonnes of CO_2 equivalents released over a duration of one year and expressed in million tonnes (Mt CO_2-eq per year). The global warming potential (GWP) used by the companies to determine CO_2 equivalents varied across companies, using either the IPCC Assessment Report (AR) 4 or AR5. Particularly the global warming potential of methane is significantly different in these two reports. While methane is also an important emission for agriculture, this inconsistency cannot be corrected for our analysis because underlying emission calculations (e.g. how much methane is emitted) are not always made public by the companies.

2.3. Analysis of corporate GHG emissions data

2.3.1. Reporting score

To quantify the coverage and completeness of each company’s emissions report, we created a scoring system that awards points for each additional reported emission category, i.e. the *reporting score* (Table 1). Thus, the more specific and complete a report, the higher the score is. We decided to specifically award an extra point for i) the Scope 3 category PG&S and ii) land-use emissions. These two emission sources were expected to be the most significant for food sector companies, given the large emissions associated with agricultural commodity production and specifically the role of land use identified above.

2.3.2. Emission totals and averages by company category

We used the collected corporate emissions data to determine total reported emissions by company, and aggregated these by company categories (Section 2.1). Given the importance of Scope 3 emissions for the food and beverage sector, we looked into the Scope 3 emissions in more detail. First, we calculated the average share of Scope 3 emissions in the total emissions to quantify the relative size of Scope 3 compared to Scope 1 and 2. Second, we also calculated the fraction of each Scope 3 category in the total emissions to assess the relevance of each of these categories for the food sector.

One company was excluded from Scope 3 calculations. This was because their calculated Scope 3 emissions were found likely to be miscalculated or mis-represented in the report, as they were more than 200 times higher than the calculated average of the other companies. This was the first time that the company reported Scope 3 emissions, so no earlier data could be used for checking the correctness of the reported emissions, while the company also did not respond to the authors’ request for more information.

2.4. First-order estimation of under-reported emissions

Our survey showed that 41 companies publicly reported emissions but only inconsistently covered Scope 3 emissions. Two companies

Table 1
Reporting scores defined for number of emission categories reported.

Reporting Score	Categories reported
0	No emissions report could be found
1	Emissions were report as totals but not distinguished by scope; the report did not define what is included in emissions; or the report presented only relative shares of each scope but not absolute emissions
2	Scope 1 + 2
3	Scope 1 + 2 + 3 (excluding PG&S)
4	Scope 1 + 2 + 3 + PG&S (excluding LUC)
5	Scope 1 + 2 + 3 + PG&S + LUC

Abbreviations: PG&S – purchased goods and services (including emissions from agricultural management), LUC – land-use change.

[2] The CDP follows the definitions of scopes from *The GHG Protocol Corporate Accounting and Reporting Standard* (WBCSD, 2004), henceforth the GHG Protocol. It categorizes emissions to be reported in three *scopes*: Scope 1 contains all direct emissions, meaning emissions from sources that are owned or controlled by the company. Scope 2 contains indirect emissions, generated from purchased energy such as electricity or steam needed for processing agricultural crops. Scope 3 contains all other indirect emissions and is further divided into 15 categories for emissions from upstream activities (e.g. land-use emissions from producing the agricultural crops) and downstream activities (e.g. transportation of processed foods), and one category for other emissions, thus a total of 16 categories are included: 1) Purchased goods and services (including, if reported, land use and land-use change), 2) Capital goods, 3) Fuel- and energy-related activities, 4) Upstream transportation and distribution, 5) Waste generated in operations, 6) Business travel, 7) Employee commuting, 8) Upstream leased assets, 9) Downstream transportation and distribution, 10) Processing of sold products, 11) Use of sold products, 12) End-of-life treatment of sold products, 13) Downstream leased assets, 14) Franchises, 15) Investments, 16) Other.

report totals but no information for breaking down the emissions by scope and category. Seven companies do not report any emissions publicly. This indicates a potentially large under-reporting of emissions. Therefore, we made a first-order estimate of under-reported emissions. To do so, we took the following three steps: (i) estimation of total Scope 3 emissions excluding LUC for the 41 companies, (ii) estimation of total Scope 3 LUC emissions for these 41 companies, and (iii) estimation of emissions (all Scopes including Scope 3 LUC) for the nine companies without reported emissions.

In the first step, for each product group we calculated the ratios of Scope 3 emissions excluding LUC to Scope 1 emissions from the data for companies that scored 4 or 5, then multiplied by total reported Scope 1 emissions of that product group. To estimate a lower and upper bound, the ratios are calculated in three different ways: (a) sum of reported Scope 3 emissions excluding LUC divided by sum of Scope 1 emissions, (b) average of the ratios calculated for individual companies, (c) median of the ratios calculated for individual companies.

In the second step, we estimated Scope 3 LUC emissions. This is because only five of the 50 companies specifically mentioned emissions from LUC. The only company that then explicitly reported those emissions found that 42% of its total reported emissions is from land-use change alone. From another company we were able to deduct the share of LUC emissions in the total emissions as 20%. The share of LUC emissions in total emissions is likely to vary strongly depending on the company portfolio of products, underlying agricultural commodities and sourcing regions. Still, for the lack of more detailed company data on agricultural commodities and their sourcing regions, we assumed 42% as maximum and 20% as minimum, with an average of 31% for the share of land-use change in all emissions. This range fits well with data from life cycle assessment studies for agricultural goods (Poore and Nemecek, 2018). Thus, dividing the total of reported emissions and under-reported Scope 3 emissions determined in the first step above by the share of LUC emissions results in the total reported and under-reported emissions associated of the 41 companies, including land-use change, respectively.

