AGRAIN

LIFE CYCLE ANALYSIS

(LCA)

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TABLE OF CONTENT

BACKGROUND

Every grain counts if we want to feed 8 billion people.

Every grain counts if we want to consume less and save the planet.

Every grain counts if we want less farmland and more nature.

And every grain counts if we want to make food taste better.

Because when we up-cycle every grain, instead of wasting it,

we can create new exciting food ingredients.

So tasty, people will choose them over traditional options.

So good, they can help restore human and planetary health.

We are Agrain. The re-harvest company where every grain counts

Intro to report

The LCA presented in this document represents the environmental profile of Agrain flour produced in 2019, 2020, 2021 and 2022. It is therefore a representative product for Agrain that is the declared unit for this analysis. The reason behind the four year period is to make it representable for an up-cycled flour from spent grains, utilizing the factory of Agrain. During the period, there were many external factors affecting the efficiency and processing, e.g., COVID-19, Ukrainian war, different yields, etc. The data collection and analysis were performed by Agrain and Re-Viu, and thereafter validated by Bureau Veritas. It is the first attempt at calculating and presenting a full overview of LCA for Agrain's ingredients.

The LCA has been conducted to identify where changes are necessary in order to reduce the environmental footprint of the Agrain flour. In the report, we lay out four next steps towards reducing the LCA. Furthermore, to assess the environmental impact of Agrain, we make comparisons to other flours currently utilized in the food industry.

In addition, we compare the Agrain flour representative product as well as Agrain best case scenario (where identified optimizations have been implemented) to 40 food products that constitute 90% of all calories and proteins being consumed worldwide.

Agrain flour is high in protein and dietary fibre and therefore has the potential to replace other ingredients than flour, e.g., replace meat in recipes. In the comparison with the 40 food products, the analysis is based on the same categories as Poore & Nemecek (2018) identified, in which land use, climate change, water use, acidification and eutrophication have been identified as major environmental impact categories for food. This part of the LCA analysis also takes nutritional values into account. Therefore, the comparisons investigated are not only (as in other industries) by per 1 kg product, but also taking nutritional value for people into account, namely per 100g protein and per 1000kcal. The study shows that, a) the Agrain flour is the most environmentally friendly flour, with only few trade-offs (Agrain performs best or second best in six out of nine impact categories. And b) Agrain flour is the most environmentally sustainable food protein resource (Poore & Nemecek method).

All in all, this report exemplifies the benefits of up-cycling side-streams, and the extensive environmental benefits that exist when utilizing resources already in the food system.

EXECUTIVE SUMMARY

The current food system is a large contributor to our current climate crisis. According to The Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change it is assessed that food accounts for 10.8-19.1 billion tonnes of CO_2-equivalent (CO_2e) emissions per year (Mbow et al, 2019). That's between 21% to 37% of global total emissions. At the same time, agriculture utilizes half of the world's habitable land (World in data, 2019). As a result, agriculture is responsible for 80% of global deforestation and 70% of terrestrial biodiversity loss. Over half (52%) of agricultural land is degraded, undermining soil health and the possibility of growing food on the same land in the future (WWF, 2021). In addition, resources are becoming scarce, and agriculture and food production is utilizing a majority of water resources, agriculture alone accounting for 70% of global freshwater use (WWF, 2021). While the food system is putting severe pressure on planet, it also is challenged by a growing population. We have reached 8 billion people, and it is necessary to ensure that food scarcity is effectively addressed through sustainable food products and equitable distribution. This challenge requires a comprehensive and innovative approach to reshape the way we produce and consume food.

Agrain was established in 2018 with a strong wish to change this. We therefore set out to figure out how we could up-cycle spent grains, harnessing their full value in terms of nutrients and deliciousness, while not harming the environment. At the same time, it has been a goal to build a strong financial business for our team and investors to grow in, thus being a food company where environmental, financial and social sustainability went hand-in-hand.

To understand the environmental aspects of the Agrain flour, we conducted this report consisting of LCA data analysis of the last four years operational data. The site and the sourcing of spent grains from breweries close to the factory site is the first of its kind world wide, and we have dealt with more than 100 different types of spent grains. The data therefore also represents huge amounts of learnings. These learnings we have also outlined in the strategic choices for operations which we will implement to reach our sustainability goals. By 2030 we want to become the most environmentally sustainable food product in the world, measured by all PEF impact categories. As you will see in the report, the Agrain flour is already best in several impact categories, and can claim to be the most environmentally sustainable flour, as well as the world's most environmentally sustainable protein resource, so this goal is possible, and the road there achievable.

Despite the Agrain production site at Gummermarksvej 7a, 4632 Bjæverskov (Denmark) being still a small site compared to the amounts of spent grains that could potentially be up-cycled world wide, the present LCA also assesses the pathway to scale up and optimize the process to make it more efficient and even more sustainable. The flour assessed in this report has been a core ingredient in more than 20 launches of RTE products, and the liquid (still not commercially available), has proven to be a possible replacement of diary milk and cream in a number of products. This we will also analyse in depth in the future in terms of the liquid's environmental sustainability.

Also, despite the size of the operations, the results presented in this report show the strong environmental potential of utilizing side-streams for food production. The comparative LCAs against an average of 13 possible substitutional flours (all from large industrial mills, available in Ecoinvent and Agribalyse databases) show that with the current factory site, which we measure from day one of operations in 2019, the Agrain flour (representative product) performs better in eight out of the nine impact categories compared to average substitution flours in the most important impact categories. The PEF weighted results have been used to select the most relevant impact categories. Note that this part is not conformant with ISO 14044, as weighting is not allowed when comparisons are intended to be disclosed to public, as it provides subjectivity to the interpretation. From the most relevant impact categories, Agrain flour performs better in Climate change, Water use, Ecotoxicity (freshwater), Eutrophication (marine), Land use, Acidification, Particulate Matter, and Resource use in minerals and metals – against alternative flours. It only performs less than the substitution flour average in one category, Resource use, fossils; an element which we have already identified how to change, as it is merely making green energy available in the amounts needed at the site.

In the second part of the analysis, we present our strategy for improving our environmental impact. There are 4 operational tasks which Agrain has initiated to improve the environmental impacts of our flour. First, between 60-90% of spent grains are liquids, liquids that could become delicious vegan alternative to diary cream and milk. However, while Agrain has been experimenting with the liquid in ice cream, oat drinks, yoghurts etc, we have yet to set up a full scale pilot plant. However, when this is done, a full circularity of the spent grains will be achieved, alongside a reduction in the environmental impact of 12% . Secondly, already now in 2023 we are striving for no spent grain waste. However, this requires logistics and operations to succeed in good manner, while handling the everyday challenges when brewery plans are changed as well as the short lifetime of spent grains. This challenge will be much easier to deal with when we will have several production lines running instead of only one, as we can then assure operations even when one line is down. Implementing this second step will reduce the flour's environmental impact by 14%. Third, is operating with no transport or net zero transport. The current transport is a large contributor to the environmental impact of the flours. This can be fully removed if located next to brewery, or partly removed if prolonging of shelf-life for spent grains is possible, so we can pick up on less trips with more volume in greener vehicles. When no transport of raw spent grains is achieved it will enable a further 34% reduction in environmental impact of the flour. Fourth, converting machines into only operating on renewable energy is challenging at our current site. However, we can work with PPAs as well as planning the next location in an area with sufficient access to needed green energy. 100% green energy in operations would mean a further 55% reduction in the environmental footprint of the flour – removing our challenges with resource use of fossils. This means that even though we have launched a flour that already is performing very best in terms of almost any environmental impact category against substitute flours and mainstream food products, we are able with only 4 operational strategies to improve it even more by a total of 91% reduction (PEF weights). Note that these conclusions are not compliant with ISO 14044, as they are based on the weighted results, not the characterized results.

Finally, in the report we present the results from a comparison between Agrain flour representative product and 40 food products that constitute 90% of global calorie and protein consumption. The impact categories and comparison data originates from Poore & Nemecek 2018 Nature paper (Poore and Nemecek, 2018), and is a comprehensive and detailed LCA food study. By analyzing the five hotspot categories (defined by Poore and Nemecek) climate change, land use, acidification, eutrophication, and water scarcity, we find that Agrain Flour in this analysis is the most sustainable protein food in the world. In terms of environmental impact per 100g of protein, Agrain Flour is even with the current non-optimized production facility having least impact on Land-use, Water scarcity, Acidification, and Eutrophication. While being less good than nuts and peas as protein resource in current scenario in terms of CO2eq/100g protein, however, Agrain flour has the potential of becoming best in this impact category as well.

In terms of calories and environmental impact, the Agrain flour also shows best results in Water scarcity, Eutrophication, Acidification and Land use, while the outlined improvements to the facility need to be incorporated before becoming the least emitting in terms of climate change.

When not taking the nutritional benefits in to consideration, namely analyzing the 5 impact categories from a per kg perspective, the Agrain flour stands out as well: it has lowest impact in three out of five impact categories, namely Eutrophication, Land use, and Water scarcity. Root vegetables is the only other food that in current scenario performs better in terms of Acidification, and certain fruits and vegetables (e.g., nuts, citrus fruit, potatoes, onions) perform better than the Agrain flour in current scenario in terms of Climate Change, but will be outperformed by the Agrain flour when the four above strategies have been implemented.

In total, the extensive data and analysis presented in this report shows that the Agrain flour is outstanding in terms of low environmental impact. Overall, in the comparisons we have not been able to find any other food product that performs equally well. Furthermore, the analysis shows that the Agrain flour is a significant contribution to biodiversity, it is the most environmental sustainable protein resource, and with the identified viable strategies, the Agrain flour can come close to zero in all impact categories. With the potential volume of spent grains, this could have large positive implications for not only food scarcity in the regions it is implemented but also for people having access to environmentally friendly and delicious food worldwide.

1. Goal and scope

1.1 Goal of the study

The goal of the study is to environmentally assess the flour from spent grain, produced in four different years: 2019, 2020, 2021 and 2022. The assessment is based on the LCA methodology, following the LCA standards:

- ISO 14040: 2006 Environmental Management - Life cycle assessment - Principles and framework

- ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines

Current assessment reflects the current production process, but when Agrain scales up, there are several scenarios that would result in reduced impact. The scenarios identified are assessed in this report and compared with current production.

Moreover, the LCA will be used to assess if the implementation of food up-cycling technologies for the production of BSG flour substituting conventional and alternative flours in processed foods would result in lower environmental impact. The study thus intends to support comparative assertions intended to be disclosed to the public.

Specific data were collected accounting for all spent grain inputs, transport operations and production process consumptions and outputs. As Agrain only initiated the production of the up-cycled spent grain flours from 2019, and has since increased production in volume and extent, as well as increased data availability, there are variations across the four years assessed. To minimize the role of single years, a representative product is assessed.

The LCA study is oriented to internal audience, stakeholders and LCA reviewers. The results from this study will also be used for communicative purposes.

An external critical review is carried out by a panel of three independent LCA reviewers.

1.2 Scope of the study

1.2.1 Product under study

The product under study is the Agrain flour, obtained from spent grain. The production process could generate two ingredients, a flour and liquid. As the liquid production setup is not yet established, it is excluded from the study. However, in the report, we show how also upcycling the liquid from spent grains influences results for the flour.

Agrain flour's nutrient profile is comparable to the most nutritious grains, as it contains high fibre (+50g/100g) and high protein content (26% protein by energy). Agrain flour can therefore replace highly nutritious ingredients, depending on the application, and will often offer increased nutritional values, when replacing regular flours, such as whole wheat, rye, spelt, etc. For example, replacing 5-10% of wheat flour in a bread with Agrain flour can boost the fiber and protein content significantly. Below we present the nutrient content of the Agrain flour as well as the substitute flours utilized for the comparison.

*Table 1. Nutritional content Agrain flour and Substitution flour products**

Per 100g	Agrain Flour	Wheat Flour	Maize Flour	Barley Flour	Buckwheat Flour	Chesnut Flour	Chick Pea Flour	Millet Flour	Oat Flour	Rice Flour	Soy Flour	Spelt Flour
Energy, kj	1205	1454	1528	1428	1454	1491	1390	1486	1583	1527	1877	1402
Energy, kcal	292	343	361	338	343	355	313	354	377	360	449	332
Fat, g	8.1	1.55	2.8	3	2.75	3.5	5.4	1.7	5.67	1.3	22.2	2.25
Of which Saturates, g	2.1	0.38	0.44	0.53	0.32	0.38	0.5	Na	1.33	0.30	3.10	0.32
Carbohydrates, g	6.1	68.72	75.5	64.04	64.51	64	49.6	75	63	78.93	16.48	56.02
Of which Sugars, g	0.9	1.125	1.26	0	1.35	6.69	2.6	Na	Na	0	3.1	1.4
Dietary Fibre, g	59	5.975	3.2	7.6	4.65	11	Na	Na	Na	0.8	10.4	15.25
Protein, g	19.5	9.70	6.8	9.20	11.98	5.5	19.7	5.8	12.3	7.30	40.72	13.41
Salt, g	0.127	0	0.0025	0.006	0.001	0	Na	0	0	0.007	0.005	0.003
Protein as % of Energy	26.7%	11.3%	7.5%	10.9%	14.0%	6,2%	23.8%	6.6%	13.1%	8.1%	36.2%	16.1%

*Source: FRIDA FoodDatabase version June 2023, Fitatu (for Chesnut, Millet, Chick Pea, and Oat) and Agrain technical datasheet

1.2.1.1 Representative product assessed

The LCA assesses a representative product, based on the flour produced in four years: 2019, 2020, 2021 and 2022. It is calculated as the average of the four years.

At the current stage of Agrain process maturity, a representative product reflects better the product profile, as it dilutes the processing variations between years , as well as the characteristics of the spent grain received. Also, as the period in which the production has been running has been heavily i by a global pandemic (COVID-19), and a European war (Ukraine), production efficiency has been impacted as incoming spent grains could have large variation dependent on access to malt, as well as whether society was open or not. Simultaneously, Agrain has as a company developed from start-up to scale up during the period, with all the insecurities during certain periods that this has. It is clear that as the production site matures, single years can be utilized as reference for the LCA calculations.

Agrain flour is to be compared to agricultural products from annual crops. According to the PEF method (European Commission, 2021), an assessment period of at least three years shall be used for annual crops, to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests and diseases, etc., for which it is mandatory to have several years observation in PEF.

1.2.2 Declared unit

The declared unit has been defined as:

- 1 kg of Agrain spent grain flour, unpacked

According to the “Guidance on the use of PEF for the food and drink sector” published in 2022 by the international sectorial association FoodDrinkEurope (2022), the functional unit should be expressed per weight or per volume depending on the reference used on the product packaging. Flour is inherently an intermediate product, making the use of a functional unit not applicable. As Agrain flour is sold by mass, the declared unit is expressed per weight. This is the same approach taken by Poore & Nemecek (2018), that assessed mass/volume units and nutrition units. This section approach is considered in section 4.3 when comparing Agrain in the framework of the food system.

This declared unit allows the comparison with substitution flour products.

1.2.3 SYSTEM BOUNDARY

The LCA has a cradle-to-gate approach, where all stages from spent grain acquisition to the gate are included. The system under study covers:

- Raw materials acquisition: Spent grain is a by-product of breweries
- Raw materials transport: Agrain collects the spent grain (with own vehicles or subcontracted) and transports it to its production site.
- Flour manufacturing: Once the spent grain has reached the production, it is processed following different steps, which are shown in Figure 1: it first goes into a screw press, where the moisture content is reduced to about 60-65% from the original 70-90%. At this stage the wet fraction (WF) is extracted. Currently it is not up-cycled but managed together with wastewater. In the scenarios defined in section 4 the environmental impact when both the flour and the liquid are generated and valorized is assessed. The spent grain then goes into a drying machine, where the grains are dried to a lower moisture content, about 7%. Finally, the material is grinded and transformed into the finished product, the spent grain flour. Currently, the process consumes electricity and natural gas.

The packaging has not been included. The flour can be used B2B as an ingredient for ready-to-eat products or B2C and it is a scalable process. Flour in B2B is usually delivered by trucks in silos which would be applicable to Agrain flour in the future. So current packaging is considered not representative of the product once scaled. Moreover, the datasets used for the comparison don't include the packaging.

As the product can be used for different purposes, downstream processes are not included in the system boundaries.

Other activities excluded from the LCA are:

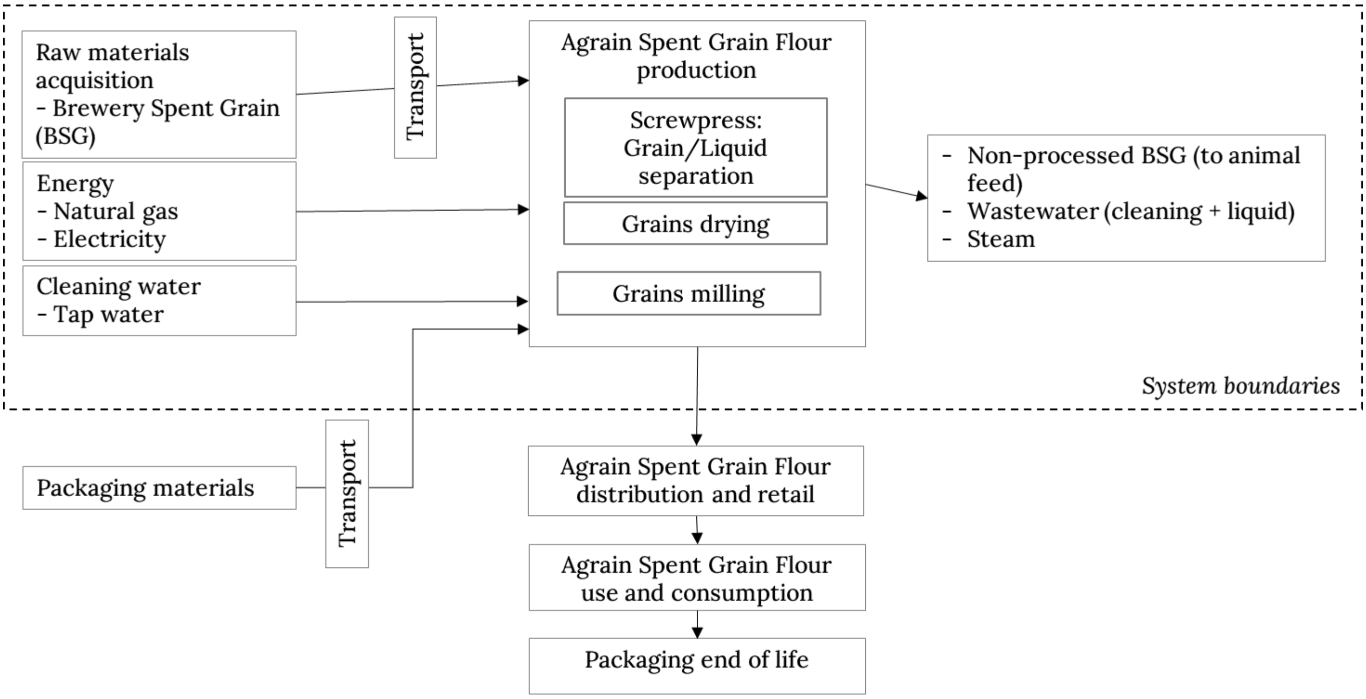
- Equipment
- Personnel-related processes:
  - Business travel of personnel
  - Travel to and from work by personnel
- Research and development and other supporting activities such as e.g. marketing & sales, finance, office activities, etc.

The lighting and the heating of the production site is part of the energy consumption and therefore included, however, equipment maintenance not.

However, if wanting to understand the CO2 emissions from other parts of Agrain, the Agrain Corporate Baseline report (incl. scope 1, 2, and 3) can be downloaded from the Agrain website: www.agrainproducts.com

The system boundaries defined allow the comparison with the substitution flour products.

Figure 1. Agrain flour (current production) system boundaries



1.2.4 CUT-OFF CRITERIA

All inputs and outputs to a unit process for which data are available have been included in the calculation. In case of insufficient input data or data gaps for a unit process, the cut-off criteria is limited to 1% of primary energy usage and 1% of the total mass input of that unit process, unless a material has the potential of causing significant emissions into the air, water, or soil or is known to be resource intensive. The total sum of neglected input flows is limited to 5% each of energy usage and mass.

1.2.5 ALLOCATION

Allocation in this LCA is performed according to ISO 14044, which is done in the following order of priority:

Step 1 – Avoid allocation by dividing the unit processes into sub-processes or expanding the product system to include additional functions.

Step 2 – Partitioning the inputs and outputs of the system between its different products or functions in a way that reflects the underlying physical relationships between them: when (i) there is a relevant underlying physical relationship between the products and co-products, and (ii) the difference in revenue per physical unit (for example mass or energy unit) from the products and co-products is low.

Step 3 – Partitioning the inputs and outputs of the system between its different products or functions in a way that reflects other relationships between them. Examples of this is economic value.

Agrain products use as raw material a side stream of other industries, such as breweries. Breweries produce beer but also spent grain, resulting in a multifunctional process. As an attributional approach assessment, a certain environmental impact is assigned to each product coming from the previous system.

In this LCA, spent grain is considered burden free as indicated by the beer PEFCR (European Commission, 2018a) and following the polluter pays principle. The proposed allocation modelling between beverages (beer) and other co-products (e.g. brewers' grain) is to "*avoid allocation, by putting 100% of the impact on beer if the co-products are used for animal feed purposes*." Agrain explores an alternative to keep the value of the co-product other than as animal feed in contraposition to an end-of-life situation. We thus find the PEFCR consideration valid for Agrain products assessment under the attributional approach. However, in the sensitivity analysis part we present the LCA results if an economic allocation method was utilized instead.

Process inputs and outputs when only flour is produced are mass allocated considering the total flour production.