The third step estimates emissions of companies that did not report emission publicly (seven of the 50 companies) or that reported emissions but did not define shares by scope (two companies). Five of these companies were included in the estimate of GRAIN (2018), an in-depth study of the corporate emissions of 35 global dairy and meat producers. We used their estimates in our calculation. For the remaining four companies, we approximated their emissions by determining an average emission factor per company based on reported and under-reported emissions determined in the previous steps, then multiplying it by four for the four companies that did not report any emissions and adding it to the estimate of the 46 companies. This is clearly a first, rough estimate. Still, our estimate can indicate the level of under-reporting and in how far this is even a concern. It can also illustrate overall emissions associated with the food and beverage manufacturing sector, which is important to understand looking at future emissions reductions and identifying actors to take responsibility for these reductions.

As an alternative to this approach for estimating unaccounted emissions, we also calculated the emission intensity of each company (supplementary material, Section 2). Next, we used the average emission intensity per product group to estimate individual company's and then the entire sector's unaccounted emissions (supplementary material, Section 3). Given the emission intensities are based on incomplete emission reports, this approach results in significantly lower estimates for unaccounted emissions. Still, we consider the approach presented here more suitable as emission intensities based on incomplete emission reporting underestimate unaccounted emissions (see also supplementary material). Moreover, we also compared our estimate for dairy and meat producers with the above-mentioned study of global meat and dairy producers by GRAIN (2018) in order to assess the reliability and usefulness of our estimate.

2.5. GHG emissions reduction targets

GHG emissions data are fundamental for setting robust emissions reduction targets and for tracking progress towards the targets. It is therefore useful to obtain insights into the extent that targets are being set for the emissions that the companies are reporting and monitoring. We analysed the extent to which emissions accounting is used for planning and implementing their future emissions reduction efforts. We collected GHG emissions reduction targets data for target years between 2020 and 2035, including both absolute emission targets and emission intensity targets, from the public responses to the CDP Climate Change 2020 Questionnaire (CDP, 2020). We did not consider long-term targets (i.e. after 2035) and renewable energy targets.

3. Results

3.1. Level of reporting

43 of the 50 surveyed companies (86%) reported some kind of emissions data, leaving 14% which did not report any emissions. 80% (40 companies) followed the minimum recommendations for reporting of the GHG Protocol as they reported both Scope 1 and 2. 52% reported all three scopes, including Scope 3 category PG&S. However, only 10% reported all five surveyed categories, showing that LUC emissions are rarely included (Fig. 1).

The average reporting score for all surveyed companies was 3.1 (Fig. 2, top). If considering only those 43 companies that actually reported emissions, it was 3.6. There was a tendency towards higher revenue companies having more complete reporting (higher score) than lower revenue companies (Fig. 2, top). This mirrors the previous findings of Widianto and Sari (2020) that company size has a positive relationship with more complete carbon disclosure.

Companies across the globe generally had similar reporting scores, with the exception of Oceania. This outlier is explained by the fact that only one company in our survey is located there and this one received the maximum reporting score. Asian companies were on average similar to other regions but had greater variation within, as all Chinese companies scored zero while Japanese and Singaporean companies scored higher than average. In a recent study, Schulman et al. (2021) found that a company's headquarter country (as represented by the country's UN climate change negotiation group) was a significant predictor of scope 3 disclosure, score 3 or higher in our study. This suggests that a country's higher climate change ambitions influences the willingness of companies to disclose more of the emissions associated with their supply chains.

For the ownership model, we find that the average reporting score is more than one point higher for publicly traded companies (3.3) than for private companies (2.0). This is different from the findings of Kleemann and Murphy-Bokern (2014) who found that the ownership model is not a

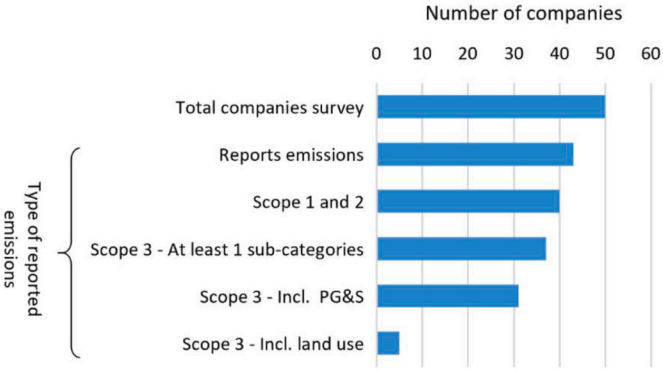

Fig. 1. Number of companies reporting different types of emissions.

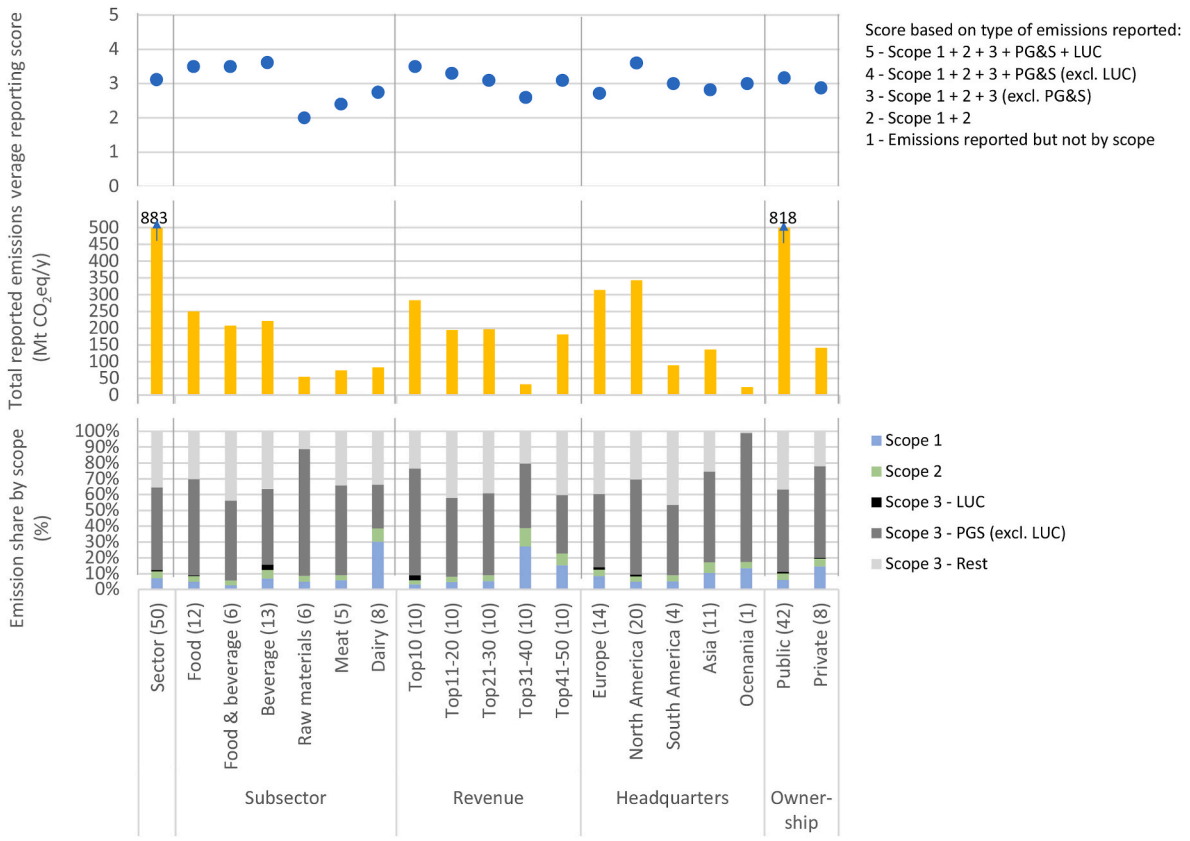

Fig. 2. Reporting scores (top), reported emissions (middle) and emission shares by scope (bottom), by company category. Number in parentheses refers to the number of companies included per category.

reason for differences in GHG emission reduction commitments in the food sector. However, there were only 8 companies classified as private in our study, making the sample very small. One interesting aspect is that 4 of these private companies are dairy producers and 3 of these did not or only very superficially report GHG emissions publicly.

When reviewing reporting scores by product group, the dairy and meat sectors scored the lowest with 2.0 and 1.75, respectively (Fig. 2, top). Scope 3 emissions are hardly reported in these subsectors although these emissions are very high when looking at life cycle assessments of meat and dairy products (Poore and Nemecek, 2018). This means that the two likely highest emitting subsectors also had the most incomplete emissions reporting. A recent study by Lazarus et al. (2021) also found large discrepancies in emissions reporting among the 35 largest global industrial meat and dairy producers.

3.2. Reported emissions

Total reported emissions by the global top 50 companies of the food and beverage manufacturing sector were 901 Mt CO_2-eq. in 2018. As two companies reported only total emissions, not broken down by scope or emission category, the emissions of these companies cannot be used for further analysis of emissions by scope. As a result, the following presentation and discussion of results refer to 888 Mt CO_2-eq. in 2018 (Fig. 2, middle). As seven companies did not report any emissions, this means that the emissions arising from just 43 food and beverage manufacturers' productions and value chains are equal to 2.5% of global total emissions. This is larger than those from all of aviation, or around the same size of the total emissions of Germany, the sixth highest emitting country in the world (The World Bank, n.d.).

Breaking down the food and beverage manufacturing sector in different company categories shows that for product groups, the mixed food and beverage companies (36%, 6 companies) and the raw material companies (27%, 6 companies) report most emissions. The top 10 companies reported 45% of the emissions, which is equivalent to the emissions of the next 24 companies ranked by revenue. Classification by company headquarters shows that companies from North America (51%, 21 companies) and Europe (34%, 14 companies) make up most of the emissions, reflecting also that many companies are located there. The ownership-based category shows that publicly owned companies make up 93% of the reported emissions while they represent 82% of total revenue.