1.2.5.1 Description of the polluter pays principle

For all generic data the system model 'Allocation, cut-off by classification - unit' is used. This model is based on the approach that primary production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. The consequence is that recyclable materials are available burden-free to recycling processes and secondary (recycled) materials bear only the impacts of the recycling processes. Also, producers of waste do not receive any credit for the recycling or re-use of products resulting out of any waste treatment. So, processes of waste processing shall be assigned to the product system that generates the waste until the end-of-waste state is reached.

1.2.6 Assumptions and limitations

Over the years it has been observed that BSG moisture content varies significantly, and so the fractions of the first part of the process, the screwpress, are not constant. For the years 2019, 2020 and 2021 a constant solid fraction to the dryer of 60% and an output of 20% was assumed, as no specific data was available. The solid and liquid flows along the process were calculated based on theoretical data, which is a limitation of current LCA inventory data. In 2022 it is being solved by improving process flows monitoring. In this year it showed a 12% valorization (see Table 2). In Table 2, we show that incoming spent grains increased over the 4 years by 348%; however, during the same years, we also had an increase in wasted spent grains that were used as feed (only 46% of picked up spent grains were processed). It is therefore expected that the LCA of the flour will be less good for year 2022. When expanding the site, these variations will be reduced. Moreover, a close to 95% utilization of spent grains have already been achieved in 2023, meaning that improvements will already be seen when repeating the LCA analysis next year. In the Table below, year 2019 is used as baseline for the index, and all following years are calculated based on percentage increase in relation to year 2019 (the index=100).

Table 2. Yearly variation in incoming, processed and valorization, using 2019 data as baseline (index=100)

	2019	2020	2021	2022
Incoming spent grain index	100	108	213	348
Percentage spent grain processed of incoming	82%	73%	70%	46%
Percentage valorization	20%	20%	20%	12%

Due to the small number issues which influence the environmental impact of the Agrain site, we will therefore present in the sensitivity analysis how only taking year 2022 as reference influences results, as compared to the representative product assessed.

Once at the dryer the moisture content is more stable, with a calculated 66% of the output as steam and 33% the flour (before grinding).

Regarding electricity modelling, Agrain is located in a leased production facility, where electricity from the grid is consumed. Landlord was contacted and three named electricity suppliers over the 4 years of observation was identified in the invoices to landlord, where Agrain electricity usages is part of. These three electricity providers were contacted, whereas the first two reported to have been delivering the electricity grid as reported on governmental websites, the last supplier from sept.

2022 reported a 100% wind supply, also explicitly mentioned on invoices to landlord. In the current assessment, and based on its purpose, electricity consumed in the facility was modelled using the Ecoinvent Danish medium voltage dataset as average grid mix. This approach has been chosen for the following reasons:

- It allows us to assess the representative product considering primary inventory data variations but not datasets variation. We want to make it as representable as possible for the product, not taking individual years reflections from energy mixes into account (e.g. reflections from nature impact on solar and wind, political instability, other buyers of green credits in certain years, etc).
- Currently Agrain does not have control over the contract with which electricity provider the landlord chooses.
- As the LCA is based on a representative product across 4 years the market consumption fits analysis best.
- In future it can be representable if e.g., purchase of green energy has been specifically assured by contracting this with landlord and electricity supplier (as also presented in future strategies).
- Comparisons made in the LCA (i.e.., on the other flours and Poore data) are made utilizing the same assumptions and system boundaries, which is required for a comparison. They use grid mix Ecoinvent datasets. If changing away from market database mix, the comparison would not be accurate, as the assumptions on electricity calculation would be different.

In the sensitivity analysis the flour is assessed considering the residual mix of Denmark for the years assessed, reflecting the electricity consumption of the country excluding any previously claimed attributed electricity.

The energy mix considered by the dataset used is:

- Wind: 37.40%
- Hydro: 17.06%
- Hard coal: 16.67%
- Biomass: 10.20%
- Nuclear: 6.90%
- Natural gas: 5.32%
- Lignite: 3.66%
- Biogas: 1.68%
- Municipal solid waste: 0.83%
- Oil: 0.21%
- Blast furnace gas: 0.04%
- Peat: 0.02%

- Coal gas: 0.01%
- Geothermal: 0.004%

Besides the inventory data assumptions, all hypotheses considered by the database are assumed to be valid. The LCA database Ecoinvent 3.8 (Wernet et al, 2016) available in Simapro 9.4.0.2 has been used to model upstream processes.

Agrain flour is compared with alternative flours. Limitations regarding the data variation between datasets and databases and nutritional values were detected.

1.2.7 Life cycle impact assessment

The results are presented at the characterization, normalization and weighting level.

The LCA was calculated including the following PEF impact categories using the method EF 3.0 Method (adapted) V.1.03 EF 3.0, available in Simapro 9.4.0.2.

Table 3. List of the PEF impact categories and methods used

Method	Impact Category	Description (European Commission, n.d., Huijbregts et al, 2017a and 2017b)
Bern model – Global Warming Potentials (GWP) over a 100 year time horizon (based on IPCC 2013)	Climate change	This indicator refers to the increase in the average global temperatures as result of greenhouse gas (GHG) emissions. The greatest contributor is generally the combustion of fossil fuels such as coal, oil, and natural gas. The global warming potential of all GHG emissions is measured in kilogram of carbon dioxide equivalent (kg CO2 eq), namely all GHG are compared to the amount of the global warming potential of 1 kg of CO2 .
EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time horizon (WMO 2014 + integrations)	Ozone depletion	The stratospheric ozone (O3) layer protects us from hazardous ultraviolet radiation (UV-B). Its depletion increases skin cancer cases in humans and damage to plants. The potential impacts of all relevant substances for ozone depletion are converted to their equivalent of kilograms of trichlorofluoromethane (also called Freon11 and R-11), hence the unit of measurement is in kilogram of CFC-11 equivalent (kg CFC-11 eq).
Human health effect model as developed	Ionising radiation	The exposure to ionising radiation (radioactivity) can have impacts on human health. The Environmental Footprint only considers

by Dreicer et al. 1995 (Frischknecht et al, 2000)		emissions under normal operating conditions (no accidents in nuclear plants are considered). The potential impact on human health of different ionising radiations is converted to the equivalent of kilobequerels of Uranium 235 (kg U235 eq).
LOTOS-EUROS model (Van Zelm et al, 2008) as applied in ReCiPe 2008	Photochemical ozone formation	Ozone (O3) on the ground (in the troposphere) is harmful: it attacks organic compounds in animals and plants, it increases the frequency of respiratory problems when photochemical smog ("summer smog") is present in cities. The potential impact of substances contributing to photochemical ozone formation is converted into the equivalent of kilograms of Non-Methane Volatile Organic Compounds (e.g. alcohols, aromatics, etc.; kg NMVOC eq).
PM model (Fantke et al., 2016 in UNEP 2016)	Particulate matter	This indicator measures the adverse impacts on human health caused by emissions of Particulate Matter (PM) and its precursors (e.g. NOx , SO2). Usually, the smaller the particles, the more dangerous they are, as they can go deeper into the lungs. The potential impact of is measured as the change in mortality due to PM emissions, expressed as disease incidence per kg of PM2.5 emitted.
based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018	Human toxicity, non-cancer	This indicator refers to potential impacts on human health caused by absorbing substances through the air, water, and soil. Direct effects of products on humans are currently not measured. The unit of measurement is Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.
based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018	Human toxicity, cancer	This indicator refers to potential impacts on human health caused by absorbing substances through the air, water and soil. Direct effects of products on humans are currently not measured. The unit of measurement is Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.
Accumulated Exceedance (Seppälä et al.	Acidification	Acidification has contributed to a decline of coniferous forests and an increase in fish mortality. Acidification can be caused by emissions getting into the air, water and soil.

2006, Posch et al, 2008)		The most significant sources are combustion processes in electricity, heating production, and transport. The contribution to acidification is greatest when the fuels contain a high level of sulphur. The potential impact of substances contributing to acidification is converted to the equivalent of moles of hydron (general name for a cationic form of atomic hydrogen, mol H+ eq).
EUTREND model (Struijs et al, 2009) as applied in ReCiPe	Eutrophication, freshwater	Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). If algae grows too rapidly, it can leave water without enough oxygen for fish to survive. Nitrogen emissions into the aquatic environment are caused largely by fertilizers used in agriculture, but also by combustion processes. The most significant sources of phosphorus emissions are sewage treatment plants for urban and industrial effluents and leaching from agricultural land. The potential impact of substances contributing to freshwater eutrophication is converted to the equivalent of kilograms of phosphorus (kg P eq).
EUTREND model (Struijs et al, 2009) as applied in ReCiPe	Eutrophication, marine	Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). As a rule, the availability of one of these nutrients will be a limiting factor for growth in the ecosystem, and if this nutrient is added, the growth of algae or specific plants will be increased. For the marine environment this will be mainly due to an increase of nitrogen (N). Nitrogen emissions are caused largely by the agricultural use of fertilisers, but also by combustion processes. The potential impact of substances contributing to marine eutrophication is converted to the equivalent of kilograms of nitrogen (kg N eq).
Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	Eutrophication, terrestrial	Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). These nutrients cause a growth of algae or specific plants and limit growth in the original ecosystem. The potential impact of substances contributing to terrestrial

		eutrophication is converted to the equivalent of moles of nitrogen (mol N eq).
based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018	Ecotoxicity, freshwater	This indicator refers to potential toxic impacts on an ecosystem, which may damage individual species as well as the functioning of the ecosystem. Some substances have a tendency to accumulate in living organisms. The unit of measurement is Comparative Toxic Unit for ecosystems (CTUe). This is based on a model called USEtox.
Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Maier, 2018)	Land use	Use and transformation of land for agriculture, roads, housing, mining or other purposes. The impacts can vary and include loss of species, of the organic matter content of soil, or loss of the soil itself (erosion). This is a composite indicator measuring impacts on four soil properties (biotic production, erosion resistance, groundwater regeneration and mechanical filtration), expressed in points (Pts).
Available WAter REmaining (AWARE) model (Boulay et al., 2018; UNEP 2016)	Water use	The withdrawal of water from lakes, rivers or groundwater can contribute to the 'depletion' of available water. The impact category considers the availability or scarcity of water in the regions where the activity takes place, if this information is known. The potential impact is expressed in cubic metres (m3) of water use related to the local scarcity of water.
van Oers et al., 2002 as in CML 2002 method, v.4.8	Resource use, fossils	The earth contains a finite amount of nonrenewable resources, such as fossil fuels like coal, oil and gas. The basic idea behind this impact category is that extracting resources today will force future generations to extract less or different resources. For example, the depletion of fossil fuels may lead to the non-availability of fossil fuels for future generations. The amount of materials contributing to resource use, fossils, are converted into MJ.
van Oers et al., 2002 as in CML 2002 method, v.4.8	Resource use, minerals and metals	The basic idea behind this impact category is the same as the one behind the impact category resource use, fossils (namely, extracting a high concentration of resources today will force future generations to extract lower concentration or lower value resources). The

		amount of materials contributing to resource depletion are converted into equivalents of kilograms of antimony (kg Sb eq).
ReCiPe 2016 Midpoint (H) V1.07	Water consumption	Water consumption is the use of water in such a way that the water is evaporated, incorporated into products, transferred to other watersheds or disposed into the sea (Falkenmark et al. 2004). Water that has been consumed is thus not available anymore in the watershed of origin for humans nor for ecosystems.
ReCiPe 2016 Midpoint (H) V1.07	Land use	The land use impact category reflects the damage to ecosystems due to the effects of occupation and transformation of land. The midpoint characterisation factors (in m2·yr annual crop equivalents) refer to the relative species loss caused by a specific land use type (annual crops, permanent crops, mosaic agriculture, forestry, urban land, pasture).

The full list of normalization factors and weighting factors used from EF 3.0 are presented in Table 4.

Table 4. EF 3.0 Normalization and Weighting factors used per Characterization impact category

Characterization		Normalization			Weighting	
Impact category	Unit	Impact category	Unit	Factor	Impact category	Weighting factors (%)
Climate change	kg CO2 eq	NF Climate change	kg CO_2 eq./person	8.10E+03	Climate change	21.06
Ozone depletion	kg CFC11 eq	NF Ozone depletion	kg CFC-11 eq./person	5.36E-02	Ozone depletion	6.31
Ionising radiation	kBq U-235 eq	NF Ionising radiation	kBq U-235 eq./person	4.22E+03	Ionising radiation, human health	5.01
Photochemical ozone formation	kg NMVOC eq	NF Photochemical ozone formation	kg NMVOC eq./person	4.06E+01	Photochemical ozone formation - human health	4.78

Particulate matter	disease inc.	NF Particulate matter	disease incidences /person	5.95E-04	Particulate matter	8.96
Human toxicity, non-cancer	CTUh	NF Human toxicity, non-cancer	CTUh/person	2.30E-04	Human toxicity, non-cancer	1.84
Human toxicity, cancer	CTUh	NF Human toxicity, cancer	CTUh/person	1.69E-05	Human toxicity, cancer	2.13
Acidification	mol H+ eq	NF Acidification	mol H+ eq./person	5.56E+01	Acidification	6.20
Eutrophication, freshwater	kg P eq	NF Freshwater eutrophication	kg P eq./person	1.61E+00	Eutrophication, freshwater	2.80
Eutrophication, marine	kg N eq	NF Marine Eutrophication	kg N eq./person	1.95E+01	Eutrophication, marine	2.96
Eutrophication, terrestrial	mol N eq	NF Terrestrial eutrophication	mol N eq./person	1.77E+02	Eutrophication, terrestrial	3.71
Ecotoxicity, freshwater	CTUe	NF Ecotoxicity freshwater	CTUe/person	4.27E+04	Ecotoxicity, freshwater	1.92
Land use	Pt	NF Land use	pt/person	8.19E+05	Land use	7.94
Water use	m3 depriv.	NF Water use	m^3 water eq of deprived water/person	1.15E+04	Water use	8.51
Resource use, fossils	MJ	NF Resource depletion, fossils	MJ/person	6.50E+04	Resource use, fossils	8.32

Resource use, minerals and metals	kg Sb eq	NF Resource depletion, minerals and metals	kg Sb eq./person	6.36E-02	Resource use, minerals and metals	7.55

Moreover, a water consumption indicator (without considering scarcity) and a land use category expressed considering temporality and area are assessed:

- Water consumption (m^3) from the method ReCiPe 2016 Midpoint (H) V1.07
- Land use (m^2crop eq) from the method ReCiPe 2016 Midpoint (H) V1.07

These methods were used for both Agrain flour and the substitution flour products.

1.2.8 Critical review type

A post-study (a posteriori) critical review by an external and independent panel of reviewers was performed after completion of the study. The critical review was performed against the requirements of ISO 14040:2006, ISO 14044:2006 and ISO 14071:2016. The critical review panel is formed by:

- Julie M. V. Larsen, LCA & EPD Consultant, Chair person
- Odyssefs Papagiannidis, LCA & EPD Consultant
- Waldemar C. Hemdrup, LCA & EPD Consultant

All critical review panel members work for Bureau Veritas HSE Denmark.

2. Life cycle inventory

2.1 Data requirements

An LCA calculation requires two different kinds of information:

- data related to the environmental aspects of the considered system (such materials or energy flows that enter the production system), usually from the company that is performing the LCA calculation.
- data related to the life cycle impacts of the material or energy flows that enter the production system, usually from databases.

Specific data has been collected for the years 2019, 2020, 2021 and 2022, following the same methodology and, if the operative was improved, with more accurate data based on records. The production site is at Gummermarksvej 7a, 4632 Bjæverskov (Denmark).

The data requirements considered in order to perform this LCA are:

- Specific data: input and output flows from the manufacturing process for the years assessed and coming from reported data. Specific data refers to:
  - BSG transport: distance and means of transport
  - Processes and non-processed BSG
  - Energy and water consumption
  - Flour production
- Generic data: Data that is not based on measures or direct calculations for the specific processes or activities of the company, but is obtained from a database or from other sources. Ecoinvent database version 3.8, Allocation, cut-off by classification (2021) included in the LCA software Simapro 9.4.0.2 has been used as secondary data. It has been used for:
  - Energy production
  - Transport
  - Water supply
  - Wastewater treatment

Agribalyse 3.0 database (2020), together with Ecoinvent, and also included in the LCA software Simapro 9.4.0.2, has been used as secondary data to assess the substitution flours.

2.2 INVENTORY DATA

In Table 5, the average inventory data for the four years assessed is presented together with the Ecoinvent dataset or elementary flow selected. In addition, index values for each of the years in the data is presented. Where the actual data in 2019 has been asserted as index 100, and each of the following years counted either as increase or decrease in comparison to the indexed year 2019.

Agrain flour carbon content is 1.705 kg CO_2/kg of flour, modelled with the elementary flow "Carbon dioxide, in air (raw)".

Table 5. Inventory data considered to model the Agrain flour assessed, per declared unit and index per year, where 2019 is defined as baseline (index=100).

Process	Units	Amount per declared unit	2019 index	2020 index	2021 index	2022 index	Ecoinvent dataset/Elementary flow
Flour produced	Kg	1	100	-3,4	83,2	13,1	
BSG Input	Kg	9.74	100	8,2	113,6	248,9	Burden free
BSG transport	Tkm	0.57	100	56,2	164,2	219,3	Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO5 | Cut-off, U
BSG processed	Kg	5.90	100	-3,4	83,2	94,8	Internal flow
Natural gas	MJ	6.37	100	-9,6	-15,0	89,2	Heat, central or small-scale, natural gas {Europe without Switzerland}| market for heat, central or small-scale, natural gas | Cut-off, U
Electricity	kWh	0.84	100	33,3	108,6	96,5	Electricity, medium voltage {DK}| market for | Cut-off, U
Water use	Litres	3.33	100	8,2	113,6	104,9	Tap water {Europe without Switzerland}| market for | Cut-off, U
Wastewater_water	Litres	3.33	100	8,2	113,6	104,9	Wastewater, unpolluted {CH}| market for wastewater, unpolluted | Cut-off, U
Wastewater_liquid	Litres	2.90	100	-3,4	83,2	217,3	Wastewater, unpolluted {CH}| market for wastewater, unpolluted | Cut-off, U
Transport of BSG to farms	Tkm	0.06	100	60,4	250,1	940,8	Transport, freight, lorry >32 metric ton, EURO5 {RER}| transport, freight, lorry >32 metric ton, EURO5 | Cut-off, U
BSG at farm	Kg	3.84	100	60,4	250,1	940,8	Burden free
Steam output	Kg	2	100	-3,4	83,2	13,1	Water

2.2 DATA QUALITY ASSESSMENT

This study has taken into account the data quality requirements established by ISO 14044, covering technological, geographical and time-related representativeness.

The data quality is in all cases rated as “Very good = 1”, “Good = 2”, “Fair = 3”, “Poor = 4” and “Very Poor = 5”. Only data from Ecoinvent 3.8 have been used and validated in the LCA software Simapro 9.4.0.2 version. Specific production data in Bjæverskov facility have been used referring to annual data.

Table 6. Level of Data Quality

Quality level	Geographical representativeness	Technical representativeness	Time representativeness
Very Good = 1	Data from an area under study	Data from processes and products under study. The same state of technology applied as defined in the goal and scope.	Less than 3 years difference between the reference year according to the documentation, and the time period for which data are representative.
Good = 2	Average data from a larger area in which the area under study includes.	Data from processes and products under study (with similar technology). Evidence of deviations in state of technology, e.g. different by-product.	Less than 6 years of difference between the reference year according to the documentation, and the time period for which data are representative.
Fair = 3	Data from an area with similar production conditions.	Data from processes and products under study but from different technology.	Less than 10 years of difference between the reference year according to the documentation, and the time period for which data are representative.
Poor = 4	Data from an area with slightly similar production conditions.	Data on related processes or products; for example, organic wheat under study. Data for organic rye provided.	Less than 15 years of difference between the reference year according to the documentation, and the time period for which data are representative.
Very Poor = 5	Data from unknown or distinctly different area (North America instead of Middle East, OECD-Europe insteard of Russia).	Data on related processes on but with a different scale or from different technology; for example organic wheat under study, data for conventional wheat provided.	Age of data unknown or more than 15 years of difference between the reference year according to the documentation, and the time period for which data are representative.

In the following table data quality is assessed considering the processes as they are modelled for the representative product but also for the scenarios assessment and the cradle to retail assessment.