The vast majority (88%) of the reported emissions by the food and beverage manufacturing sector were Scope 3 (aggregating LUC, PG&S and other scope 3 emissions; Fig. 2, bottom). The remaining emissions are from Scope 1 (8%) and Scope 2 (4%). This shows that emissions under direct control of the company are small compared to the indirect emissions from the value chain. Within Scope 3, emissions from purchased good and services (PG&S, here primarily agricultural commodities) are especially significant as 52% of all reported emissions was found within this single category. This share is likely even bigger considering that many companies did not report land-use emissions (see also below).

Emission shares by scope strongly vary across company categories (Fig. 2, bottom) but the largest variation can be explained by companies not reporting emissions from the key Scope 3 category PG&S. For example, the meat subsector shows a significant deviation: Scope 1 accounts for 37%, Scope 2 for 18% and Scope 3 for 45%. However, only two of the five companies in the meat subsector report emissions from Scope 3 and of these only one reports PG&S emissions. The headquarter location category shows South America to deviate from the main pattern of high shares for Scope 3 emissions. This is the result of the three South American companies not reporting emissions for PG&S. Excluding companies with the low Scope 3 reporting in the meat subsector and South America, Scope 3 emissions vary between 78 and 94% of total

emissions.

3.3. Breakdown of Scope 3 emissions and reporting

The size of Scope 3 emissions emphasizes the importance of reporting these emissions. Of the surveyed companies, 74% of companies reported emissions for at least some Scope 3 categories. However, no single company reported all of the 16 Scope 3 categories. There is also a large variability in how often each Scope 3 category was reported, with each of the 16 categories being reported on average 34% of the time and no single category being reported by more than 62% of companies (Fig. 3). Of the 37 companies, which reported Scope 3 emissions, eleven companies reported less than 5 categories, 17 companies reported between five and ten categories and nine companies reported more than ten categories. No companies reported data in more than 13 of the 16 categories.

The PG&S category of Scope 3 was shown to be most significant source of all emissions, consisting of on average 53% of all reported emissions (Fig. 2, bottom) and 60% of Scope 3 emissions (Fig. 3). Nonetheless, this category was included by only 30 of the 43 companies that reported emissions. The most frequent explanation given for the omission of PG&S was the CDP's standard description "Relevant, not yet calculated" with no further details provided. Similarly, in many company reports, it was not made explicit why other categories were omitted. Only in some of the surveyed companies' emissions reports, it was explained that certain categories were unnecessary to calculate and report, as preliminary calculations had revealed them to comprise less than 1% of the company's total emissions. For example, Scope 3 categories 5, 6, 7, 8 and 16 were all on average below 1% of total emissions (Fig. 3).

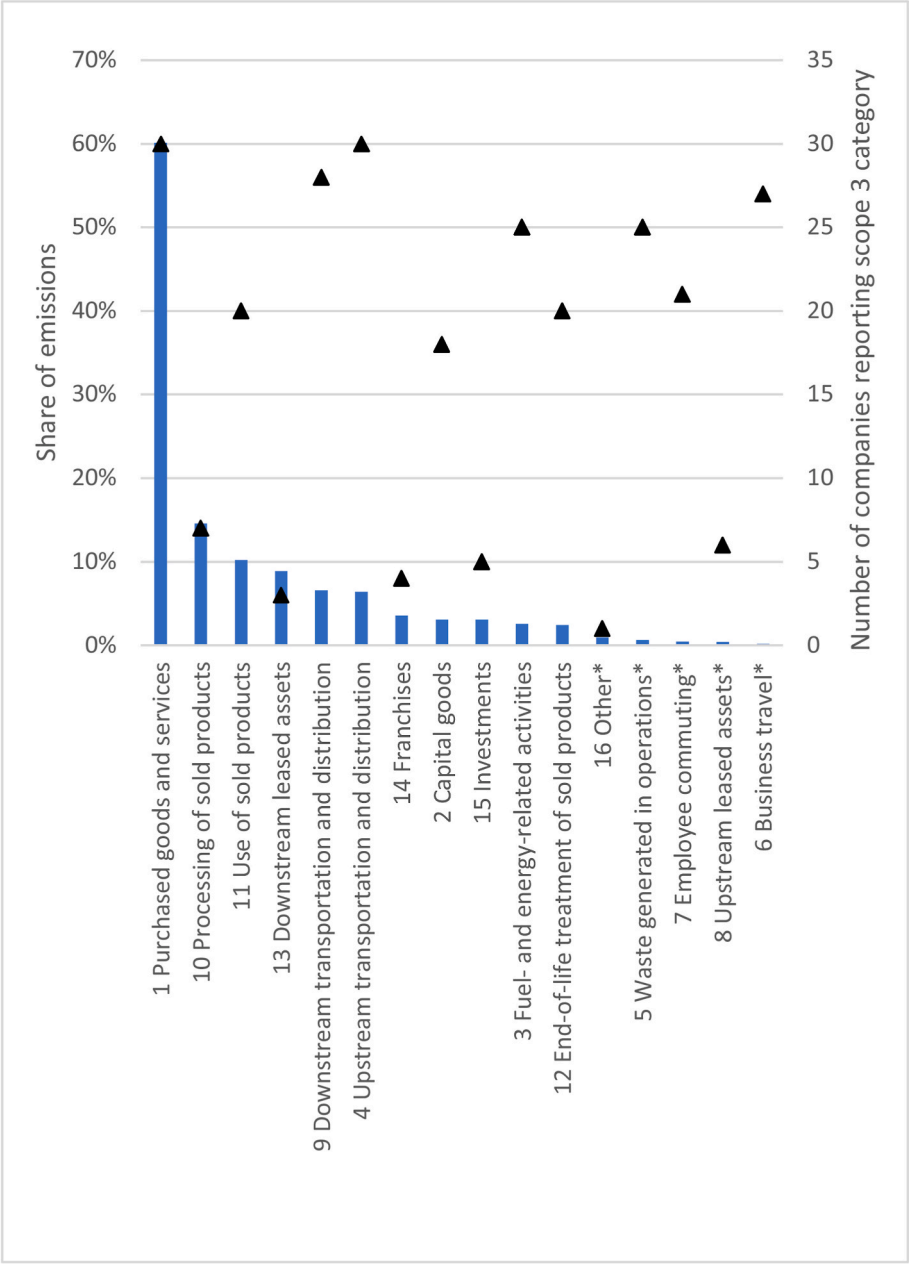

Fig. 3. Share of emissions (n = 50, blue bars left Y-axis) and number of companies reporting (n = 50; black triangles, right Y-axis) for each of the 16 Scope 3 categories, sorted from highest to lowest by fraction of the total emissions. The asterisks indicates Scope 3 categories containing less than 1% of the Scope 3 emissions.

Fig. 3 illustrates the inconsistency between the frequency of reporting a certain Scope 3 category and the importance of that category for total emissions. The choice of which Scope 3 emissions categories are reported thus seems to not necessarily be decided by the relative importance or size of that category. This is similar to the findings of Downie and Stubbs (2013), who in 2010 interviewed 22 companies from a broad range of sectors in Australia, and found that there was a wide discrepancy in the number of categories included between different companies. Also Huang et al. (2009b) found in their study of 426 sectors in the American economy (based on 2002 data) that categories that are easy to calculate, such as business travel, were emphazised above categories which contain high amounts of emissions.

3.4. Estimating unaccounted emissions

Our results indicate that there is a large variation in which scopes and categories of Scope 3 companies include in their emissions reports. Despite the large size of the reported emissions, this suggests that potentially large amounts of emissions are currently unaccounted for, especially those arising from the agricultural value chain.

Based on a first order magnitude estimation, we found that unaccounted emissions from Scope 3 (excluding LUC) can range from 0.4 to 1.1 Gt CO_2-eq per year. This assumes that those companies reporting Scope 3 emissions did so completely. However, our results (Fig. 3) showed that this was not the case. Although 60% of companies reported the most relevant Scope 3 category PG&S, they did not always include all emissions associated with agricultural commodities. Some reports covered only part of the value chain and in nearly all company reports, LUC emissions were not included. We estimate that LUC emissions would add yet another 1.1 to 2.2 Gt CO_2-eq per year, which are currently unaccounted for. Finally, we also estimated the emissions of the seven companies, which did not report any emissions, to amount to 0.3 to 0.4 Gt CO_2-eq per year. In total, this results in an estimated 1.7 to 3.7 Gt CO_2-eq per year of unaccounted emissions, or 1.9–3.8 Gt CO_2-eq per year associated with the top 50 food and beverage manufacturing companies. Comparing this amount to the emissions which were reported suggests that only 23–47% of the total emissions related to the 50 companies' production are currently being reported.

It is important to note though that care must be taken in interpreting this result as we apply a simple approach to estimate the first order magnitude of underreported emission and assumptions had to be made for key parameters. Especially uncertain are the unaccounted emissions from LUC and potential double counting of emissions when surveyed companies buy from each other.

Our findings agree with a previous study that revealed significant unreported emissions of meat and dairy companies (GRAIN, 2018); they found that only 13% of the estimated total emissions of the sector are reported by companies. We estimated this percentage to be higher, ranging between 23% and 47%. Direct comparison of the reporting percentage values between the two studies is not possible due to the different company (and food industry subsector) coverage as well as the different data year (the GAIN and IATP study is based on data from 2015/2016). At the same time, our estimates of unaccounted emissions may also be conservative due to, among others, the method used, sample bias, and possible underreporting of some Scope 3 emission categories by companies.

3.5. Emissions reduction targets

Not all of the top 50 food and beverage manufacturers have short-to mid-term GHG emissions reduction targets (Table 2). We found that among the 41 companies that reported emissions per Scope, 32 companies had one or more GHG emissions reduction targets for target years between 2020 and 2035; 29 companies had absolute targets and 3 had only intensity targets. All 32 companies' targets covered Scope 1 and 2 emissions (including both market-based and location-based). Companies that did not report emissions also did not have emissions reduction targets.

Table 2
Overview of greenhouse gas emissions reported by food and beverage manufacturers and the emission covered by their reduction targets set for the period 2020–2035.