Table 7. Data quality assessment

Process	Ecoinvent dataset/Elementary flow	Time period of the dataset from Ecoinvent	Dataset extrapolated from year:	Time of the data collected	Geographical representativeness	Technical representativeness	Time representativeness
Representative product							
BSG Input	Burden free	-	-	-	-	-	-
BSG transport	Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO5 | Cut-off, U	2009-2022	2013	2019-2022	2	2	1
BSG processed	Internal flow	-	-	-	-	-	-
Natural gas	Heat, central or small-scale, natural gas {Europe without Switzerland}| market for heat, central or small-scale, natural gas | Cut-off, U	2011-2022	2011	2019-2022	2	1	1
Electricity	Electricity, medium voltage {DK}| market for | Cut-off, U	2014-2022	2017	2019-2022	1	2	1
Water use	Tap water {Europe without Switzerland}| market for | Cut-off, U	2012-2022	2012	2019-2022	2	2	1
Wastewater_water	Wastewater, unpolluted {CH}| market for wastewater, unpolluted | Cut-off, U	2011-2022	2011	2019-2022	2	2	1
Wastewater_liquid	Wastewater, unpolluted {CH}| market for wastewater, unpolluted | Cut-off, U	2011-2022	2011	2019-2022	2	2	1
Transport of BSG to farms	Transport, freight, lorry >32 metric ton, EURO5 {RER}| transport, freight, lorry >32 metric ton, EURO5 | Cut-off, U	2009-2022	2013	2019-2022	2	2	1
BSG at farm	Burden free	-	-	2019-2022	-	-	-
Steam output	Water	-	-	2019-2022	-	-	-
Product carbon content	Carbon dioxide, in air (raw)	-	-	2019-2022	-	-	-
Additional for the scenarios assessment							

Renewable electricity	Electricity, high voltage {DK}| electricity production, wind, <1MW turbine, onshore | Cut-off, U	2000-2022	2015	2019-2022	1	2	1
Packaging							
Kraft	Kraft paper {RER}| market for kraft paper | Cut-off, U	2015-2022	2020	2022	2	2	1
LDPE film	Packaging film, low density polyethylene {GLO}| market for | Cut-off, U	2011-2022	2011	2022	2	2	1
Paper white	Printed paper {GLO}| market for | Cut-off, U	2002-2022	2006	2022	2	2	1
PET	Polyethylene terephthalate, granulate, amorphous {GLO}| market for | Cut-off, U	2011-2022	2011	2022	2	2	1
Transport	Transport, freight, lorry >32 metric ton, EURO5 {RER}| transport, freight, lorry >32 metric ton, EURO5 | Cut-off, U	2009-2022	2013	2022	2	2	1
Logistics							
Transport Agrain - Distribution centre	Transport, freight, lorry 7.5-16 metric ton, EURO5 {RER}| transport, freight, lorry 7.5-16 metric ton, EURO5 | Cut-off, U	2009-2022	2013	2022	2	2	1
Transport Distribution centre - Retail	Transport, freight, lorry >32 metric ton, EURO5 {RER}| transport, freight, lorry >32 metric ton, EURO5 | Cut-off, U	2009-2022	2013	2020 (European Commission, 2020)	2	2	1
Retail							
Electricity	Electricity, low voltage {RER}| market group for | Cut-off, U	2015-2022	2015	2018 (European Commission, 2018b)	1	2	1
Tap water	Tap water {RER}| market group for | Cut-off, U	2015-2022	2015	2018 (European Commission, 2018b)	2	2	1
Wastewater	Wastewater, from residence {CH}| market for wastewater, from residence | Cut-off, U	2011-2022	2011	2018 (European Commission, 2018b)	2	2	1

3. LIFE CYCLE IMPACT ASSESSMENT

According to the ISO 14040, the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

The results are presented per declared unit, 1 kg of Agrain spent grain flour, unpacked. They are presented at the characterization, normalization and weighting level.

Table 8. Characterized values for the declared unit, per year and the representative product

Impact category	Units	Agrain flour 2019	Agrain flour 2020	Agrain flour 2021	Agrain flour 2022	Representa tive product
Climate change	kg CO2 eq	8.37E-01	9.80E-01	6.79E-01	1.62E+00	1.03E+00
Ozone depletion	kg CFC11 eq	9.26E-08	1.14E-07	8.28E-08	2.01E-07	1.23E-07
Ionising radiation	kBq U-235 eq	3.38E-02	4.80E-02	4.00E-02	7.13E-02	4.83E-02
Photochemical ozone formation	kg NMVOC eq	1.51E-03	2.01E-03	1.58E-03	3.31E-03	2.10E-03
Particulate matter	disease inc.	1.70E-08	2.49E-08	2.11E-08	4.23E-08	2.63E-08
Human toxicity, non-cancer	CTUh	5.52E-09	7.56E-09	6.12E-09	1.20E-08	7.81E-09
Human toxicity, cancer	CTUh	2.70E-10	3.50E-10	2.70E-10	5.71E-10	3.65E-10
Acidification	mol H+ eq	1.88E-03	2.51E-03	1.97E-03	4.00E-03	2.59E-03
Eutrophication, freshwater	kg P eq	1.87E-05	2.54E-05	2.07E-05	3.43E-05	2.47E-05
Eutrophication, marine	kg N eq	4.08E-04	5.61E-04	4.53E-04	9.11E-04	5.83E-04
Eutrophication, terrestrial	mol N eq	4.80E-03	6.61E-03	5.35E-03	1.06E-02	6.84E-03
Ecotoxicity, freshwater	CTUe	8.76E+00	1.14E+01	8.88E+00	1.76E+01	1.17E+01
Land use	Pt	4.73E+00	6.70E+00	5.60E+00	9.75E+00	6.70E+00
Water use	m3 depriv.	1.51E-01	1.80E-01	1.74E-01	2.78E-01	1.96E-01
Resource use, fossils	MJ	1.24E+01	1.45E+01	9.98E+00	2.40E+01	1.52E+01

Resource use, minerals and metals	kg Sb eq	2.41E-06	3.31E-06	2.67E-06	5.33E-06	3.43E-06
Climate change – Fossil	kg CO2 eq	8.35E-01	9.77E-01	6.76E-01	1.62E+00	1.03E+00
Climate change – Biogenic	kg CO2 eq	1.77E-03	2.40E-03	1.96E-03	3.16E-03	2.32E-03
Climate change - Land use and LU change	kg CO2 eq	5.25E-04	7.24E-04	5.93E-04	1.02E-03	7.16E-04

Normalized life cycle impact assessment results express the relative shares of the impacts of the analysed system, in terms of the total contributions to each impact category per capita. Normalized results are dimensionless.

Table 9. Normalized values for the declared unit, per year and the representative product, dimensionless

Impact category	Agrain flour 2019	Agrain flour 2020	Agrain flour 2021	Agrain flour 2022	Representative product
Climate change	1.03E-04	1.21E-04	8.39E-05	2.00E-04	1.27E-04
Ozone depletion	1.73E-06	2.13E-06	1.54E-06	3.74E-06	2.28E-06
Ionising radiation	8.01E-06	1.14E-05	9.47E-06	1.69E-05	1.14E-05
Photochemical ozone formation	3.72E-05	4.95E-05	3.88E-05	8.16E-05	5.18E-05
Particulate matter	2.85E-05	4.19E-05	3.55E-05	7.10E-05	4.42E-05
Human toxicity, non-cancer	2.40E-05	3.29E-05	2.67E-05	5.25E-05	3.40E-05
Human toxicity, cancer	1.60E-05	2.07E-05	1.60E-05	3.38E-05	2.16E-05
Acidification	3.39E-05	4.51E-05	3.55E-05	7.21E-05	4.66E-05
Eutrophication, freshwater	1.16E-05	1.58E-05	1.29E-05	2.13E-05	1.54E-05
Eutrophication, marine	2.09E-05	2.87E-05	2.32E-05	4.66E-05	2.98E-05
Eutrophication, terrestrial	2.72E-05	3.74E-05	3.03E-05	5.99E-05	3.87E-05
Ecotoxicity, freshwater	2.05E-04	2.68E-04	2.08E-04	4.12E-04	2.73E-04
Land use	5.77E-06	8.18E-06	6.84E-06	1.19E-05	8.17E-06
Water use	1.31E-05	1.57E-05	1.52E-05	2.43E-05	1.71E-05
Resource use, fossils	1.90E-04	2.22E-04	1.54E-04	3.69E-04	2.34E-04

Resource use, minerals and metals	3.79E-05	5.20E-05	4.20E-05	8.38E-05	5.39E-05

Weighted results support the interpretation and communication of the analysis results, which reflect the perceived relative importance of the impact categories considered.

Table 10. Weighted values for the declared unit, per year and the representative product, Pt

Impact category	Agrain flour 2019	Agrain flour 2020	Agrain flour 2021	Agrain flour 2022	Representative product	Impact category contribution to the average (%)	Std.Dev
Climate change	2.18E-05	2.55E-05	1.77E-05	4.21E-05	2.68E-05	37.42%	1.07E-05
Ozone depletion	1.09E-07	1.34E-07	9.74E-08	2.36E-07	1.44E-07	0.20%	6.31E-08
Ionising radiation	4.01E-07	5.70E-07	4.75E-07	8.46E-07	5.73E-07	0.80%	1.95E-07
Photochemical ozone formation	1.78E-06	2.37E-06	1.86E-06	3.90E-06	2.47E-06	3.46%	9.86E-07
Particulate matter	2.55E-06	3.75E-06	3.18E-06	6.36E-06	3.96E-06	5.54%	1.67E-06
Human toxicity, non-cancer	4.42E-07	6.06E-07	4.90E-07	9.65E-07	6.26E-07	0.88%	2.36E-07
Human toxicity, cancer	3.41E-07	4.41E-07	3.41E-07	7.20E-07	4.61E-07	0.64%	1.79E-07
Acidification	2.10E-06	2.80E-06	2.20E-06	4.47E-06	2.89E-06	4.05%	1.09E-06
Eutrophication, freshwater	3.25E-07	4.43E-07	3.60E-07	5.97E-07	4.31E-07	0.60%	1.21E-07
Eutrophication, marine	6.18E-07	8.50E-07	6.86E-07	1.38E-06	8.83E-07	1.24%	3.45E-07
Eutrophication, terrestrial	1.01E-06	1.39E-06	1.12E-06	2.22E-06	1.44E-06	2.01%	5.48E-07
Ecotoxicity, freshwater	3.94E-06	5.14E-06	3.99E-06	7.92E-06	5.25E-06	7.34%	1.86E-06
Land use	4.58E-07	6.49E-07	5.43E-07	9.45E-07	6.49E-07	0.91%	2.12E-07
Water use	1.12E-06	1.34E-06	1.29E-06	2.07E-06	1.45E-06	2.03%	4.19E-07
Resource use, fossils	1.58E-05	1.85E-05	1.28E-05	3.07E-05	1.94E-05	27.19%	7.84E-06

Resource use, minerals and metals	2.86E-06	3.93E-06	3.17E-06	6.33E-06	4.07E-06	5.69%	1.57E-06
SINGLE OVERALL SCORE	5.57E-05	6.84E-05	5.02E-05	1.12E-04	7.15E-05		2.79E-05

4. INTERPRETATION

4.1 AGRAIN FLOUR LCA RESULTS AND SUBSTITUTE FLOUR COMPARISON

4.1.1 SUMMARY OF MOST RELEVANT IMPACT CATEGORIES

To identify which categories are important to investigate, the PEF weighted results were used, see Table 10 above.

To determine the most relevant impact categories for Agrain flour, the representative product was used. For the substitution products we do an average based on datasets available for flour products from two databases, a) based on Ecoinvent 3.8 dataset which includes 3 observations but from an original source from South Africa and b) the Agribalyse 3.0 database which has information on 10 different flours. All datasets selected have a cradle to gate (unpacked) scope, the same system boundaries as Agrain flour and, the inventory data come from recognized LCA databases, which ensures the inclusion of the life cycle perspective to be used in the comparison. Ecoinvent 3.8 was published in 2021 while Agribalyse 3.0 in 2020.

The most relevant impact categories from the PEF weighted results are used to compare with Agrain flour. In Table A.1 in Appendix individual calculations per substitution product are presented.

The PEF weighted values approach to identifying important categories to report ensures that the data demonstrates the significance of impacts, aspects and performance from a life-cycle perspective[1]. Hereunder, that it takes into account all significant impacts to assess the environmental performance; it provides information on whether the product performs environmentally significantly better than what is common practice for substitution products; it identifies whether a positive achievement leads to significant worsening of another impact (this we will highlight below);and it includes accurate primary or secondary information.

[1] Disclaimer: According to ISO 14044, weighting shall not be used in comparative assertions intended to be disclosed to the public. So this part, where weighting results are used for the comparison, does not follow the standard for LCA meant for the public.

Therefore, the PEF weights guide Agrain in clearly indicating which categories are most important to assess at the characterized level. In addition it presents, how both the PEF weights from Agrains own circular food production and the substituting flours, from large scale industrial linear food productions, are assessed. Furthermore, the PEF weighted results allow us to identify trade-offs as well as unintended burden shifting.

Figure 2. Agrain Flour and Substitution flours PEF weighted results (Cradle to gate), Pt per 1 kg of flour in totals

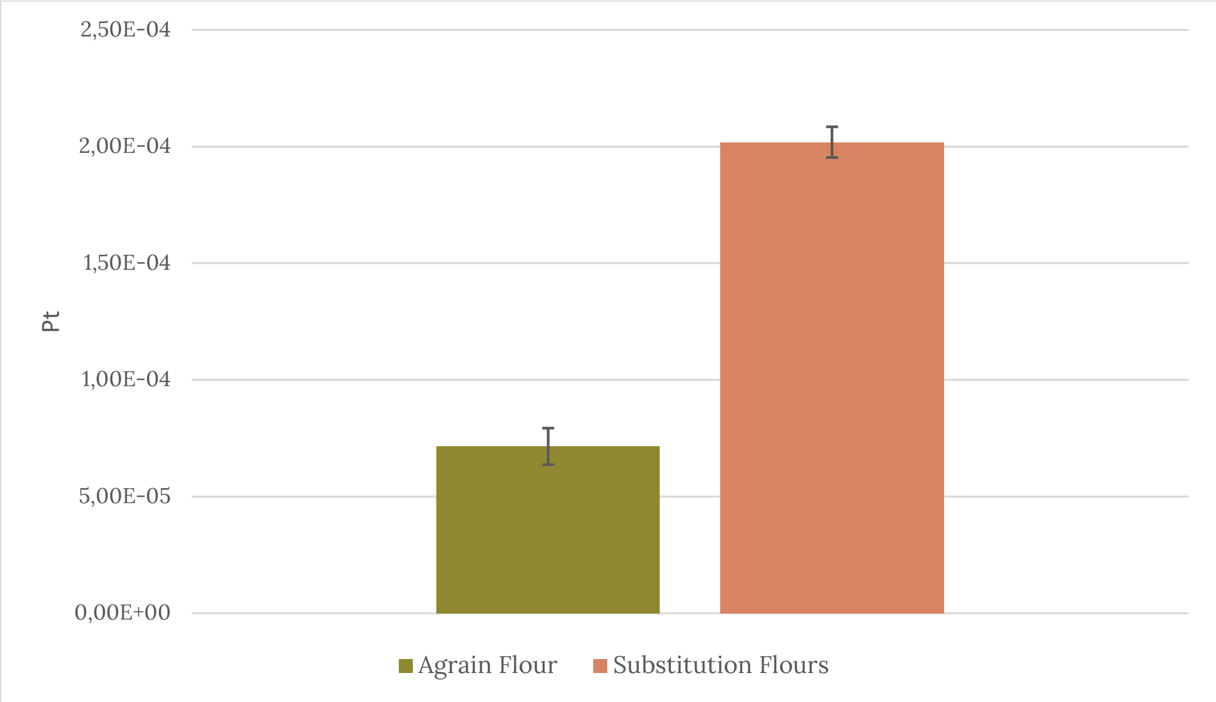
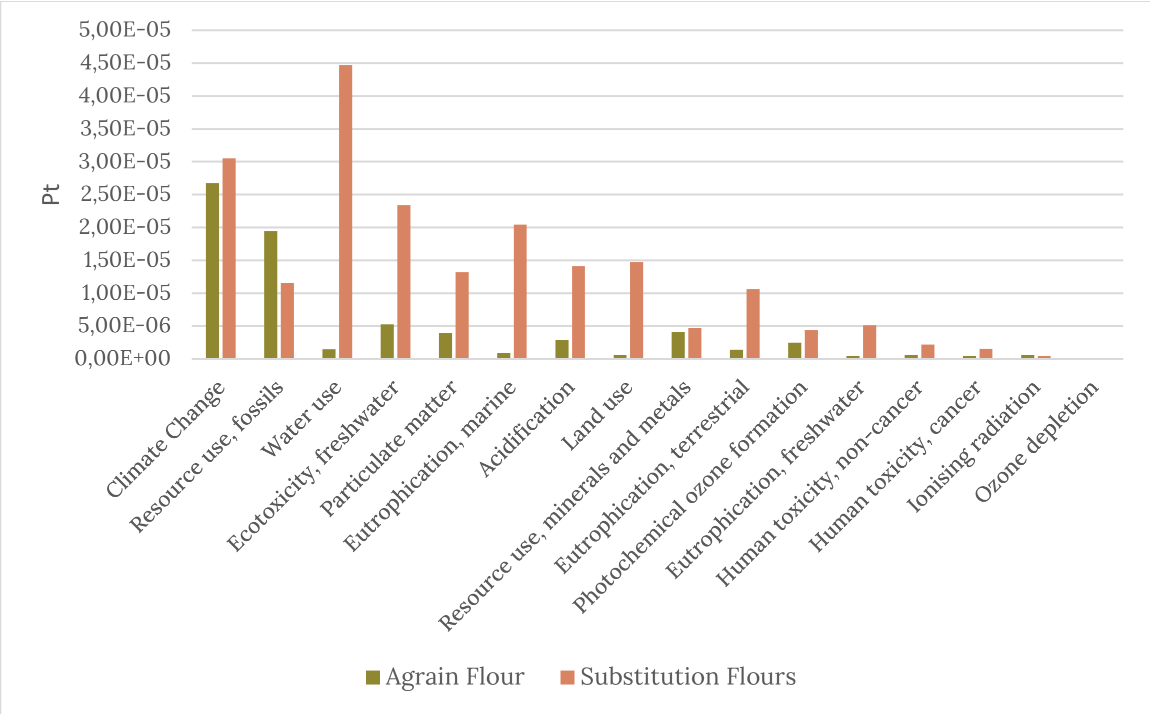


Figure 3. Agrain Flour and Substitution flours PEF weighted results (Cradle to gate), Pt per 1 kg of flour by impact category



Initially, if we look at the total PEF weighted value (see Figure 2), the results show that despite Agrain production being still in its early years – measuring environmental impact from the very first day of production- one kg of flour produced at the site has significantly less impact than the average comparison flour (substitution flour on average=202µPt; Agrain representative flour: 71.5µPt).

The results also clearly show that the most relevant impact categories are different depending on Agrain's up-cycled food production producing the Agrain flours, and the alternative linear food production, which the substitution flours represent.

The impact categories that are the most influential for the substitution flours are 1) Water use (22.16%), 2) Climate change (15.11%), 3) Ecotoxicity, freshwater (11.59%), 4) Eutrophication, marine (10.13%), 5) Land-use (7.29%), 6) Acidification (6.99%), 7) Particulate Matter (6.53%), and 8) Resource use (fossils) (5.74%) that in sum account for 85.54% of the single overall score. These are therefore the impact categories that according to the PEF method are reported (PEF method states that impact categories cumulatively contributing at least 80% of the single overall score are the most relevant (European Commission, 2021)). For reference, see Table A.2 in Appendix for contribution of each impact category to the PEF weighted results, and Table A.1 in Appendix on each of the substitution flours in the comparison.

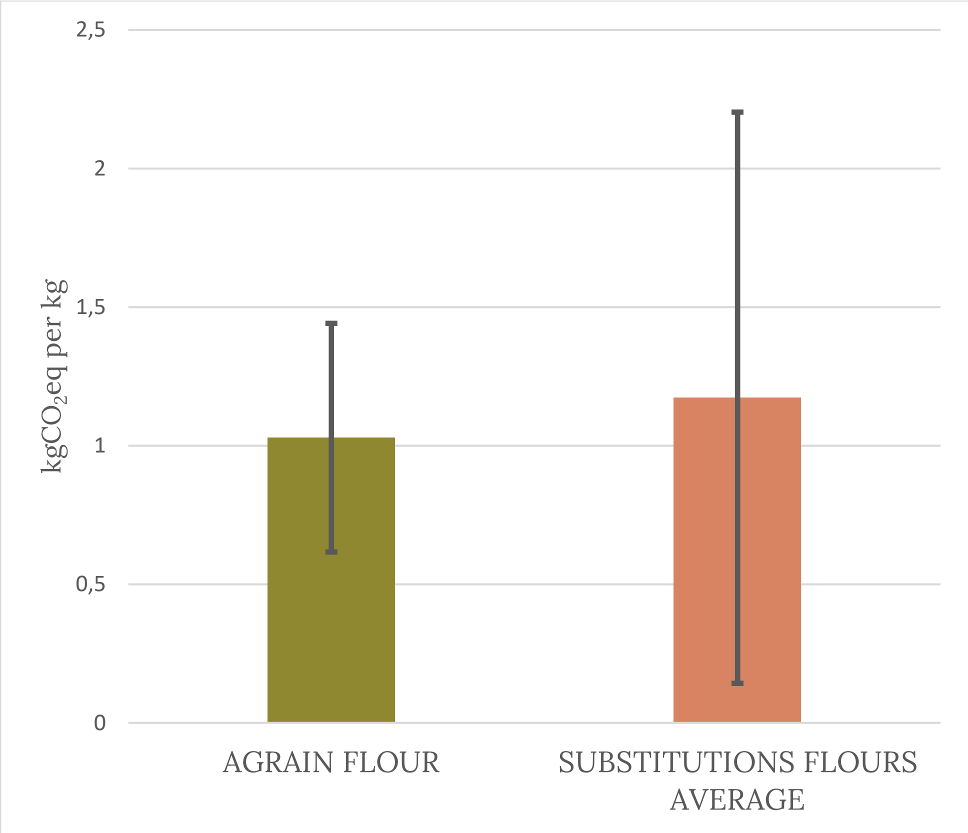
In comparison, the impact categories for Agrain flour of importance are 1) Climate change (37.42%), 2) Resource use, fossils (27.19%), 3) Ecotoxicity, freshwater (7.34%) 4) Particulate matter (5.54%), and 5) Resource use, minerals and metals (5.69%), representing 83% of the total weighted result. These are then included in the reporting when comparing Agrain flour characterized results with substitution flours.