Indicator	2018 emissions of the companies with targets ($MtCO_2$-eq/year)[a]	
	Scope 1 & Scope 2	Scope 3
Reported emissions	98 [b] (n = 41[c])	785 (n = 41[c])
Aggregate emissions of companies with reduction targets[a]	75 [b] (n = 32)	Absolute and intensity targets: 511 (n = 22) Absolute targets only: 325 (n = 15)

n - Number of companies in parentheses.
[a] Note that not all targets cover 100% of the emissions from the targeted Scope in the base year.
[b] We aggregated location-based Scope 2 emissions, while some targets consider market-based Scope 2 emissions.
[c] Of the 50 companies included in our survey, 41 companies reported emissions per Scope. Two additional companies included in the emission survey above did not report emissions per scope and are therefore not included here.

Even fewer companies had their Scope 3 emissions covered by their emissions reduction targets (n = 22). Together these companies account for about 0.5 Gt CO_2-eq/year or two-thirds of reported emissions in 2018 presented in Section 3.1. While it was beyond the scope of this paper to examine the details of Scope 3 emissions reduction targets, the collected data shows that Scope 3 targets did not necessarily cover the entirety of the Scope 3 emissions that the companies have been monitoring.

Moreover, only 15 companies (together accounting for 0.3 Gt CO_2-eq/year of reported Scope 3 emissions in 2018) had absolute emissions reduction targets. While intensity targets could effectively guide specific sectors toward decarbonisation, a statistical analysis has shown clear association of absolute emissions reduction targets, rather than intensity targets, with measurable reductions in emissions (Dahlmann et al., 2017).

We also found that 19 of the 22 companies' targets covering Scope 3 emissions were approved as "science-based" by the Science Based Targets initiative (SBTi). However, only three out of 19 companies reported LUC emissions. There were also three companies that had targets to reduce full value chain emissions, even though they do not report full value chain emissions. This reduces credibility of these targets as it either means they calculated value chain emissions but chose not to disclose them publicly, or they set value chain emissions reduction targets without knowing what the amount of emissions are or where they arise in the value chain. The lack of disclosure means that outsiders cannot verify the progress the companies are achieving on these targets.

4. Discussion

4.1. Study limitations

This study surveyed the global top 50 food and beverage manufacturers' GHG emissions reports and their emission reduction targets in order to assess the quality and status of corporate emissions reporting in this sector. The study relied on voluntary corporate emissions reports to the CDP. Despite criticism related to data reliability, quality and comparability across companies (Busch et al., 2020b), CDP data can provide relevant insights in the current status and quality of corporate emission reporting in the food and beverage manufacturing sector as shown in our study. Four key limitations are identified. First, some companies do not or only inconsistently report emissions publicly. For the seven companies that did not submit public emissions reports to the

CDP, we conducted an internet search to find alternative emission information. This search was conducted in English, not accounting for reports in other languages. Access to reports in other languages can increase completeness. Besides these seven companies not reporting emissions, under-reporting of indirect value chain emissions by other companies is a key concern (see Section 4.2).

Second, some surveyed companies produce not only food but also other products, such as personal hygiene products. Although our analysis focussed on food and beverage manufacturers, emissions of those products are also included in our survey. This is because these emissions cannot be separated from food and beverage emissions due to lack of disaggregation in the company emission reports. In addition, at least some of these emissions are also related to agricultural commodity production, e.g. palm oil is used for both food and non-food applications such as personal hygiene products, and are therefore also relevant here.

Third, for an overall estimate of reported emissions, we summed up the reported emissions of each company. This can result in double counting of emissions if companies purchase intermediate products from one of the other surveyed companies, e.g. a food processor buying from a meat or dairy company or a meat producer buying soy from an agricultural raw material producer. This double counting is difficult to estimate without detailed company supplier information. This is generally not publicly available, although the Trase project database (Godar, 2018) is increasing data availability for the value chains of and links between specific companies. This could be a starting point for better understanding the potential of double counting emissions in our study. Double counting becomes even more important when also other types of companies in the value chain are included that share the indirect emissions from the value chain, e.g. supermarket chains.

Four, our estimate of unaccounted emissions is based on a simple extrapolation of reported emissions and should be treated as such. This estimate comes with significant uncertainties as a result of its simplistic approach, potential intended biases in reporting (e.g. companies only reporting emissions of specific categories when it makes them look good) or unintended biases (i.e., the representative of the companies that comprehensively report emissions). Two alternative approaches are available. The first is based on emission intensity (see supplementary material, Section 3). However, it underestimates unaccounted emissions for Scope 3 as the emission intensities are calculated based on reported emissions while many companies that report emissions for Scope 3 do so only for some and not necessarily the most important emission categories of Scope 3 (Fig. 3). The second is based on detailed company assessments of how much and from where agricultural commodities are sourced and regional averages for land use emissions (GRAIN, 2018). This approach requires a large amount of data from companies, which are often not available publicly and therefore result in additional assumptions. The GRAIN and IATP study assessed 35 meat and dairy companies that partially overlapped with companies included in our survey. Despite the simplicity of our approach, our estimates compare well with the more detailed study of GRAIN (2018). Our first estimate of unaccounted emissions can thus give a good indication of the problem of under-reporting value chain emissions. This under-reporting is significant because these emissions are key for food and beverage manufacturers to target in future emission reduction programs. Future work on improving the estimate of unreported emissions is needed. A useful contribution in this regard is a recent study by Schulman et al. (2021) who indicated that the overall environmental performance (as rated by the Yale Environmental Performance Index) and the international negotiation group of a company's headquarter country are significant predictors of scope 3 emissions reporting. Besides improved corporate emission reports, important aspects for more research are trade between surveyed companies and potential double counting of emissions.