Based on the Agrain flour and substitution most relevant impact categories using the PEF weighted results, we therefore choose to focus on comparing the results for these categories below. However, full Agrain results are presented in section 3 and full weighted LCA results of substitution flour including all assessed impact categories are available in Appendix 1. Due to the large differences in how a circular food production (i.e. the Agrain flour) and a linear food production (i.e. the substitution flours) are influential in terms of the impact categories, we chose in this report to compare what accounts for +80% weighted importance for each of the categories (where only 3 categories are overlapping: Climate Change, Ecotoxicity (freshwater), and Resource use (fossil)). This means that the deep dive in the assessments are done for what accounts for 93% of the average weights between the two categories. The impact categories are: 1) Climate change, 2) Water use, 3) Resource use (fossils), 4) Ecotoxicity (Freshwater), 5) Eutrophication, marine, 6) Land-use. 7) Acidification, 8) Particulate Matter, and 9) Resource use minerals and metals.

4.1.2 Results on climate change

Below we present the CO_2-eq data based on the characterized results from the PEF method, using the unit of 1 kg of product from Cradle to Gate, the declared unit. We utilize the Agrain flour representative product and compare it with an average of 13 different flours originating from two databases (the datasets behind the figure are presented in Appendix 1 Table A.1).

Figure 4. Climate Change (kgCO_2eq per kg of flour (Cradle to gate), EF Method 3.0



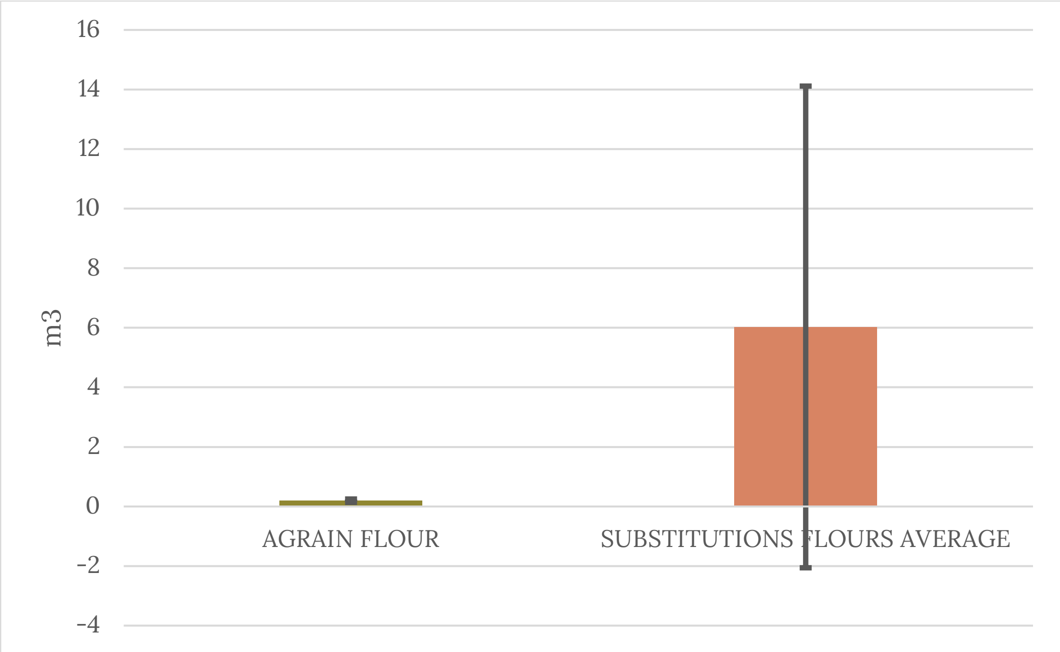
The results show kg CO_2-eq emissions per kg of Agrain flour of 1.03 kg CO_2-eq. This is a 12% saving compared with the substitution flours' average. What the graph also shows is that there is a large standard deviation for the flours Agrain is substituting. As a result, this saving can become much larger or even a cost, depending on the actual comparison in a given situation. This is analyzed in detail in the sensitivity analysis below.

The results from Agrain also indicate that there are variations in the different years. This is not surprising, as data measurements have changed depending on availability, and as calculations have been done from day 1 of production where machines were installed and operation started, and also through a scale up period. Also, as Agrain operations have scaled, new machines have been installed. Moreover, as new breweries have been assigned, distances to breweries and waste to feed have varied, as well as downtime. These are challenges that will be mitigated in the future, as production will be located in closer proximity to the brewery, and several lines of production will be built, limiting waste as well as green energy assessed. See more about the pathway in section 4 on Future Scenarios below.

In the sensitivity analysis we further investigate the climate change variable, and the variations in the substitution flours as well as the variations in the Agrain flour across years.

4.1.3 Results on water use and water consumption

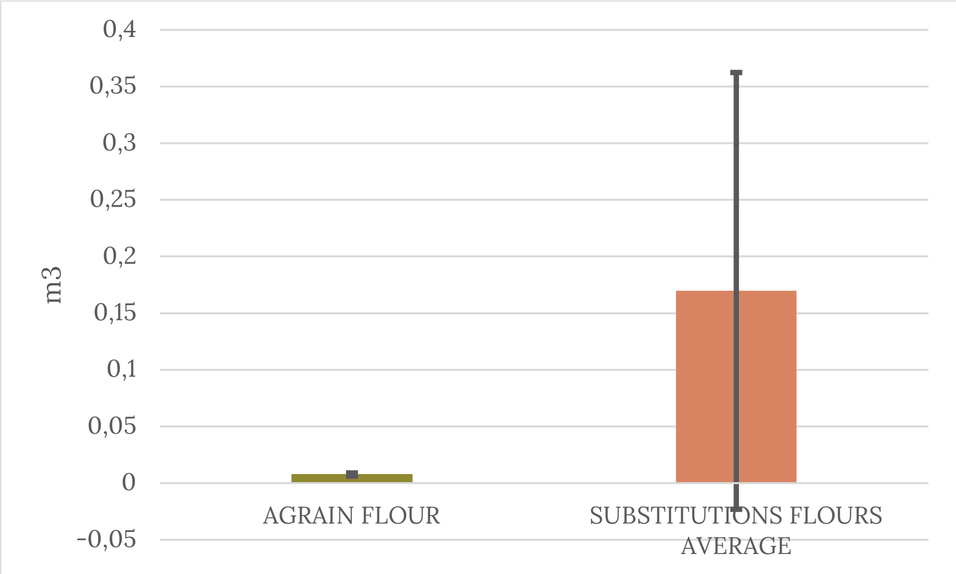
Figure 5. Water use m³ deprived (Cradle to gate), EF Method 3.0



In the EF Method 3.0 Water Use is used to examine the depletion of available water, measured by m^3 deprived. As seen from the graph above the water use for 1 kg of Agrain flour (cradle to gate) is significantly smaller than the average substitution. On average 96% of water use is saved if replacing flour with Agrain. On average, each kg of substitution flour has a water use of $6m^3$ deprived, whereas Agrain flour is $0.2m^3$ deprived. This is explained by the avoidance of the agricultural stage of Agrain flour, which is a water intense stage of linear food products.

As the water use impact category from PEF evaluates water scarcity, it is considered relevant to present the comparison for the water consumption indicator, which is often easier to communicate, obtained from the ReCiPe 2016 Midpoint (H) method. This indicator is presented below.

Figure 6. Water Consumption m³ (Cradle to gate), ReCiPe 2016 Midpoint (H) V1.07

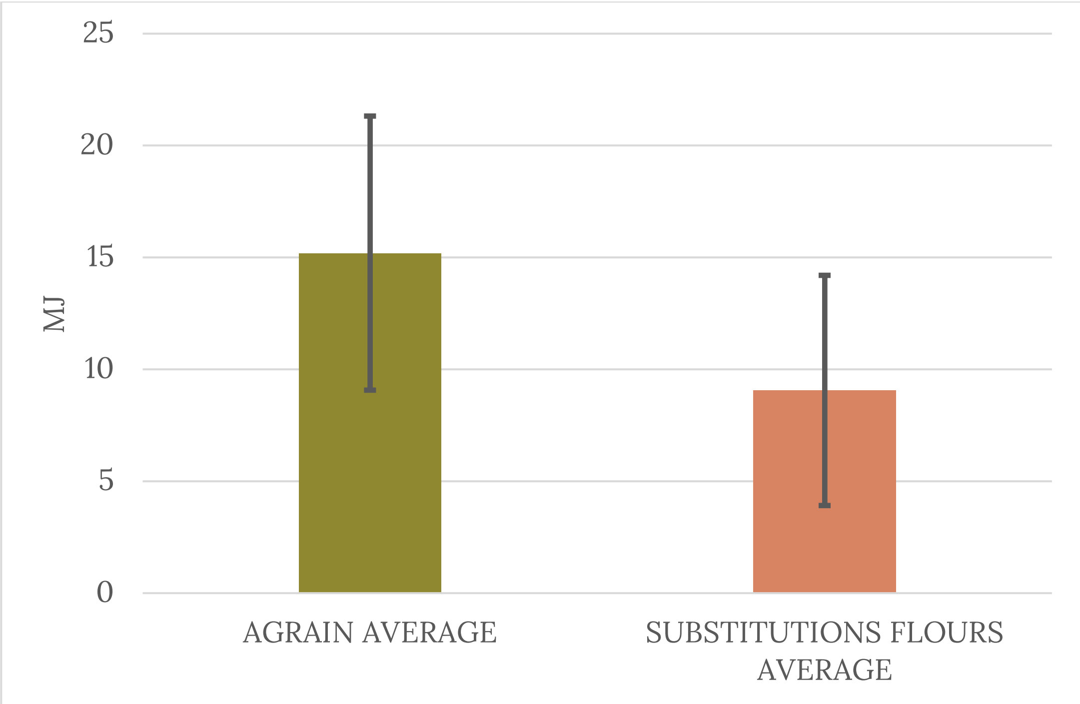


Utilizing the ReCiPe 2016 method we also compare the water resources spent by calculating the Water Consumption by m^3. This graph (Figure 6) shows that 1 kg of substitute flour on average consumes $0.17m^3$ of water, equivalent to 170 liters, whereas Agrain flour utilizes $0.0076m^3$, equivalent to 7.6 liters. This means saving on average approx. 162 liters of water per kg of Agrain flour substituting an average flour.

4.1.4 Results on Resource Use (Fossils)

In Figure 7 we show the comparison between the resource use (fossils) of producing 1 kg of Agrain flour, compared to 1 kg of substitution flour.

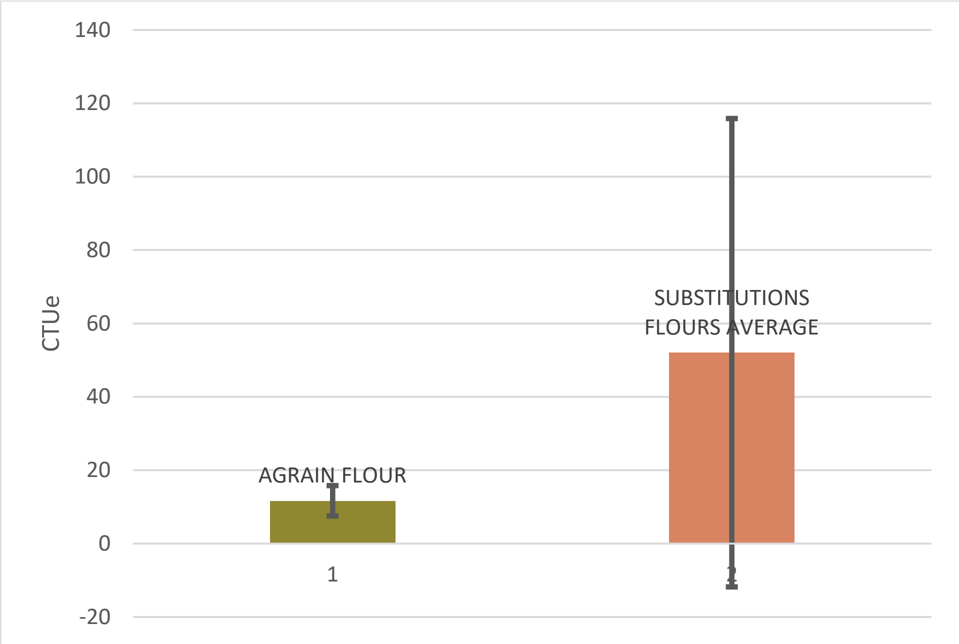
Figure 7. Resource use, fossils, MJ (Cradle to gate), EF Method 3.0



As the results show, Agrain has a larger impact in terms of Resource use, from fossils, than compared to 1 kg of Substitution flour. The main reason for this is that the Agrain flour production is done partly by a gas turbine in combination with grid electricity (see energy mix considered in section 1.2.6). In future sites, renewable energy covering both heat and electricity demand will be available. Secondly, the resource use (fossils) originates from the transport of spent grain from breweries to the Agrain production site, which is a process that will be removed when establishing the next sites next to selected breweries. These future strategies are described below in Section 4 on Future Scenarios. Moreover, substitution flours are produced in very mature processes, while Agrain flour production process is young and has the potential for improvement in terms of efficiency.

4.1.5 RESULTS ON ECOTOXICITY, FRESHWATER

Figure 8. Ecotoxicity, freshwater, CTUe (Cradle to gate), EF Method 3.0

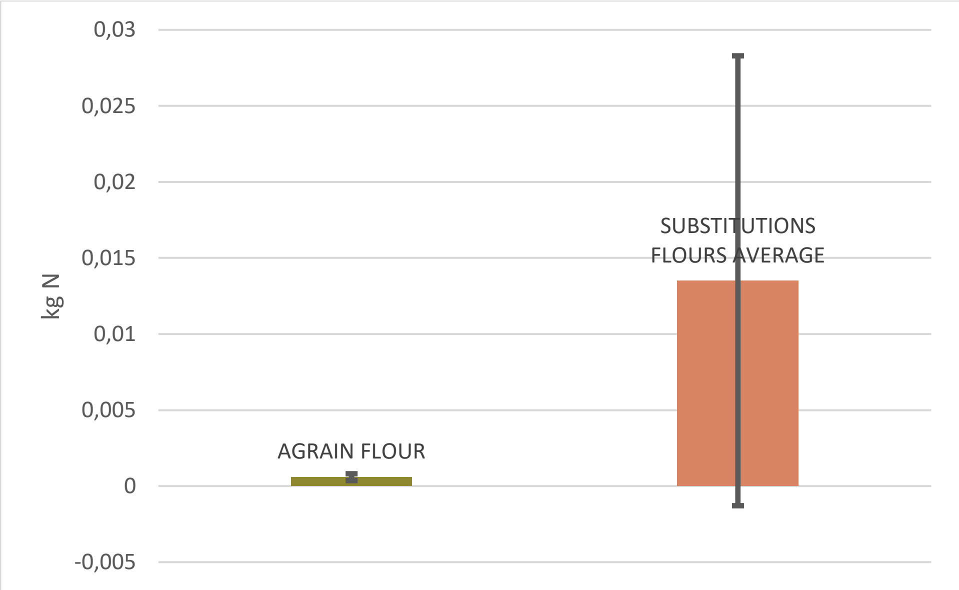


As shown in Figure 8, 1 kg of Agrain flour (cradle to gate) has significantly less Ecotoxicity to freshwater impact than 1 kg of substitution flour, as it is a 78% reduction. Conventional flours use agrochemicals in the agricultural stage, which makes this impact category relevant and where Agrain makes a difference.

4.1.6 RESULTS ON EUTROPHICATION, MARINE

While the Agrain flour has 0.00058 kg N eq emissions per kg flour, the substitution flours have on average 0.0135 kg N eq (cradle to gate). This means that replacing the substitution flours with Agrain would enable a 96% reduction in Eutrophication. As observed in Ecotoxicity (freshwater), this is attributed to the utilization of fertilizers and agrochemicals commonly associated with the substitution flours.

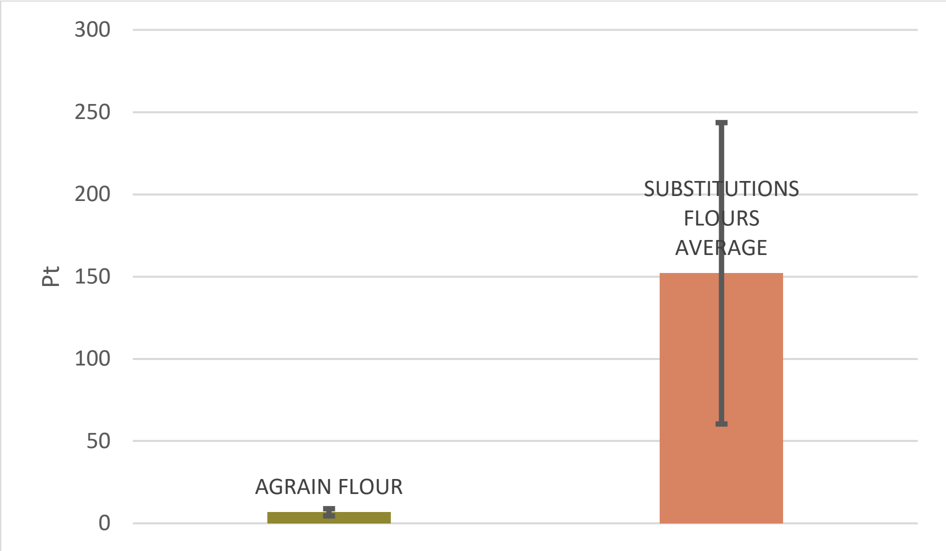
Figure 9. Eutrophication, marine, kg N *(Cradle to gate), EF Method 3.0*



4.1.7 RESULTS ON LAND USE

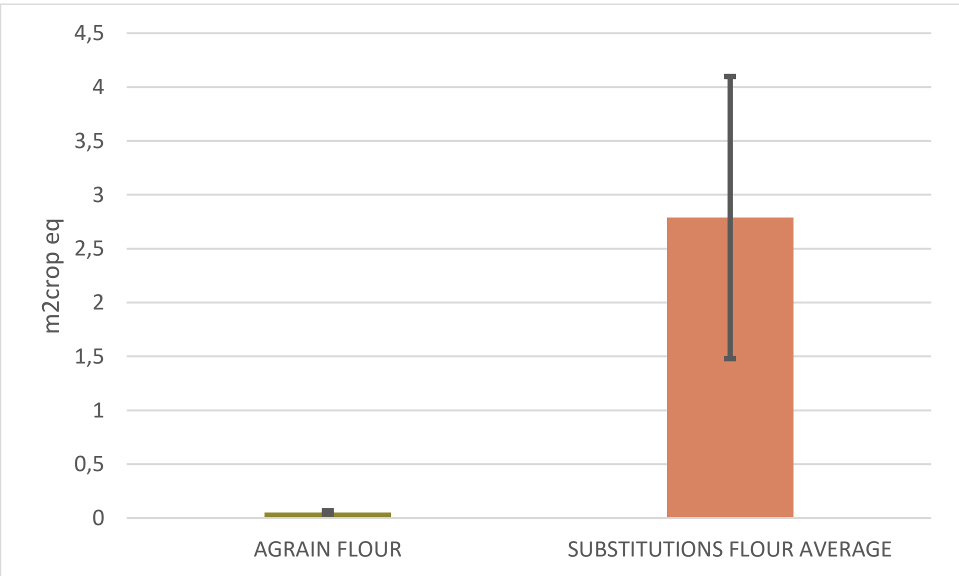
We use the Land use indicator from EF Method to assess the use and transformation of land for specific products. This measure is a composite measure, accounting for impacts on four soil properties (biotic production, erosion resistance, groundwater regeneration and mechanical filtration), expressed in points (Pts). As shown Figure 10, the Agrain flour has significantly less impact (6.69Pts) on land use than that of the substitution average (152Pts). This means 95% saving in comparison to the Substitution average.

Figure 10. Land use, Pt (Cradle to gate), EF Method 3.0



To supplement the composite Land Use EF Method measurements, which is hard to communicate, we also below utilize the Land Use impact category from ReCiPe method, which measures the m^2crop eq per kg flour. The results from that analysis show that Agrain flour utilizes 0.05m^2crop eq per kg flour. By comparison, the substation utilizes an average of 2.7m^2crop eq per kg flour. This means that 98% of land use can be saved if substituting the average flour with Agrain flour.

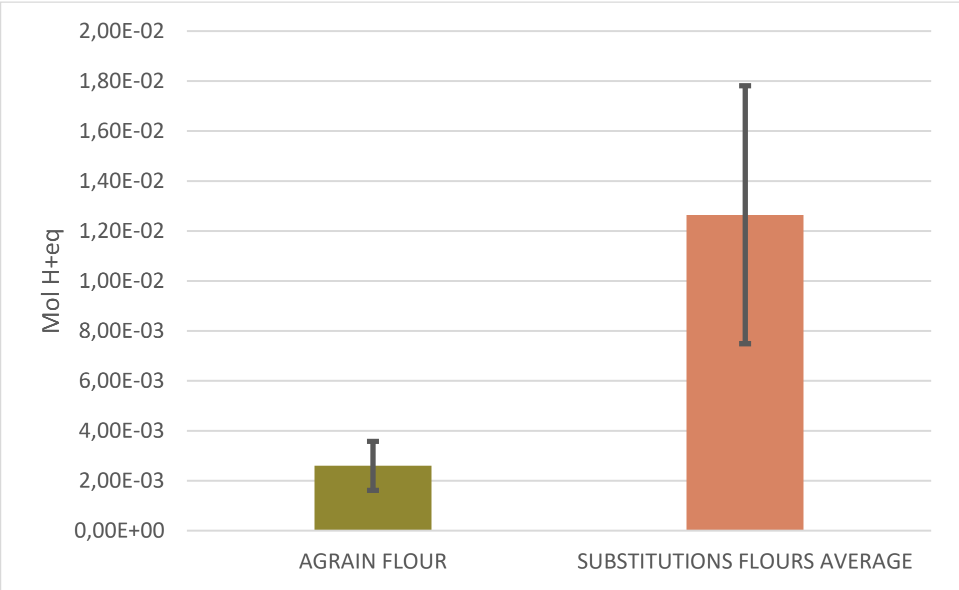
Figure 11. Land use, m2crop eq (Cradle to gate), ReCiPe 2016 Midpoint (H) V1.07



4.1.8 RESULTS ON ACIDIFICATION

Acidification is assessed using the EF Method characterized results, which calculates the potential impact of substances contributing to acidification by the equivalent converted measure moles of hydron. As shown in Figure 12, the Agrain flour has significantly less impact (0.0025 Mol H+eq) on acidification than that of the substitution average (0.0126 Mol H+eq). This means 80% saving in comparison to the Substitution average.

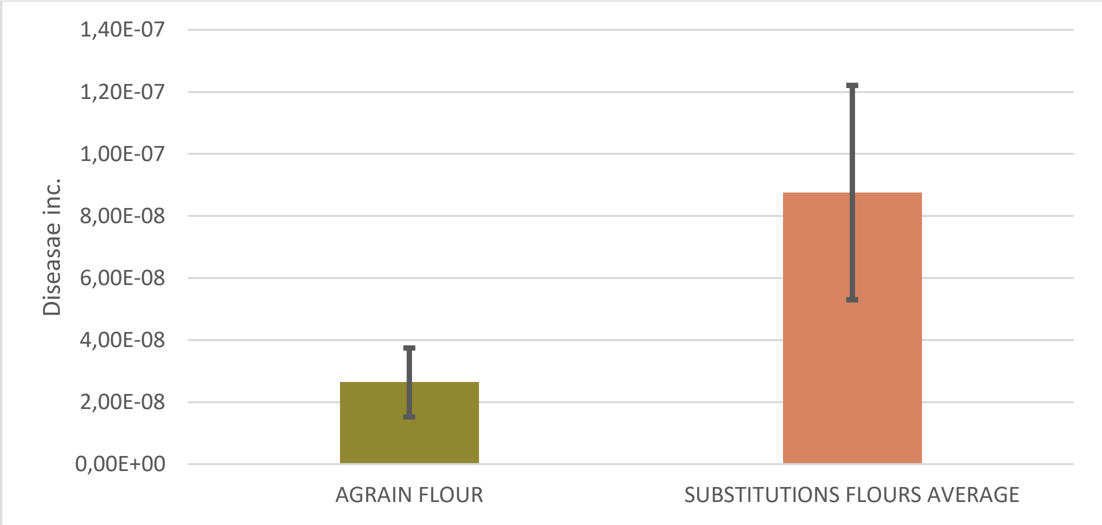
Fig.12 Acidification Mol H+eq (Cradle to gate), EF Method 3.0



4.1.9 RESULTS ON PARTICULATE MATTER

Particulate Matter is assessed using the EF Method. This indicator measures the adverse impacts on human health caused by emissions of particulate matter and the precursors hereto (e.g. NOx, SO2). The measure is therefore a measure for disease incidence per kilo of particulate matter emitted. As shown in the graph below, the Agrain flour has significantly less impact (2.6E-08) on particulate matter than that of the substitution average (8.7E-08). This means 70% saving in comparison to the Substitution average.

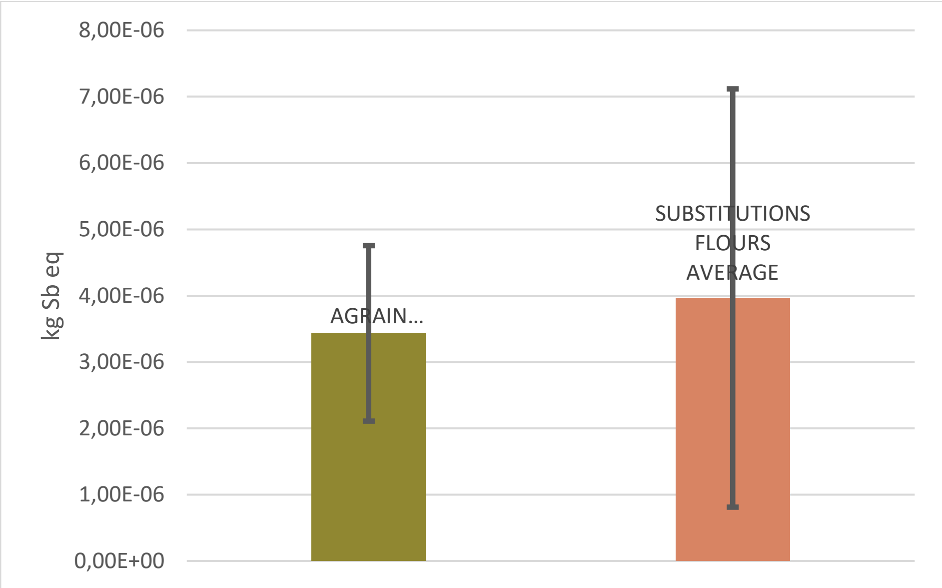
Figure 13 Particulate Matter, disease inc. (Cradle to gate), EF Method 3.0



4.1.10 Results on Resource use, minerals and metals

The final of the 9 categories examined to investigate the full comparison (80% weighted importance of each type of product) is Resource use in minerals and metals. When it comes to the impact categories on Resource uses, (including this category on minerals and metals) the basic concern is that if we utilize high levels of these resources today, it will leave future generations with fewer resources to use, or lower quality resources to use. The measure is kgSb eq and is a measure for resource depletion. As shown in the graph below, the Agrain flour has significantly less impact (3.43E-06 kg Sb eq) on particulate matter than that of the substitution average (3.96E-06 kg Sb eq). This means 13% saving in comparison to the Substitution average.

Figure 14 Resource Use, Minerals and metals, kg Sb eq (Cradle to gate), EF Method 3.0

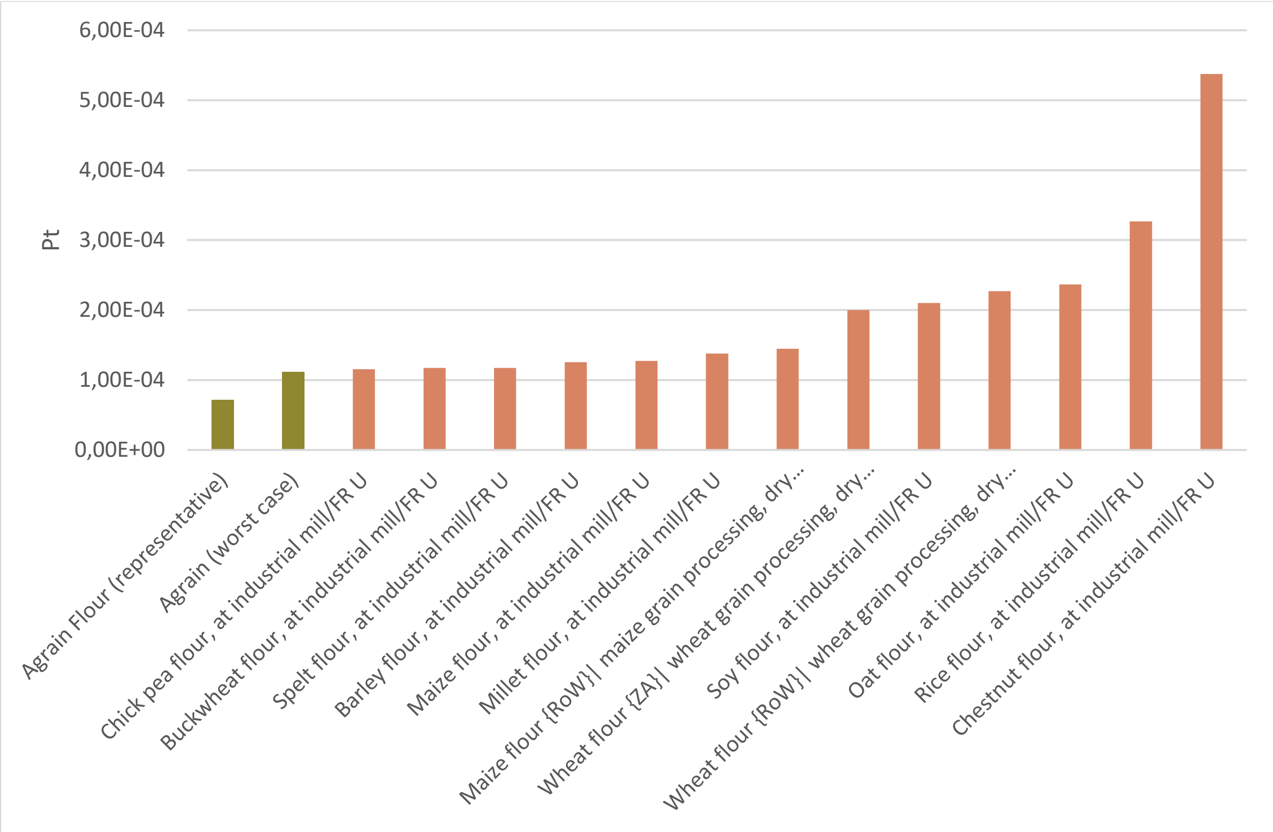


4.2 SENSIVITY TESTS ON RESULTS – ALL CATEGORIES

As explained in the intro, and as can be seen in the Agrain yearly data above and Appendix Table A.1, there are large variations in terms of both Agrain year by year, and in between the different available observations of flour substitutes.

We conduct a number of sensitivity analyses to assess the validity of our results. Initially, we compare the PEF total weights Agrain flour against all the substitute flours individually, illustrated in Figure 15 below, arranged in order of performance with the best performing (with the lowest Pt value) to the left. As the figure shows, the Agrain flour is lowest in weighted PEF results, whereas the Agrain worst case (the year 2022) is second best, so still better than any of the alternative flours when taking all environmental impact factors into account.

Figure 15 PEF Totals weighted, Agrain and Substitutes (Cradle to gate), EF Method 3.0



Subsequently, we do a sensitivity check on each of the hotspot categories analyzed. In Table 11 we present an overview of the sensitivity of the results against the comparisons. In column 'Agrain Flour better than Substitution AVERAGE' we present the results outlined in detail above. In column 'Agrain Worst Case better than Substitution AVERAGE' we take the results from the worst year of Agrain and compare it with the Average substitution flours. This column shows that in this case two categories, namely Climate Change and Resource Use, minerals and metals, change so that the Agrain flour isn't the best performing. Next, we analyze Agrain flour against the best possible observation within each category for the Substitution flours. We find that one flour, namely Soya flour (Agribalyse observation) has lower water deprived (0.1683m^3 depriv) than Agrain flour (worst case) (0.127m^3 deprived). Finally, we compare the Agrain worst case with Substitution flours' best case per category, and we find that Agrain is still best performing in Land-use, Acidification, and Eutrophication.

All in all, the sensitivity analysis shows that despite the small facility of Agrain, and the large variation in the substitution flours that it is compared with, there is no other flour that performs environmentally as well as Agrain in the overall total PEF weighted results. Seen from a full environmental perspective, taking all impact categories into account, the Agrain flour is (even in the worst performing year) better performing than any of the flours that together constitute the average of the substitution flours. This indicates that Agrain is the most environmentally friendly flour.

Table 11. Sensitivity Analysis EF Method 3.0

Impact Category	AGRAIN Flour (representative)	AGRAIN 2019-2022 (MIN)	Agrain 2019-2022 (Worst case)	SUBSTITUTIONS FLOURS (AVERAGE)	Substitution Flours (MIN)	Substitution Flour (Worst case)	Agrain Flour better than Substitution AVERAGE	Agrain (worst case) better than Substitution AVERAGE	Agrain Flour (representative) better than Substitution MIN	Agrain (worst case) better than substitution MIN?
Total, pts	7,15E-05	5,02E-05	1,12E-04	2,02E-04	1,16E-04	5,38E-04	YES	YES	YES	YES
Climate change, kgCO2eq	1,03E+00	6,79E-01	1,62E+00	1,17E+00	3,64E-01	4,17E+00	YES	NO	NO	NO
Particulate matter, PM2.5	2,63E-08	1,70E-08	4,23E-08	8,75E-08	3,53E-08	1,57E-07	YES	YES	YES	NO
Acidification, mol H+ eq	2,59E-03	1,88E-03	4,00E-03	1,26E-02	6,00E-03	2,42E-02	YES	YES	YES	YES
Eutrophication, marine Kg N eq	5,83E-04	4,08E-04	9,11E-04	1,35E-02	3,87E-03	6,19E-02	YES	YES	YES	YES
Ecotoxicity, freshwater CTUe	1,17E+01	8,76E+00	1,76E+01	5,20E+01	1,57E+01	2,57E+02	YES	YES	YES	NO
Land use, Pts	6,70E+00	4,73E+00	9,75E+00	1,52E+02	2,61E+01	4,11E+02	YES	YES	YES	YES
Water use, m3 deprived	1,96E-01	1,51E-01	2,78E-01	6,03E+00	1,68E-01	2,85E+01	YES	YES	NO	NO
Resource use, fossils MJ	1,52E+01	9,98E+00	2,40E+01	9,06E+00	5,74E+00	2,37E+01	NO	NO	NO	NO
Resource use, minerals and metals Kg Sb eq	3,43E-06	2,41E-06	5,33E-06	3,96E-06	1,10E-06	1,05E-05	YES	NO	NO	NO

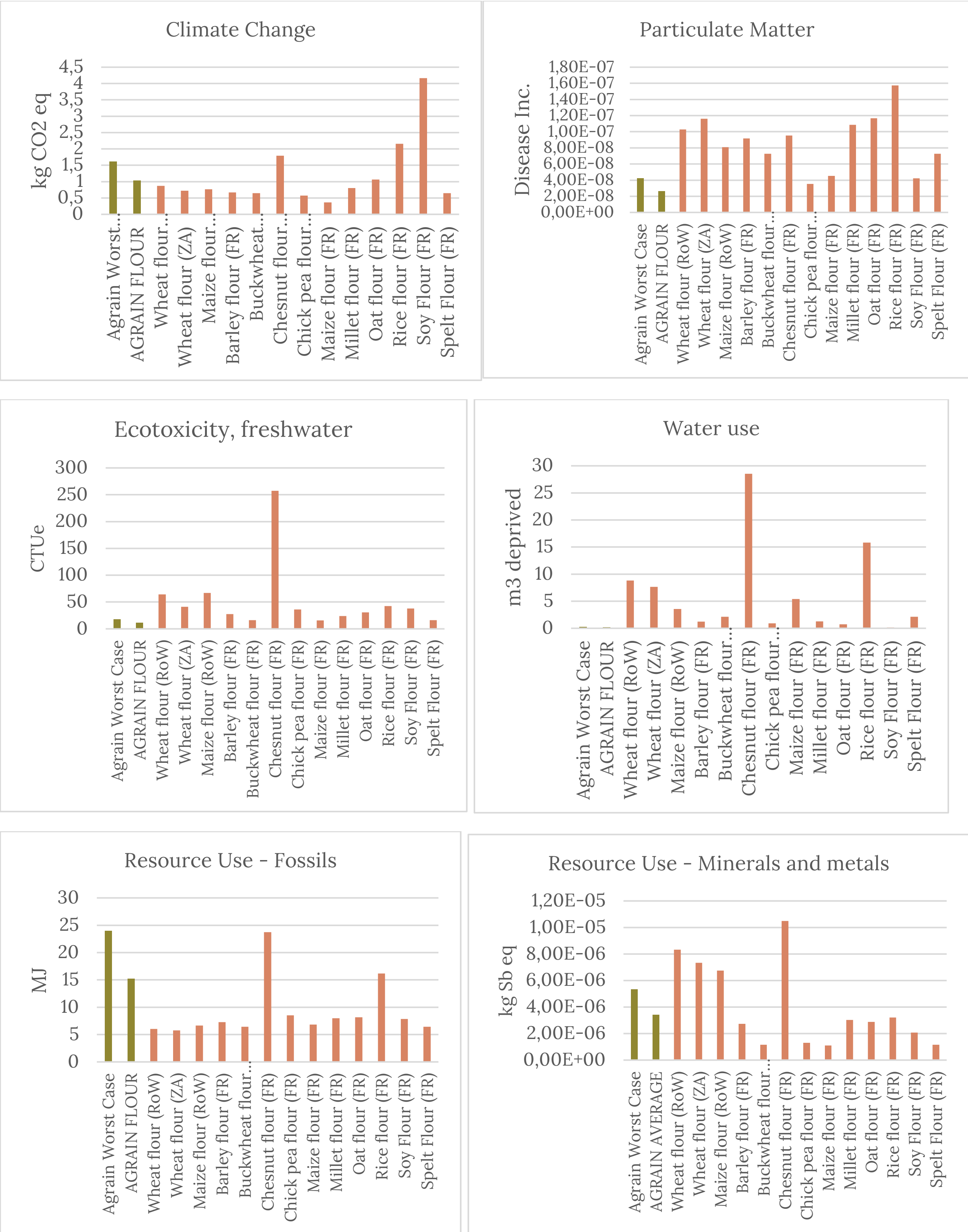
While the sensitivity above shows that the Agrain flour performs best in all individual comparisons on the total weighted results, meaning that the Agrain flour is the most environmentally sustainable flour in the comparison, it also shows that there are trade-offs where the Agrain flour currently isn't the best performing in all impact categories. Agrain flour (even worst case) performs best against any flour from the comparisons in 3 out of the 9 categories, namely: Acidification, Eutrophication (Marine) and Land-use. However, in 6 categories, one or more flours have a better result than Agrain in the impact category. To further investigate the categories, we present individual comparisons for the categories where the Agrain flour worst case isn't better than the substitution flour minimum. This will allow us to understand individual observations among the substitution flours that perform better within a certain category. The six categories are presented below in Figure 16.

For three out of the six categories investigated, there is one out of the 13 substitute flours that in the individual category performs better, namely Particulate Matter where Soy flour performs better than Agrain worst case (by 0.01E-08 disease inc.), in Water Use Soy flour also performs better than Agrain worst case (by 0.11 m3 deprived), and in Ecotoxicity (Freshwater) where Spelt flour performs better than Agrain worst case (by 1.3 CTUe).

In three categories, Climate Change, Resource use (fossils), and Resource use (Minerals & metals), Agrain worst case is worse performing than a number of different flours. As seen from the figure below, Agrain worst case only performs better than 4 of the substituting flours in the sample with regards to the impact factor Resource Use (Minerals and Metals): namely, Wheat flour (RoW), Wheat Flour (ZA), Maize flour (ZA) and Chesnut Flour (FR). Regarding Resource use (fossils), Agrain flour worst case is performing worse than all 13 substitution flours, and for Climate Change only three of the substitution flours are performing worse than the Agrain worst case scenario, namely, Soy flour, Rice flour and Chesnut flour.

This sensitivity analysis therefore underlines that the Agrain flour's environmental impact is remarkably low, performing best on the overall measure (PEF weighs) taking all impact categories into consideration. When analyzing the 9 hot spot impact categories of influence, the Agrain flour (worst case) performs best or second best in 6 out of 9 categories. For the categories Climate Change, Resource Use (Fossils) and Resource Use (minerals and metals) there are still improvements to be made for becoming best. However, even when taking this into account it is evident that the Agrain flour is most environmentally friendly against the 13 substitution flours.

Figure 16 PEF Impact Categories, Where Agrain isn't best against all individual alternatives, Agrain and Substitutes (Cradle to gate), EF Method 3.0



4.3 Agrain flour hotspots

In order to define further actions to reduce Agrain flour environmental impact and to provide knowledge of the product, the processes contribution to the cradle to gate environmental impact is analysed, considering the characterized results for the most relevant impact categories identified for Agrain.

For all the impact categories, we can observe that the BSG transport and energy consumption in the production process (natural gas and electricity) are the main contributors. This interpretation is confirmed when analyzing the PEF weighted total result.