4.2. Incomplete Scope 3 emissions reporting

Although Scope 3 is the largest source of emissions for companies that report all scopes, we found that the reporting of Scope 3 emissions was often incomplete or sometimes even lacking completely. This may be explained by Scope 3 not being mandatory for the CDP questionnaire, the complexity of determining these emissions (including e.g. dependence on information and data availability from suppliers), and most frequently used protocols not being designed to comprehensively and consistently quantify Scope 3 emissions (Li et al., 2019). Some authors have also raised concern about whether it is even feasible for companies to account for their complete indirect emissions from the whole value chain (Huang et al., 2009a; Patchell, 2018).

Estimating emissions stemming from agricultural production is especially complex as it requires tackling additional challenges not seen in most other sectors. Gathering primary data is for example more difficult in this sector due to the large amount of suppliers and the production heterogeneity in terms of e.g. management systems, biophysical conditions and land-use changes. This large heterogeneity in production means that a single product can have impacts varying up to 50-fold (Poore and Nemecek, 2018). Using secondary data, e.g. average land-use change emissions per region may reduce the cost of data collection but does not allow representing this diversity. Other reasons for incomplete or inconsistent reporting of emissions from the different Scope 3 categories may be that some categories are more easily assessed and their emissions more easily be reduced, allowing companies to profile themselves in these categories.

Despite these challenges, there were also companies in each product group category that *did* report emissions from these Scope 3 categories. For example, meat and dairy producers generally score low in terms of coverage of different scopes and Scope 3 categories, with several companies not publicly reporting any emission data. However, two dairy and one meat company report emissions for PG&S and one of these even for LUC. Companies not reporting these key sources of emissions generally recognize the sources' importance. One company indicated in its response to the CDP questionnaire that it "did not find consensus about the best methodology to calculate it [PG&S]". Therefore, it is important that sector-specific guidance and even calculation tools with default values are made available that can reduce the calculation and data barriers. Several tools are already available, e.g. Cool Farm Tool (Cool Farm Alliance, n.d.), Agricultural Life Cycle Inventory Generator (Quantis, n.d.), Direct Land Use Change Assessment Tool (Consultants, 2018) and GLEAM (FAO, n.d.). Recently, new methodologies for accounting of LUC emissions have been or are being developed, such as Quantis Land-Use Change Guidance (Quantis, 2019) and the SBTi Forest, Land and Agriculture (FLAG) project (SBTi, 2020). An overview of all the methodologies and tools used by the surveyed companies is presented in the supplementary material (Tables 1 and 2).

The fact that some companies publicly report Scope 3 emissions, while others with similar value chains do not, suggests that the lack of reporting by some companies cannot be solely attributed to the lack of or consensus on accounting methodologies or data availability. It likely also relates to company values in terms of sustainability and concerns about reputation risk for companies with high emission value chains. For example, Busch et al. (2020b) discuss several studies that indicate that poor sustainability performers have lower quality reports on sustainability or GHG emissions. We find similar results; meat and dairy producers that are likely to have high indirect emissions from their value chain emissions generally have low reporting scores that companies from other product groups.

Accounting for Scope 3 emissions can provide several benefits for companies, including being able to define cost-effective emission reduction strategies (Blanco et al., 2016; Hertwich and Wood, 2018; Matthews et al., 2008), anticipate costs of future carbon pricing schemes and work with other companies that share the same supplier or value chain to reduce the emissions (Hertwich and Wood, 2018; WBCSD and WRI, 2011). In addition, reporting requirements for publicly traded companies at least in the European Union are changing with increasing emphasis on company's indirect emissions (Maas and Sampers, 2020).

Also, the recent outcome of a Dutch lawsuit against the energy company Shell has underlined that companies will have to be more pro-active in reducing indirect emissions associated with their value chains as well as downstream activities from the use of their products.

Given the large share and increasing relevance of Scope 3 emissions, it is important for corporate emission reporting by food and beverage companies to improve coverage of these emissions. One way to do so is by making it mandatory to report the most significant Scope 3 categories for this sector. Currently, the GHG Protocol and reporting initiatives such as the CDP are not designed to take differences between sectors into account. This means that the reporting guidance provided to food and beverage manufacturers is the same as for other sectors. However, the distribution of emissions in each Scope 3 category can vary strongly for different sectors (Huang et al., 2009b). Therefore, sector-specific guidance is needed to define the most relevant Scope 3 categories for reporting.