Table 12. Processes contribution (in %) to Agrain flour environmental profile per year

Impact category	Process	2019	2020	2021	2022
Climate Change (EF Method 3.0)	BSG Input	0%	0%	0%	0%
	BSG transport	20.3%	28.0%	36.0%	29.6%
	Natural gas	57.8%	46.2%	33.1%	50.0%
	Electricity	21.5%	25.3%	30.1%	19.3%
	Water consumption	0.1%	0.1%	0.1%	0.1%
	Wastewater	0.2%	0.1%	0.2%	0.2%
	Transport of BSG to farms	0.2%	0.3%	0.4%	0.9%
	Steam output	0%	0%	0%	0%
Resource use, fossils (EF Method 3.0)	BSG Input	0%	0%	0%	0%
	BSG transport	20.3%	28.2%	36.4%	29.7%
	Natural gas	58.6%	47.0%	33.7%	50.7%
	Electricity	20.7%	24.4%	29.2%	18.6%
	Water consumption	0.1%	0.1%	0.2%	0.1%
	Wastewater	0.1%	0.1%	0.1%	0.1%
	Transport of BSG to farms	0.2%	0.3%	0.5%	0.9%
	Steam output	0%	0%	0%	0%
Ecotoxicity, freshwater (EF Method 3.0)	BSG Input	0%	0%	0%	0%
	BSG transport	25.2%	31.2%	35.9%	35.4%
	Natural gas	30.1%	21.6%	13.8%	25.1%
	Electricity	44.0%	46.5%	49.4%	38.1%
	Water consumption	0.2%	0.2%	0.2%	0.2%
	Wastewater	0.3%	0.2%	0.3%	0.3%

	Transport of BSG to farms	0.2%	0.3%	0.4%	1.0%
	Steam output	0%	0%	0%	0%
Particulate matter (EF Method 3.0)	BSG Input	0%	0%	0%	0%
	BSG transport	62.6%	68.9%	72.5%	71.0%
	Natural gas	13.5%	8.6%	5.0%	9.1%
	Electricity	22.0%	20.7%	20.1%	15.3%
	Water consumption	0.3%	0.2%	0.2%	0.2%
	Wastewater	0.6%	0.4%	0.5%	0.5%
	Transport of BSG to farms	1.0%	1.2%	1.6%	3.9%
	Steam output	0%	0%	0%	0%
Resource use, minerals and metals (EF Method 3.0)	BSG Input	0%	0%	0%	0%
	BSG transport	43.6%	51.4%	56.8%	55.7%
	Natural gas	24.4%	16.7%	10.2%	18.5%
	Electricity	30.8%	31.0%	31.7%	24.2%
	Water consumption	0.2%	0.1%	0.2%	0.1%
	Wastewater	0.8%	0.7%	0.8%	0.9%
	Transport of BSG to farms	0.1%	0.2%	0.2%	0.6%
	Steam output	0%	0%	0%	0%

Table 13. Processes contribution (in %) to Agrain flour single overall total (PEF weighted results) per year

Impact category	Process	2019	2020	2021	2022
PEF weighted results (EF Method 3.0)	BSG Input	0%	0%	0%	0%
	BSG transport	26%	34%	41%	36%
	Natural gas	47%	36%	24%	39%
	Electricity	25%	28%	32%	22%
	Water consumption	1.7%	1.5%	2.1%	1.5%
	Wastewater	0.2%	0.1%	0.2%	0.2%
	Transport of BSG to farms	0.2%	0.3%	0.5%	1.1%
	Steam output	0%	0%	0%	0%

4.4. Sensitivity analysis on inventory data, allocation and characterization factors

Three sensitivity analysis are assessed that will allow to see how the climate change results are conditioned by methodological choices affecting the inventory data, allocation procedures and characterization factors:

- How the economic allocation in the beer production would influence Agrain flour environmental impact: In the LCA, BSG is considered burden free based on the PEFCR Beer approach. In this sensitivity analysis an economic allocation between the beer and the BSG is considered, based on the prices indicated by United Nations Statistics Division (n.d.). It has been only applied to the BSG processed, as the input BSG that is not consumed will be used as feed in farms and so allocated to the final user.
- 2022 valorization ratio for all years assessed: For the years 2019-2021 flour production was calculated based on theoretical ratios. In this sensitivity analysis the environmental impact of 2019, 2020 and 2021 flour is assessed considering the 2022 valorization percentage, coming from measurements of 12% instead of 20%.
- Danish residual mix for the electricity modelling, instead of the market mix: The methodological choice for the current assessment was using the average grid mix from Ecoinvent, as justified in section 1.2.6. Even though in this sensitivity analysis the residual mix for the years 2019, 2020, 2021, 2022 has been considered as the approach for electricity modelling in the PEF methodology as a way of avoiding double counting with the use of supplier specific mixes as first option.

Table 14. Sensitivity check on economic allocation processed BSG.

	Units	No allocation to BSG at the brewery	Economic allocation to the BSG at the brewery
Beer allocation factor	%	100%	98.2%
BSG allocation factor	%	0%	1.8%
Climate change	kg CO2eq/kg flour	1.03	1.06
Diference	kg CO2eq/kg flour	Na	0.03
Deviation	%	Na	3%
Sensitivity	%	Na	3%

The sensitivity analysis considering an economic allocation of the BSG at the brewery, shows that the Agrain flour would increase its impact on climate change impact category by 3%.

Table 15. Sensitivity check on inventory data, considering 12% valorization rate.

Process	Units per kg of flour (DU)	Current representative flour	12% flour rate representative flour	Difference	Deviation, %	Sensitivity, %
BSG Input	Kg	9.74	13.37	3.63	37%	na
BSG transport	Tkm	0.57	0.82	0.24	43%	na
BSG processed	Kg	5.90	8.61	2.71	46%	na
Natural gas	MJ	6.37	9.09	2.71	43%	na
Electricity	kWh	0.84	1.25	0.41	48%	na
Water consumption	Litres	3.33	4.89	1.55	47%	na
Wastewater_water	Litres	3.33	4.89	1.55	47%	na
Wastewater_liquid	Litres	2.90	5.61	2.71	93%	na
Transport of BSG to farms	Tkm	0.06	0.07	0.01	24%	na
BSG at farm	Kg	3.84	4.75	0.92	24%	na
Steam output	Kg	2.00	2.00	0.00	0%	na
Product carbon content	kg CO2eq	1.705	1.705	0.00	0%	na
Climate change	kg CO2eq	1.03	1.48	0.45	44%	44%

It is observed that the valorization rate is critical if flour is the only product. The change on the valorization rate (kg of flour/kg of processed BSG), affects all inventory data, as all processes are allocated to the quantity of flour produced. 2022 measured data showed a lower flour rate than expected due to the moisture content. If this rate is applied to all the years, Agrain flour climate change impact would increase by 44%.

Table 16. Sensitivity check on electricity mix

Climate change data input/effect	Units	Market mix (current)	Residual mix (average 2019-2022)	Difference	Deviation, %	Sensitivity, %
Climate change score	kg CO2eq/kWh	2.80E-01	0.53518349	2.55E-01	91%	na
Electricity consumption	kWh/kg	0.84	0.84	0.00E+00	0%	na
Climate change result from electricity	kg CO2eq/kg	2.36E-01	4.51E-01	2.15E-01	91%	na
Flour Climate change result	kg CO2eq/kg	1.03E+00	1.24E+00	2.12E-01	21%	21%

In this sensitivity analysis different electricity modeling are assessed: Danish market grid mix vs Danish residual mix. Using the residual mix instead of the market mix has a significant effect on the climate change result, increasing by 21%. In terms of comparison, one of the goals of the current representative product assessment, this would influence the interpretation. This supports the chosen electricity assumptions, which match the comparison datasets electricity assumptions.

5 FUTURE SCENARIOS FOR AGRAIN FLOUR AND COMPARISON

5.1 DESCRIPTION OF THE SCENARIOS ASSESSED

4 significant possible improvements to reduce environmental impacts of the Agrain flour have been identified. They are described as the following scenarios:

- S1. Flour production current situation. Current process produces flour, transporting the spent grain from the breweries to the facility and where non-processed grain is generated as waste that is used as animal feed. This scenario is the one reported above in the comparisons.
- S2. Flour and liquid production current situation. The current process produces flour and liquid, transporting the spent grain from the breweries to the facility and where non-processed grain is generated as waste, that is used as animal feed. Upcycling the liquid pressed out before the drying of the spent

grains would enable approx. 4-700 liters of liquid protein drink per metric tone of Brewers spent grain processed.

- S3. Flour production without waste generation. The current production process cannot absorb all input spent grain so non-processed grain is used as animal feed. In this scenario the production process becomes efficient and all brewers spent grain that arrives at the factory is processed.
- S4. Flour production at brewery (no transport of spent grain required). The process is located at the brewery site and so no transport of the spent waste is required.
- S5. Flour production with renewable energy. The energy usage on factory, natural gas and electricity from the grid, are replaced by renewable electricity.
- S6. Best scenario (scenarios 2, 3, 4 and 5). Flour and liquid production at brewery (no transport required), without generating non-processed BSG and produced with renewable energy.

Table 17. Main characteristics of the scenarios defined

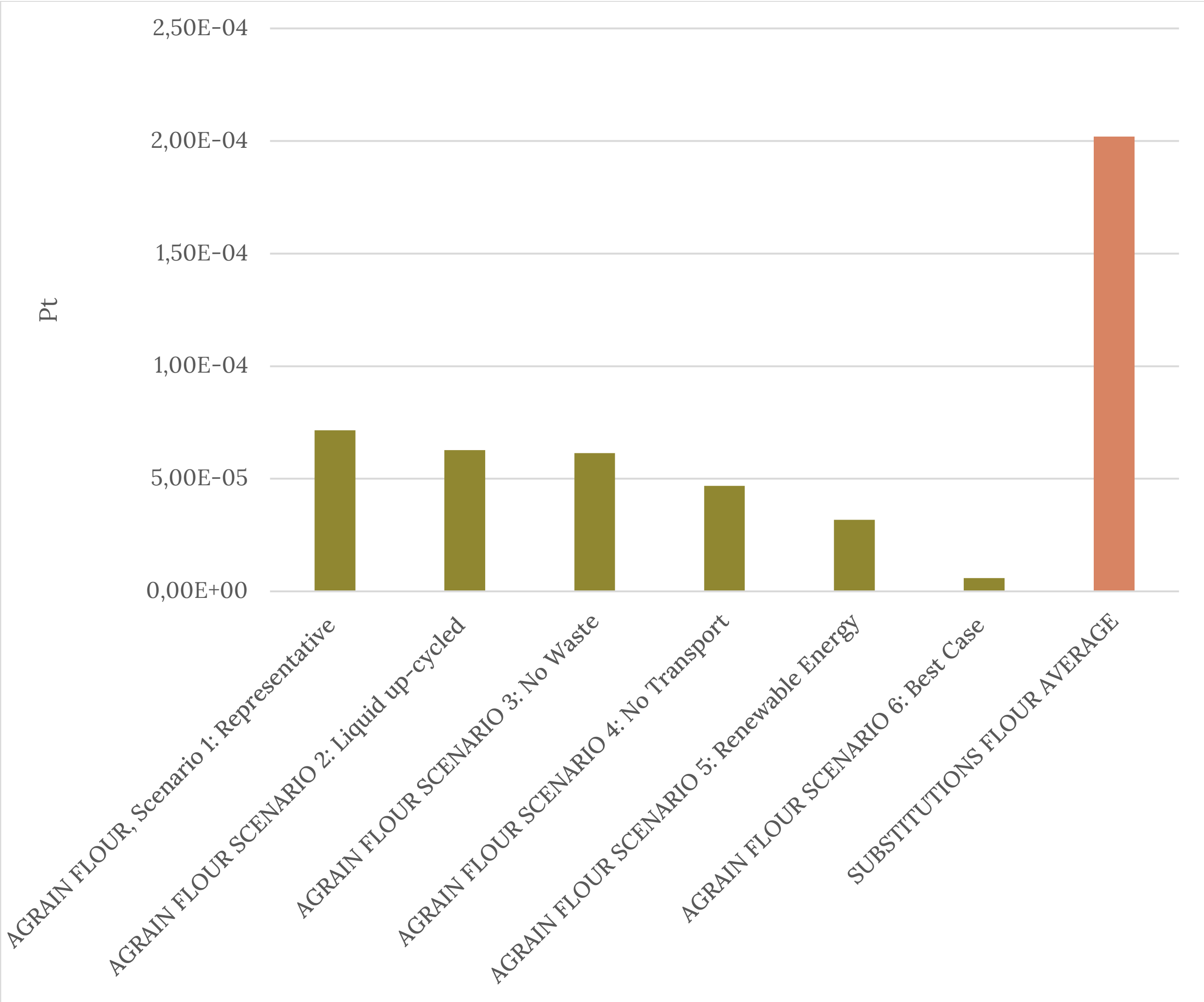
Characteristics	S1	S2	S3	S4	S5	S6
Flour production	X	X	X	X	X	X
Liquid production		X				X
No waste (all spent grain used)			X			X
Process onsite (at brewery)				X		X
Renewable electricity					X	X

Process inputs and outputs when only flour is produced are mass allocated considering the total flour production. For the scenarios where flour and liquid are produced, an economic allocation is applied.

5.2 Future scenarios assessment

Per each scenario, the representative product based on 4 years assessed has been calculated and used for the comparison among the scenarios and with the substitution average flour.

Figure 17. Agrain scenario 1-6 & Substitution average, PEF weighted results, Pt (Cradle to gate), EF Method 3.0



The results show that in Scenario 2 and 3, 12% & 14% of the single overall score could be reduced. Setting up the production next to factory enabling no transport of raw material would enable another 34% reduction, while changing energy source to become fully renewable would enable a 55% reduction of PEF weighted value. All in all, a 91% reduction in comparison to the Agrain flour current representative product can be achieved by implementing the four changes in operations. This significant reduction underscores the potential for substantial environmental improvements and highlights the effectiveness of these measures in mitigating the impact of the production process.

These changes would also have significant impact on the main impact categories mentioned above in Section 4. In the Table below, the Best Case is compared to

Agrain flour (current representative product) and compared to Substitution Average Flour results. The results show that despite the current Agrain flour performing excellent in comparison to average alternative flours, the Agrain flour can become even better. Most remarkable is that the Agrain flour environmental impact can become very close to zero on several impact categories, e.g., climate change. The current Best Scenario Agrain flour only emits 0.03 kg CO_2-eq per kg flour (cradle to gate); this is a 97% in comparison to current Agrain flour. The results also show that all other categories can be improved significantly, as it shows more than 95% reduction compared to the average of flours it can substitute.

Table 18. Agrain Flour (Scenario 1: current), Agrain Best Case Scenario (Scenario 6), Substitution Average and comparisons in percentages (1 kg flour Cradle to Gate).

Impact category	Unit	Method	Sc1: Agrain flour current	Sc 6: Agrain Best case	Substitution Flours Average	Reduction Agrain Best Case vs Agrain flour (current)	Reduction Agrain Best Case vs Substitution Flours Average
Climate Change	kgCO2eq	EF Method 3.0	1.03	0.03	1.17	96.80%	97.20%
Water use	m3 deprived	EF Method 3.0	0.20	0.08	6.03	60.39%	98.71%
Water Consumption	m3	ReCiPe	0.0076	0.0006	0.1696	92.16%	99.65%
Resource Use (Fossils)	MJ	EF Method 3.0	15.19	0.38	9.06	97.47%	95.76%
Ecotoxicity (Freshwater)	CTUe	EF Method 3.0	11.67	1.18	52.03	89.86%	97.73%
Eutrophication, marine	kg N eq	EF Method 3.0	0.00058	0.00004	0.01350	93.79%	99.73%
Land-use	Pt	EF Method 3.0	6.70	1.08	152.01	83.85%	99.29%
Land-use	m2crop eq	ReCiPe	0.052	0.003	2.789	94.23%	99.89%

The 97% saving in CO_2eq, seen in context of the global potential, is enormous. Worldwide 40 million tonnes of spent grains are available, which would result in approximately 8 million tonnes of spent grain flour. In this respect the global kg CO_2-eq reduction would enable over 9 mil Ton COe saved (8 mio tonnes of flour= 8mio*(1.17-0.03kg CO_2-eq).

5.3 COMPARISON AT FOOD LEVEL

Agrain is a new source of food, which is high in protein and dietary fibre (as shown in Table 1), and it has many potential applications, e.g., in bread, crisps, crackers, meat alternative, etc. it is therefore important to not only investigate the comparisons of close substitutes but also to see the flour in a wider perspective. For this purpose, we analyze the Agrain flour (representative product) and Agrain best case flour (scenario 6) to the data presented by Poore and Nemecek (2018), which covers 90% of all food consumed in the world in terms of protein and calories. In this case, not only will the investigation cover per kg of product, but also the LCA results per 100g of protein and per 1000 kilocalories will be examined.

Poore & Nemecek (2018) do not provide data per 100g protein for food products which are not protein-rich, or kilocalorie measures for non-stale crops. To provide footprints for all products Our World in Data (OurWorldInData.org) has been used, that filled these gaps by calculating footprints per nutritional unit using food composition factors from the FAO INFOODS International Database and Food Balance Sheets (FAO, 2001).

5.3.1 METHODOLOGY

For the comparison of the flour results with those published by Poore and Nemecek (2018), the functional unit is “1 kg of flour at store, packed”. So, a cradle to retail analysis.

When comparing the results with Poore and Nemecek (2018), B2C packaging, distribution and retail stages are included in the assessment in order to consider the same system boundaries. The supply chain begins with the extraction of resources needed to produce inputs for the products production and ends at the retail store, the point of choice for consumers. Post-retail stages (cooking and consumer losses) were not considered based on the Poore and Nemecek scope.

Retail Agrain flour is packed in a 0.5 kg paper and plastic film bag. Both the bag and the transport from the supplier to Agrain facility are included.

The distribution stage considers the known transport from Agrain to the distribution center, and a default distance from the distribution center to the retail, obtained from Dry Pasta PEFCR (European Commission, 2020).

Retail stage was modeled based on Retail OEFSR (European Commission, 2018b), considering energy consumption, water consumption, wastewater treatment and product losses.

- Electricity consumption: assumed a retail specialized in food/beverage products with a consumption of 400 kWh/m^2·year for the entire building surface, of 2000 m^2.
- Water (tap water and wastewater treatment): 3650 m^3 of water is used per year for activities such as cleaning, customer bathrooms, lawn irrigation, etc. The default building surface is 2000 m^2.
- Allocation of the retail space-time per product: According to Retail OEFSR, retail place can store 2000 m^3 of products during 52 weeks, i.e., 104000 m^3-weeks/year. The total storage capacity is allocated considering Retail OEFSR assumption for ambient products, 4 times the product volume * stored 4 weeks, with the retail bag volume of 12cmx30cmx6cm. As it is not a box but a bag, it is assumed the actual volume is 50% of the bag volume.

Downstream product losses were assumed from the same source as Poore and Nemecek (2018) for cereals in wholesale and retail distribution stage, 2% (FAO, 2011).

The scenarios included are currently in use and are representative for one of the most likely scenario alternatives.

Poore and Nemecek (2018) methods described in Supplementary Materials (DOI: 10.1126/science.aaq0216) were used for the benchmark comparison: Climate Change, Land Use, Acidification, Eutrophication, and Water Scarcity. The calculation methods are described below.

Table 19. Method applied from Poore & Nemecek (2018) and implementation in the LCA comparison to Poore and Nemecek data

Category/Indicator	Units	Method	Calculation
Land use * Occuppation time	m^2a	Life cycle inventory results in Simapro: Occupation, crops and pasture and schrub land	Sum of Occupation "Substances" in the Inventory results that begin as "Occupation, annual crop", "Occupation, pasture", "Occupation, permanent crop" and "Occupation, shrub land", being their unit m2a.

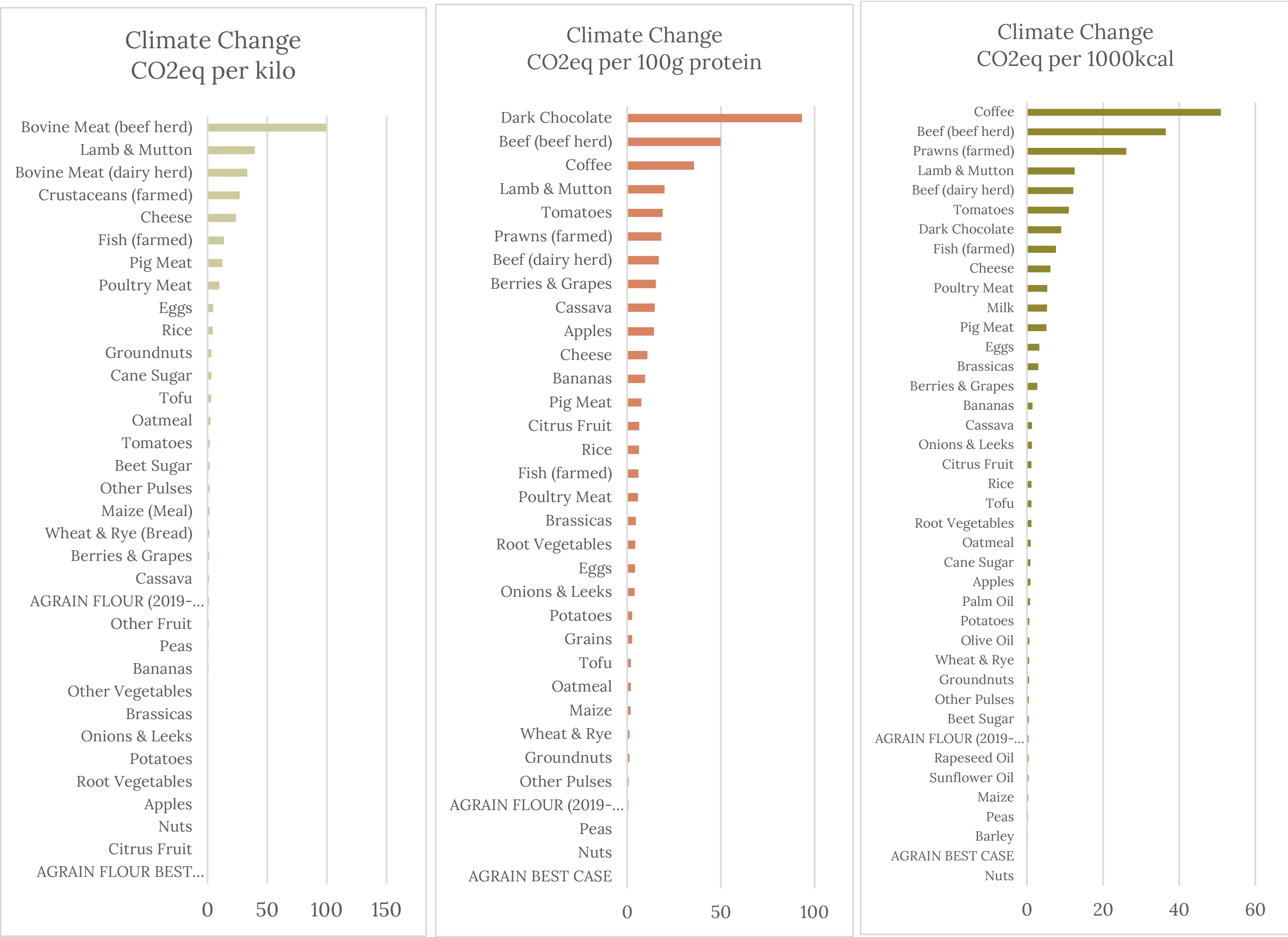
Climate change	kg CO_2 eq	Life cycle inventory results in Simapro	IPCC AR5 100-year factors with climate carbon feedbacks for CO_2, CH_4, N_2O to air. GWP factors with cc fb for CO2, CH4 and N2O and the elementary flows considered by Simapro to refer to these gases (Myhre et al, 2013)
Acidification	kg SO_2 eq	CML 2 baseline 2000 V2.05	Category "Acidification"
Eutrophication	kg PO_4--- eq	CML 2 baseline 2000 V2.05	Category "Eutrophication"
Freshwater Withdrawals: Irrigation, drinking, pond, and processing water	L	Life cycle inventory results in Simapro	Sum of water "Substances" in the Inventory results in Compartment Raw, begining with "Water, well", "Water, unspecified natural origin", "Water, river" and "Water, lake". Then converted to L by multiplying x1000
Scarcity - Weighted Freshwater Withdrawals	L eq	AWARE V1.05	Conversion from m3 eq to L eq by multiplying the result x1000

5.4 Results Agrain compared to food accounting for 90% of world protein and calories comsumption

5.4.1 Climate change

Below we show each of the results for climate change. As was shown in the comparison of Agrain flour versus substitution flours, Agrain's current production was very close to the substituting products' carbon footprint. When assessing the Agrain flour against 40 products representing ~90% of global protein and calorie consumption, per kg, per 100g protein and per 1000kcal, the results are clear. Agrain flour, still in pilot scale and based on the last 4 years of data, in pilot scale, is among the least CO_2-eq emitting food products in the world when taking protein and calorie contribution into consideration. When assessing CO_2-eq per kg, there are still a number of vegetables and fruits performing better, but Agrain flour, with the identified potential improvements, has the opportunity to become best also per kg.

Figure 18. Climate Change: Agrain flour (representative) and Best case against 90% of current food consumption (per kg, per 100g protein and per 1000kcal), in kg CO_2eq per 1 kg of packed product at retail

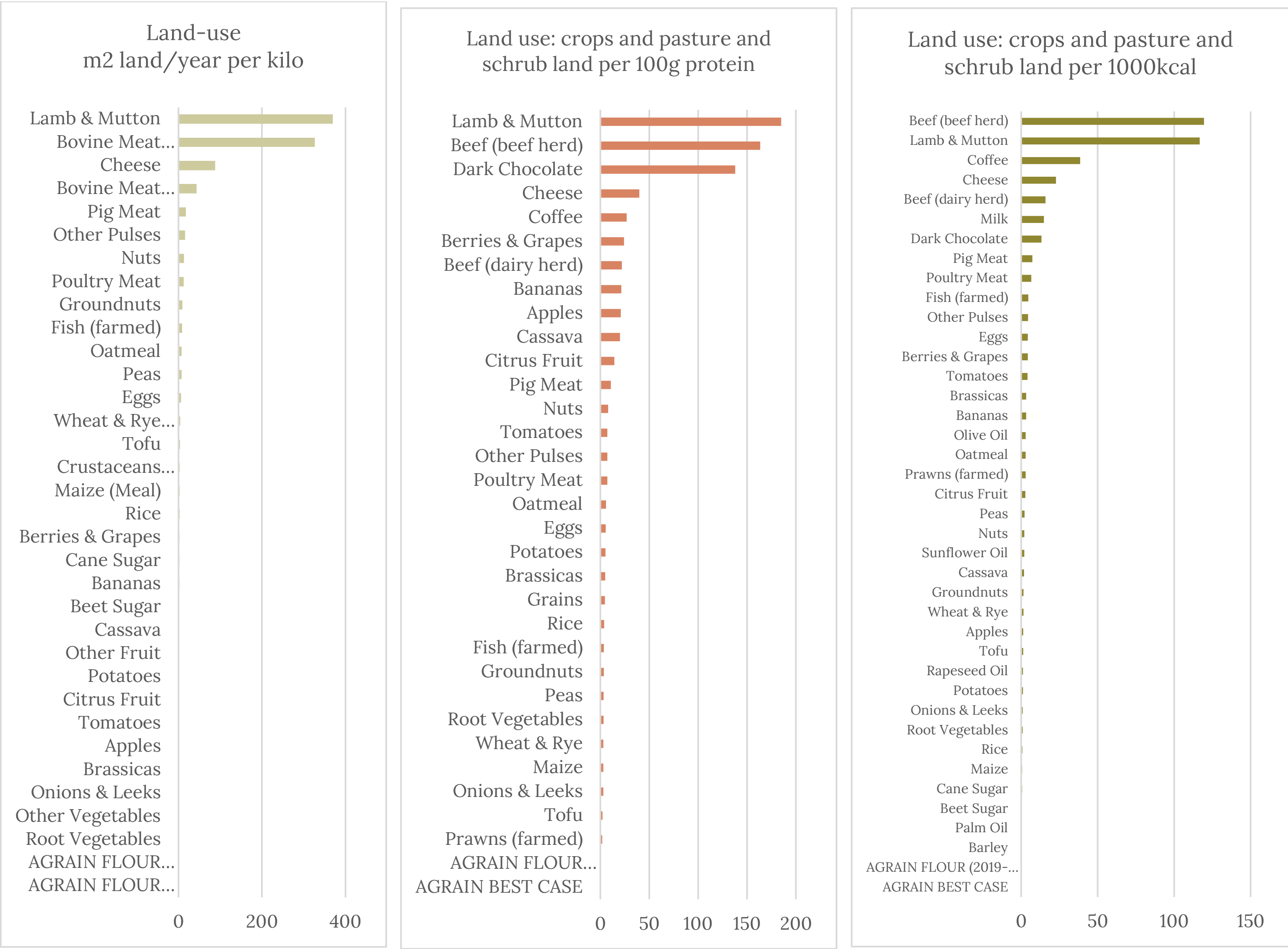


5.4.2. LAND USE

Food production is putting immense pressure on today's land use. Half of the world's habitable land is used for agriculture, of this 77% is agricultural land for livestock (37million km2), for meat and diary, whereas the remaining is crops for plant based food (11million km^2). Because the current food system puts such immense burdens on land use, it has implications for biodiversity. While the meat and dairy sector utilizes 77% of land, they only supply 18% of global calorie supply and 37% of global protein supply. It is therefore important to find alternative routes for presenting protein and calorie-rich food products, without expanding land use.

Agrain flour is by far the food product that utilizes least land, both when defined by kilo, by 100g protein and by 1000kcal.

Figure 19. Land use: Agrain flour (representative) and Best case against 90% of current food consumption (per kg, per 100g protein and per 1000kcal), in m²year per 1 kg of packed product at retail

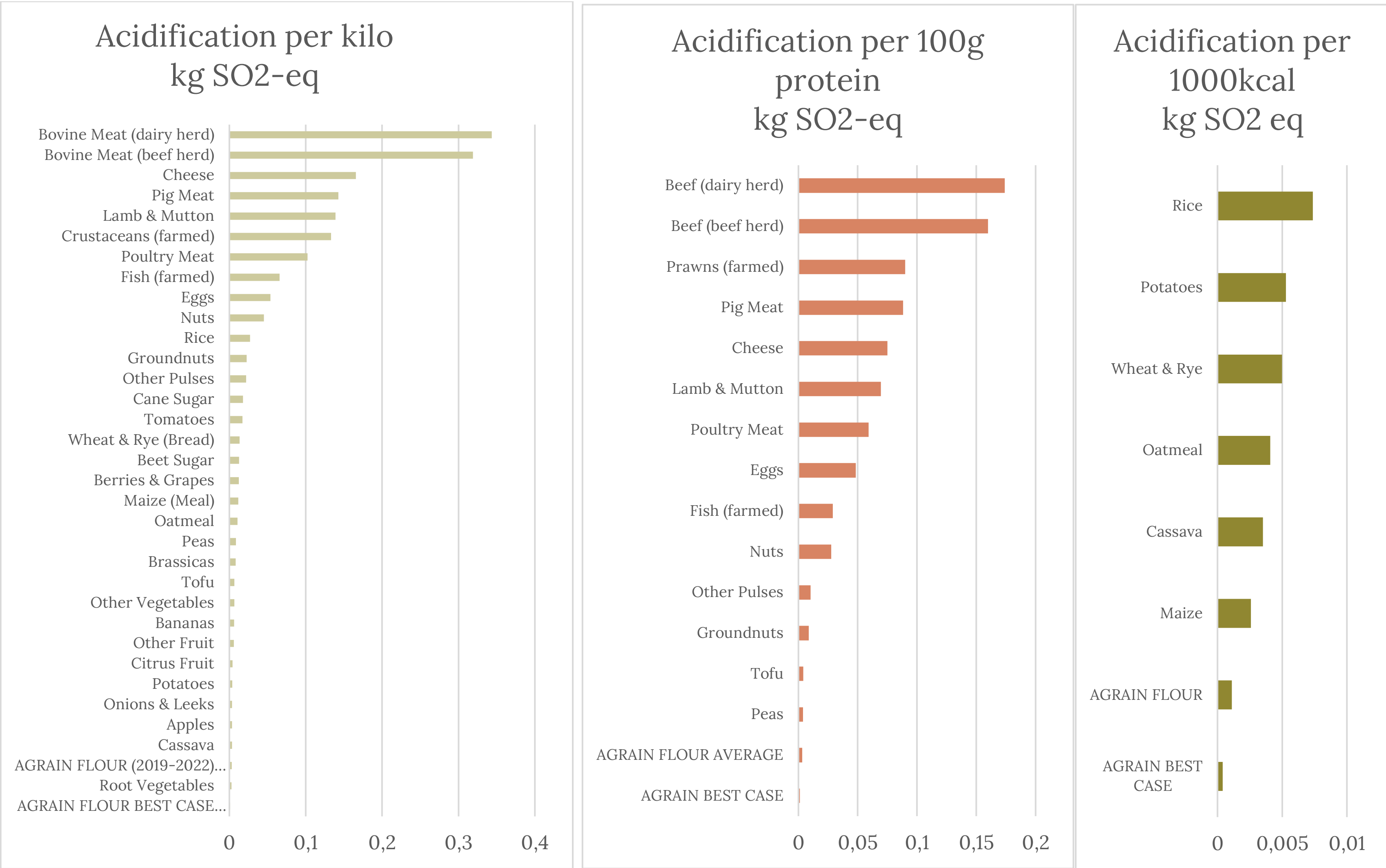


5.4.3 Acidification

The method applied for analyzing products in terms of Acidification were different than described in the other categories. Poore & Nemecek defined a different nutrition functional unit depending on if the food product is starch-rich or protein-rich. So, for Acidification we compare the results per 100g protein with protein-rich products and 1000kcal results with starch-rich products, and it is therefore not assessed by Our World in Data. This means that the comparisons below are much fewer than in the other comparisons.

The results show that Agrain flour is already best performing in terms of Acidification against the compared food products.

Figure 20: Acidification Agrain flour (representative) and Best case against 90% of current food consumption (per kg, per 100g protein and per 1000kcal), in kg SO_2eq per 1 kg of packed product at retail

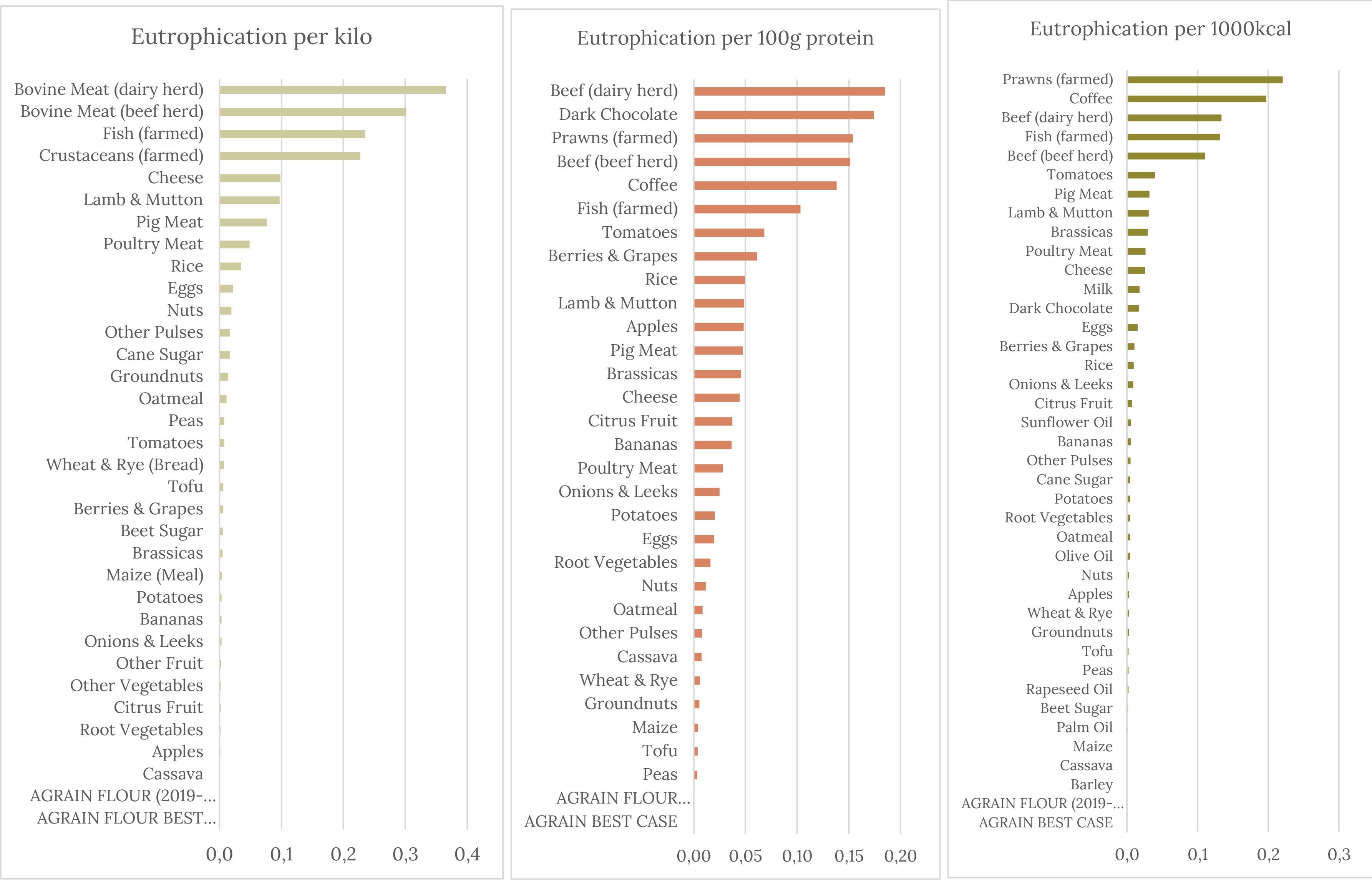


5.4.4. EUTROPHICATION

Eutrophication is important as it alters the composition of species, reduces biodiversity and decreases ecological resilience. Unfortunately, food production is the largest contributor to eutrophication, as it creates ~78% of global eutrophication (Poore & Nemecek, 2018). It is therefore also within food that there is a necessity to focus on lowering eutrophication.

The results below show that Agrain flour by kg, by 100g protein and by 1000kcal, are lowest in comparison to food products, already in the current production setup.

Figure 21: Eutrophication: Agrain against 90% of current food consumption (per kg, per 100g protein and per 1000kcal), in kg PO_4^{3-} eq per 1 kg of packed product at retail



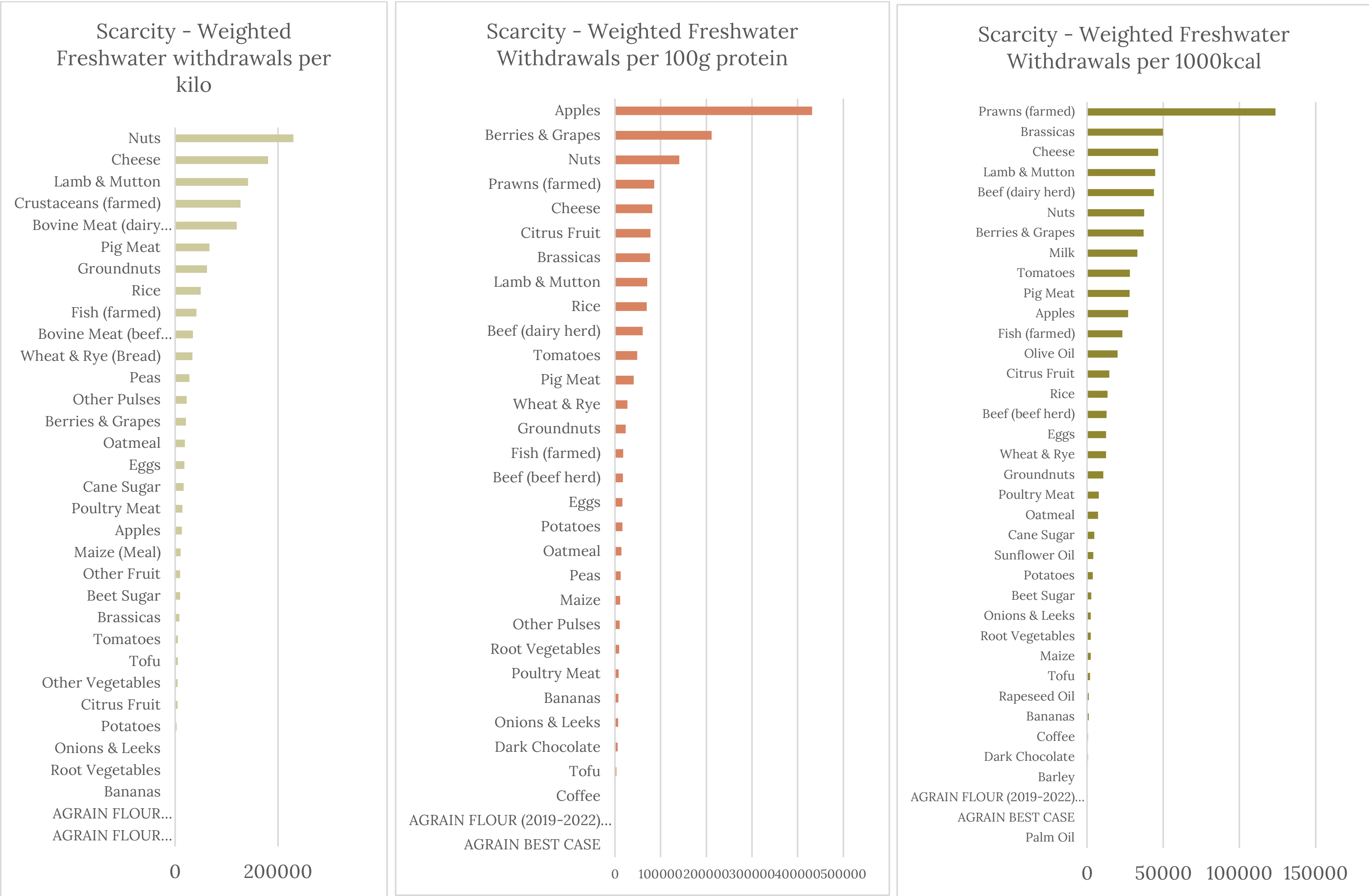
5.4.5 Scarcity - weighted freshwater withdrawals

Today's food production system is incredibly water resource demanding. According to Global Agriculture (n.d.), agriculture is by far the largest consumer of the Earth's available freshwater: 70% of “blue water” withdrawals from watercourses and groundwater are for agricultural usage, three times more than 50 years ago. In the same line, Poore & Nemecek (2018) estimate that two-thirds of freshwater withdrawals are used for irrigation. However, irrigation is a challenge to water scarcity, as irrigation returns less water to rivers and groundwater than e.g industrial and municipal uses. In this way irrigation predominates in water-scarce areas and times of the year, driving 90 to 95% of global scarcity weighted water use. It is therefore immensely important to find alternative food production methods that can have low impact on freshwater withdrawals.

The effects from water scarcity are already apparent across the globe. According to UNICEF (n.d.) almost 2/3 of the world's population is experiencing severe water scarcity at least one month a year, where the global south is hit the hardest. However, this is not a local problem: according to the European Commission (n.d.), 38% of European population in Europe was affected by water scarcity in 2019, accounting for approx. 29% of the European territory.

Results of the Agrain Flour impact on freshwater use, without considering the scarcity, in comparison to the majority of world food production, show that already in its current situation, Agrain flour is superior both when evaluated by kg and protein, and second when estimated in terms of kilocalories.

Figure 22: Scarcity - Weighted Freshwater Withdrawals: Agrain against 90% of current food consumption (per kg, per 100g protein and per 1000kcal), in liters eq per 1 kg of packed product at retail



5.4.6 Agrain flour compared to 90 % of protein and calorie

To understand the sensitivity of the numbers we compare three scenarios with any best performing food product from the Poore & Nemecek (2018) data, which consists of 90% of worldwide protein and calorie consumption. The three scenarios are Agrain Best case scenario (the Agrain future scenario), Agrain flour (current) scenario, and Agrain worst case scenario, where we use the highest variation of the observations across the 4 years of Agrain data. In total, 45 scenarios are analyzed, in the Agrain maximum observations (worst) Agrain performs best against 90% of food market in 9 out of 15 impact categories. In the average from last four years scenario it is 10 out of 15 impact categories. Whereas in the future Agrain case, Agrain is best in 13 out of 15 categories, namely Climate Change measured by 1000kcalories, where Nuts perform better, and Scarcity-Weighted Freshwater Withdrawals, where Palm Oil performs better. Overall, the sensitivity test (Table 20) confirms that already in current stage Agrain flour is the most environmentally sustainable protein resource when observing the main impact categories identified by Poore & Nemecek (2018).