Deciding when a Scope 3 category is significant can be done using a cut-off threshold which determines the boundary between significant or not, also called a materiality threshold (Huang et al., 2009a). An appropriate materiality threshold could be 1%, meaning that categories representing on average above 1% of a company's total emissions is defined as significant. Several broad estimation methods exist for deciding which categories to include, such as the GHG Protocol's Scope 3 Evaluator Tool (Greenhouse Gas Protocol, 2021). In addition, using the data gathered in this survey or similar activities for other sectors, it is also possible to define and prioritize the most significant categories. Using a materiality threshold of 1%, this would mean for the food and beverage sector that Scope 3 categories 5, 6, 7, 8 and 16 are non-significant. The three categories that contained most emissions and that should be prioritized for reporting (ordered by size of emissions) are categories PG&S, Processing of sold products and Use of sold products (see also Fig. 3).

Improving coverage of Scope 3 emissions is not only about reporting emissions for the most significant categories, but also about completeness of these emissions. We found that even when companies do report the category PG&S, which should include LUC emissions, it most often does not seem to be the case that LUC emissions are covered. Reports are often not transparent enough to evaluate this in detail. Sector-specific guidance and reporting requirements for companies in the food system could distinguish an additional Scope 3 category for LUC emissions to help alleviate this transparency issue.

We also found that most of the companies analysed in this study that have SBTi-approved targets do not report LUC emissions. Combined with the incomplete reporting on Scope 3 emissions by food and beverages sector companies presented above, our findings call for further scrutiny on corporate GHG emissions reduction actions across their entire value chain and their effective contributions to the Paris Agreement's long-term temperature goal.

5. Conclusions

This paper assessed the corporate emissions reporting of the 50 largest food and beverage manufacturers worldwide, including an assessment of the completeness of emissions reports and emission reduction targets. The results show that the majority (86%) of the surveyed companies report direct emissions arising from their own operations (Scope 1) and indirect emissions from purchased energy (Scope 2). However, indirect emissions from upstream and downstream activities (Scope 3) were far less consistently reported both in terms of the number of companies reporting these emissions and the type of emission sources included. This is problematic, as Scope 3 emissions accounted for nearly 90% of total reported emissions for companies which reported all three scopes. Food and beverage companies that do not report Scope 3 emissions may therefore largely underestimate their emissions.

Despite the incomplete reporting of the 50 surveyed companies, total reported annual emissions were 0.9 Gt CO_2-eq. This is higher than the emissions of Germany, the sixth highest emitting country in the world, or all of aviation combined. We estimated that this may nonetheless still contain only 23–47% of the total emissions related to the 50 companies' products.

Further, we found that 32 companies had one or more GHG emissions reduction targets for target years between 2020 and 2035, but more than a third of reported Scope 3 emissions were not covered by these targets. Together with the relatively poor reporting of Scope 3 emissions, our findings suggest that the food and beverages industry needs to urgently improve their GHG emissions management overall; otherwise this industry will miss out on the opportunity to set effective and efficient GHG mitigation strategies and risk losing other important benefits such as anticipate costs of potential future carbon pricing schemes, increase resource efficiency, or help secure investment from increasingly environmentally minded investors. This call for improved Scope 3 reporting is also justified scientifically (more comprehensive reporting would reduce uncertainties of analyses like ours) and politically (proper consideration of industry responsibility for emissions and their mitigation requires better understanding of all emissions associated with the industry). Improving GHG emissions reporting can focus first on improving Scope 3 reporting consistency, prioritizing the Scope 3 categories with the highest amounts of emissions. Prioritizing high emission Scope 3 categories could also come in the form of mandating reporting of Scope 3 categories above a materiality threshold of 1%. Our study showed how to define the relevant categories that contain the highest emissions in a specific industry sector. In general, guidance from the GHG Protocol or CDP targeting specific sectors and the most relevant Scope 3 categories can help increase reporting of more Scope 3 category and with more complete coverage. Such guidance can aid companies in prioritizing the most significant Scope 3 categories first. For the food and beverage industry, this is clearly the Purchased Goods & Services category, which includes emissions from the production of agricultural commodities and associated land-use change.

Additional research is needed to better assess the completeness of reported emissions, especially for the Scope 3 categories. For example, it was found that LUC emissions were often not included, but if they were, it was difficult to discern in how far they were actually complete. For companies that reported these emissions, LUC emissions represented a large part of the total emissions released each year. Further transparency is therefore needed in LUC emissions reporting of food and beverage manufacturing companies. This could be achieved by the creation of an additional Scope 3 category dedicated to LUC emissions. Particularly the better understanding of LUC emissions from a company's value chains can provide new avenues for food and beverage companies to engage and work with agricultural commodity suppliers to mitigate these emissions. In addition, defining strategies for companies throughout the value chain to work together to reduce land-use change and land use emissions by for example sustainable intensification of the agricultural production, and to assessing how these strategies affect company emissions are important topics for further research. This includes also analysing the emission reporting and target setting of other companies in the food value chain, e.g. supermarkets. Working on reducing these and all other direct and indirect emissions would allow food and beverage manufacturers to meaningfully contribute to mitigating the food system's impact on climate change.

CRediT authorship contribution statement

Alexander Damkær Hansen: Methodology, Formal analysis, Writing – original draft. **Takeshi Kuramochi:** Formal analysis, Writing – review & editing. **Birka Wicke:** Conceptualization, Formal analysis, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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