Table 20. Sensitivity test, Agrain Best Case, Average Case, And Worst case against 90% of food calorie and protein consumption worldwide

	Is Agrain Best Case Scenario / Best against all food alternatives?	Is Agrain flour (current) best against all food alternatives?	Is Agrain worst case best against all food alternatives?
By KILO			
Climate Change	YES	NO	NO
Land-use	YES	YES	YES
Acidification	YES	NO	NO
Eutrophication	YES	YES	YES
Scarcity-Weighted Freshwater Withdrawals	YES	YES	NO
By 100g protein			
Climate Change	YES	NO	NO
Land-use	YES	YES	YES
Acidification	YES	YES	YES
Eutrophication	YES	YES	YES
Scarcity-Weighted Freshwater Withdrawals	YES	YES	YES
By 1000kcalories			
Climate Change	NO	NO	NO
Land-use	YES	YES	YES
Acidification	YES	YES	YES
Eutrophication	YES	YES	YES
Scarcity-Weighted Freshwater Withdrawals	NO	NO	NO

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7 APPENDIX I

Table A.1: PEF weighted results per 1 kg of Substitution Flours (Cradle to Gate), in absolute value, average of all flours (substitutions average), average of each database flours (Average Agribalyse and Average Ecoinvent), standard deviation between flour datasets and impact category relevance (%) to the average. (Method: EF 3.0 Method (adapted) V1.03/ EF 3.0 normalization and weighting set)

Impact category	Wheat flour {RoW}| wheat grain processing. dry milling | Cut-off. U	Wheat flour {ZA}| wheat grain processing. dry milling | Cut-off. U	Maize flour {RoW}| maize grain processing. dry milling | Cut-off. U	Barley flour. at industrial mill/FR U	Buckwheat flour. at industrial mill/FR U	Chestnut flour. at industrial mill/FR U	Chick pea flour. at industrial mill/FR U	Maize flour. at industrial mill/FR U	Millet flour. at industrial mill/FR U	Oat flour. at industrial mill/FR U	Rice flour. at industrial mill/FR U	Soy flour. at industrial mill/FR U	Spelt flour. at industrial mill/FR U	TOTAL STD	AVERAGE AGRIBALYSE	AVERAGE ECOINVENT	SUBSTITUTIONS AVERAGE TOTAL	SUBSTITUTION FLOURS AVE PEF in Weights by %
Database	Ecoinvent 3.8	Ecoinvent 3.8	Ecoinvent 3.8	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0	Agribalyse 3.0					
Total	0.000227	0.000199958	0.00014486	0.00012564	0.000117	0.000538	0.000116	0.000127	0.000138	0.000237	0.000327	0.00021	0.000117	0.000119	0.000205	0.000191	0.000202	
Climate change	2.26E-05	1.87855E-05	2.0015E-05	1.7402E-05	1.69E-05	4.66E-05	1.49E-05	9.47E-06	2.09E-05	2.76E-05	5.61E-05	0.000108	1.69E-05	2.68E-05	3.35E-05	2.05E-05	3.05E-05	15.11%
Ozone depletion	6.82E-08	6.05502E-08	7.222E-08	9.5425E-08	8.28E-08	3.46E-07	1.47E-07	7.93E-08	1.14E-07	1.05E-07	1.68E-07	1.16E-07	8.28E-08	7.53E-08	1.34E-07	6.7E-08	1.18E-07	0.06%
Ionising radiation	2.09E-07	1.89185E-07	2.4758E-07	4.4018E-07	4.41E-07	1.14E-06	5.53E-07	5.63E-07	4.66E-07	4.59E-07	6.5E-07	4.92E-07	4.41E-07	2.41E-07	5.65E-07	2.15E-07	4.84E-07	0.24%
Photochemical ozone formation	4.05E-06	3.79292E-06	3.9784E-06	2.308E-06	3.1E-06	1.01E-05	4.56E-06	2.16E-06	2.59E-06	3.8E-06	8.02E-06	5.72E-06	3.1E-06	2.32E-06	4.54E-06	3.94E-06	4.4E-06	2.18%
Particulate matter	1.55E-05	1.74845E-05	1.2174E-05	1.3802E-05	1.1E-05	1.43E-05	5.31E-06	6.82E-06	1.63E-05	1.76E-05	2.37E-05	6.35E-06	1.1E-05	5.2E-06	1.26E-05	1.51E-05	1.32E-05	6.53%
Human toxicity. non-cancer	3.65E-06	2.02014E-06	2.7515E-06	3.4493E-06	3.85E-07	2.68E-06	2.53E-07	9.23E-06	3.53E-06	-5.7E-06	4.37E-06	1.72E-06	3.85E-07	3.33E-06	2.03E-06	2.81E-06	2.21E-06	1.10%
Human toxicity. cancer	1.76E-06	1.22445E-06	1.4854E-06	1.1126E-06	1.16E-06	1.09E-06	1E-06	3.4E-06	1.16E-06	1.92E-06	1.7E-06	2.06E-06	1.16E-06	6.56E-07	1.58E-06	1.49E-06	1.56E-06	0.77%
Acidification	1.64E-05	1.92782E-05	1.1609E-05	1.2899E-05	1.16E-05	1.86E-05	7.92E-06	6.9E-06	1.53E-05	1.75E-05	2.71E-05	6.7E-06	1.16E-05	5.76E-06	1.36E-05	1.58E-05	1.41E-05	6.99%
Eutrophication. freshwater	8.45E-06	7.0782E-06	2.7651E-06	1.853E-06	4.53E-06	4.14E-06	5.58E-06	4.29E-06	2.09E-06	1.27E-05	1.39E-06	6.95E-06	4.53E-06	3.14E-06	4.81E-06	6.1E-06	5.11E-06	2.53%
Eutrophication. marine	1.38E-05	8.73967E-06	5.8593E-06	1.8876E-05	1.4E-05	1.46E-05	1.87E-05	9.95E-06	2.02E-05	9.37E-05	1.51E-05	1.84E-05	1.4E-05	2.24E-05	2.37E-05	9.45E-06	2.04E-05	10.13%

Eutrophication. terrestrial	1.28E-05	1.47434E-05	8.445E-06	1.0027E-05	9.6E-06	1.38E-05	4.6E-06	5.53E-06	1.19E-05	1.37E-05	1.88E-05	4.08E-06	9.6E-06	4.3E-06	1.02E-05	1.2E-05	1.06E-05	5.25%
Ecotoxicity. freshwater	2.88E-05	1.86036E-05	3.0075E-05	1.2453E-05	7.33E-06	0.000116	1.63E-05	7.06E-06	1.07E-05	1.38E-05	1.91E-05	1.7E-05	7.33E-06	2.87E-05	2.27E-05	2.58E-05	2.34E-05	11.59%
Land use	1.59E-05	1.5269E-05	2.5294E-06	9.2279E-06	1.18E-05	3.98E-05	1.64E-05	1.18E-05	9.47E-06	2.03E-05	8.8E-06	1.82E-05	1.18E-05	8.88E-06	1.58E-05	1.12E-05	1.47E-05	7.29%
Water use	6.54E-05	5.66461E-05	2.6355E-05	9.1374E-06	1.58E-05	0.000212	6.94E-06	4.01E-05	9.54E-06	5.3E-06	0.000118	1.25E-06	1.58E-05	6E-05	4.33E-05	4.95E-05	4.47E-05	22.16%
Resource use. fossils	7.71E-06	7.35015E-06	8.4984E-06	9.3038E-06	8.21E-06	3.04E-05	1.09E-05	8.73E-06	1.02E-05	1.05E-05	2.07E-05	1E-05	8.21E-06	6.58E-06	1.27E-05	7.85E-06	1.16E-05	5.74%
Resource use. minerals and metals	9.88E-06	8.69284E-06	8.0025E-06	3.2478E-06	1.37E-06	1.24E-05	1.56E-06	1.3E-06	3.6E-06	3.41E-06	3.82E-06	2.45E-06	1.37E-06	3.74E-06	3.46E-06	8.86E-06	4.7E-06	2.33%

Table A.2 Impact category contribution to PEF weighted results, in Points and in percentages

Impact category	Substitution Flours (average)		Agrain Flour (Average 2019-2022)	
	PEF weighted results	Impact category contribution to the overall score	PEF weighted results	Impact category contribution to the overall score
TOTAL	0.000202		7.15E-05	
Water use	4.47E-05	22.16%	1.45E-06	2.03%
Climate change	3.05E-05	15.11%	2.68E-05	37.42%
Ecotoxicity. freshwater	2.34E-05	11.59%	5.25E-06	7.34%
Eutrophication. marine	2.04E-05	10.13%	8.83E-07	1.24%
Land use	1.47E-05	7.29%	6.49E-07	0.91%
Acidification	1.41E-05	6.99%	2.89E-06	4.05%
Particulate matter	1.32E-05	6.53%	3.96E-06	5.54%
Resource use. fossils	1.16E-05	5.74%	1.94E-05	27.19%
Eutrophication. terrestrial	1.06E-05	5.25%	1.44E-06	2.01%
Eutrophication. freshwater	5.11E-06	2.53%	4.31E-07	0.60%
Resource use. minerals and metals	4.7E-06	2.33%	4.07E-06	5.69%
Photochemical ozone formation	4.4E-06	2.18%	2.47E-06	3.46%
Human toxicity. non-cancer	2.21E-06	1.10%	6.26E-07	0.88%
Human toxicity. cancer	1.56E-06	0.77%	4.61E-07	0.64%
Ionising radiation	4.84E-07	0.24%	5.73E-07	0.80%
Ozone depletion	1.18E-07	0.06%	1.44E-07	0.20%

Table A.3 Agrain and Poore & Nemecek Data

Source impact category name	Land Use (m2/FU) (Life cycle inventory results in Simapro)	GHG Emissions (kg CO2eq/FU. IPCC 2013 incl. CC feedbacks)	GHG Emissions (kg CO2eq/FU. IPCC 2007 GWP 100a V1.02)	Acidification (CML 2 baseline 2000 V2.05. converted to kg SO2eq)	Eutrophication (CML 2 baseline 2000 V2.05. converted to kg PO43-eq)	Freshwater Withdrawals (L/FU) (Life cycle inventory results in Simapro)	Stress-Weighted Water Use (L/FU) (AWARE V1.05)
AGRAIN FLOUR BEST CASE SCENARIO 6	0.0008	0.2773	0.2732	0.0012	0.0002	6.0788	206.2801
AGRAIN FLOUR (2019-2022) AVERAGE	0.0011	1.2614	1.2351	0.0031	0.0005	9.7936	314.9451
Apples	0.63	0.43	0.42	0.00352	0.00145	180.1	12948.6
Bananas	1.93	0.86	0.86	0.00635	0.00329	114.5	661.9
Beet Sugar	1.83	1.81	1.8	0.01262	0.00541	217.7	9493.3
Berries & Grapes	2.41	1.53	1.52	0.01229	0.00612	419.6	21162.1
Bovine Meat (beef herd)	326.21	99.48	85.19	0.31883	0.30141	1451.2	34732.5
Bovine Meat (dairy herd)	43.24	33.3	28.79	0.34364	0.36529	2714.3	119805.2
Brassicas	0.55	0.51	0.51	0.00821	0.00501	119.4	8455.1
Cane Sugar	2.04	3.2	3.16	0.01802	0.01692	620.1	16438.6
Cassava	1.81	1.32	1.3	0.00342	0.00069	0	0
Cheese	87.79	23.88	21.44	0.16554	0.09837	5605.2	180850.6
Citrus Fruit	0.86	0.39	0.37	0.00404	0.00224	82.7	4662.7
Crustaceans (farmed)	2.97	26.87	23.99	0.13307	0.22722	3515.4	127259
Eggs	6.27	4.67	4.6	0.05367	0.02176	577.7	17982.7
Fish (farmed)	8.41	13.63	12.51	0.06591	0.23512	3691.3	41572.2
Groundnuts	9.11	3.23	3.18	0.02262	0.01414	1852.3	61797.9
Lamb & Mutton	369.81	39.72	32.71	0.13897	0.09713	1802.8	141925

Maize (Meal)	2.94	1.7	1.68	0.01168	0.00403	215.7	10863.3
Nuts	12.96	0.43	0.37	0.04515	0.01915	4133.8	229889.8
Oatmeal	7.6	2.48	2.47	0.01068	0.01123	482.4	18786.2
Onions & Leeks	0.39	0.5	0.5	0.00363	0.00324	14.3	932
Other Fruit	0.89	1.05	1.06	0.00578	0.00243	153.5	9533.1
Other Pulses	15.57	1.79	1.79	0.02207	0.01708	435.7	22477.4
Other Vegetables	0.38	0.53	0.53	0.00641	0.00227	102.5	4911.4
Peas	7.46	0.98	0.97	0.00849	0.00752	396.6	27948.2
Pig Meat	17.36	12.31	11.54	0.14266	0.07638	1795.8	66867.4
Potatoes	0.88	0.46	0.45	0.00387	0.00348	59.1	2754.2
Poultry Meat	12.22	9.87	9.82	0.10242	0.0487	660	14177.9
Rice	2.8	4.45	3.81	0.02719	0.03507	2248.4	49576.3
Root Vegetables	0.33	0.43	0.43	0.0029	0.00161	28.4	929.2
Tofu	3.52	3.16	3.14	0.0067	0.00616	148.6	5113.2
Tomatoes	0.8	2.09	2.01	0.01721	0.00751	369.8	5335.7
Wheat & Rye (Bread)	3.85	1.57	1.58	0.01335	0.00716	647.5	33385.6

8 APPENDIX 2. CRITICAL REVIEW

APPENDIX 2. CRITICAL REVIEW

CRITICAL REVIEW OF "AGRAIN LIFE CYCLE ANALYSIS (LCA)"

CRITICAL REVIEW OF LCA CARRIED OUT BY EXTERNAL EXPERT ACCORDING TO ISO 14044

Introduction

This critical review of the life cycle analysis "AGRAIN LIFE CYCLE ANALYSIS (LCA)" regarding the environmental effects of production and waste treatment of Agrain Flours for baking have been carried out by BUREAU VERITAS in accordance with the international standard ISO 14044, as far as possible.

The process for the critical review was as follows:

- BUREAU VERITAS conducts the first review carried out in September and October 2023.
- Circular Food Technology/Agrain will respond to the review and make any corrections (new version of the report) in October 2023.
- BUREAU VERITAS addresses the corrections (paragraphs and table below) in the final review note end of October 2023.

From BUREAU VERITAS, the critical review was conducted by Julie Marie Vejsgaard Larsen, Odyssefs Papagiannidis, and supplemented by Waldemar Corydon Hemdrup.

1. Dialogue between the reviewers and the LCA practitioner during the CR process

The dialogue between the external verifier and LCA Practitioner during the verification process may be documented in a separate document.

Any deviations from the requirements, the dialogue between the verifier and LCA practitioner, and as well improvements made following the verification process should be documented in a transparent way and in English.

GE = General, TE = Technical, ED = Editorial.

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
1.	Chapter: Intro to report Pager: 6	TE	ISO 14044:2006, section 4.4.3.4	Weighting is not allowed according to ISO 14044 section 4.4.5: "weighting, as described in 4.4.3.4, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public"	Ok, this is understood. Results have been specified in characterized results first. In the intro, references to the weighting are delated.	OK
2.	Chapter: 1.1 Page: 10	TE		See comment 1	See 1	OK

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
3.	Chapter: 1.1 Page: 10	ED		As mentioned in Iso14040 the critical review shall be done by three people.	Sentence corrected to: An external critical review is carried out by a panel of three independent LCA reviewers.	OK
4.	Chapter 1.2.2 Page: 13	GE	ISO14044:2006 4.2.3.1	The functional unit is not discribed here. Please add. See section 4.2.3.1 of ISO14044. Functional and declared unit is used interchangeably and should be made clearer. **Round 2:** The sectence "In this case, even though the scope doesn't cover all product life cycle stages and so the functional unit is not applicable, as Agrain flour is sold by mass, the declared unit is expressed per weight." is now a little unclear with the new section added. Please change to make more clear, perhaps add that flour is inherently an intermediate product, making the use of a functional unit not applicable.	Corrected to declared unit. Functional unit is not applicable to this assessment. Note that Poore refer to functional unit in their article. **Round 2:** Sentence changed including the proposed text, that flour is inherently an intermediate product, making the use of a functional unit not applicable	OK
5.	Chapter: 1.2.3	TE		Please justify why packaging is not included	Added justification regarding how flour is usually delivered and the comparison flours datasets scope.	OK

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
	Page: 13					
6.	Chapter 1.2.5 Page: 16	GE		Does this mean that 54% of the input does not go to flour production?	Yes, this is correct for this year.	OK
7.	Chapter 1.2.6 Page: 17	GE		Normalisation, when used, should be presented transparently. It is not mentioned her. Normalisation and weighting values should be listed in detail.	Added characterization impact categories description and EF 3.0 Normalization and Weighting factors.	OK
8.	Chapter: 1.2.7 Page: 17	ED		Critical review panel: Julie M. V. Larsen, LCA & EPD Consultant, Chair person Odyssefs Papagiannidis, LCA & EPD Consultant Waldemar C. Hemdrup, LCA & EPD Consultant All working for Bureau Veritas HSE Denmark.	Modified	OK

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
9.	Chapter 1.2 Page 10			There is no data requirement section. **Round 2:** There are still some processes which has not been reported in the report such as processes related to packaging.	Added section 2.1 Data requirements. **Round: 2** Added in Table 7 all datasets considered to model the scenarios and the cradle to retail assessments.	OK
10.	Chapter: 2.1 Page: 18	GE		Functional unit has not been described. Please clarify.	Functional unit not applicable	OK
11.	Chapter: 2.1 Page: 18	TE		Find process more aligned with geography. China cannot be compared to Danish conditions.	Dataset refers to Switzerland (CH). Checked by the auditors	OK
12.	Chapter: 2.1 Page: 18	GE		See comment 11	See 11	OK
13.	Chapter 2.2 Page 19	GE		You need to describe what "very good" and "fair" means by fx adding another table.	Data quality assessment section has been redone including: - Table with each data quality criteria - Assessment including the dataset used, validity	OK

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
					dates, year of extrapolation, data collection year and ranking for Technology, Temporal and Geographical representativeness	
14.	Chapter: 3.1 Page: 19	TE		Interpretation should not be done on weighted results.	Now the interpretation clearly refers to characterized results and the Disclaimer in comment 17 has been added when using the weighted results, as Footnote 1.	OK
15.	Chapter: 2 Page: 17	GE		AGRIBALYSE database is not mentioned. Please add to make it clear that data from this database is also used, as mentioned in section 3.1 of this report. **Round 2:** AGRIBALYSE database name is spelled incorrectly, otherwise OK.	Added in section 2.1 **Round 2:** Corrected	OK
16.	Chapter: 2	GE		See comment 15.	See 15	OK

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
	Page: 17			**Round 2:** Text is okay, but database is spelled wrong.	**Round 2:** Corrected	
17.	Chapter: 3.1 Page: 20	TE		See comment 1. Disclaimer should be added to make it clear that this part does not follow the standard for LCA meant for the public.	This has been added to text as footnote 1.	OK
17a	Chapter 3.1 Page 22	ED		There are no units on this graph. If weighted results are presented here, then the units of "points" shall be used.	Pt inserted	OK
18.	Chapter: 3.1 Page: 22	ED		See comment 17a.	See 17a	OK
19.	Chapter: 3.1 Page: 23	ED		The unit of "µP" = micro points (10E-6) is allowed for clarification.	Throughout the report, in tables and graphs, we utilize Pts in scientific expression. In the text we use µP for clarification.	OK
20.	Chapter: 3.1 Page: 23			This table should be in the report, not the annex.	Moved to section 1.2.7 Life cycle impact assessment	OK

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
21.	Chapter: 3 Pages: 20	GE		Section should be moved to after cat. Results.	Moved, now part of the Interpretation section, after the results.	OK
22.	Chapter: 3.1 Page 23			See comment 1.	See 17	OK
23.	Chapter: 3.2 Page: 24	ED		GHG emissions, does not equal climate change emissions.	Corrected	OK
24.	Chapter: 3.2 Page: 24	ED		Text okay, but remove bolding.	Removed	OK
25.	Chapter 3.3 Page 25	ED		See comment 24.	Removed	OK
26.	Chapter 3.3 Page 26	ED		See comment 24	Removed	OK
27	Chapter 3.4 Page 27	TE		You are using "general grid" process for electricity, if you know you are using green electricity this should be proven with certificates. If you are not you should use the residual mix.	We think for this assessment it's better to use the grid market mix. Justified in section 1.2.6 Assumptions and limitations.	OK, assumptions and limitations, but it is recommended to use residual mix or guaranty

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT (ED, TE, GE)	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	VERIFIER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL VERIFIER STATEMENT
				Round 2: You should still use the residual mix, since you don't know what your landlord purchases. There are high amounts of wind and hydro which has already been sold elsewhere. You can't also use this since it would be double counting.	Round 2: Landlord was contacted and individual electricity bills from three different providers over a 4 year period was identified. Each of the electricity providers were contacted and information received on the electricity mix they had been supplying to landlord. The results were: 01.01.19-31.01.21: Supplier: SEAS NVE/ ANDEL ENERGI. Info from supplier: electricitymaps.com Invoices available – but no information on them. 01.02.21-31.08.22: Supplier: GNP Energy, Info from supplier: Energi Styrelsens – monthly report. Invoices available – but no information on them.	of origin certificates in the future.

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					01.09.22→ Supplier: Natur Energi Info from supplier: 100% Wind, is available on landlords invoices. Based on this information, and previous arguments (e.g. for enabling comparison) the electricity grid is the reference used. However, residual mix sensitivity analysis is included in report.	
28	Chapter 3.7 Page 31	GE		It is very unclear whether this data is characterised or normalised or weighted.	Clarified.	OK
29	Chapter 3.9 Page 31	ED		This is the case for all graphs so far: there are no units on the y-axis making them hard to read. Please add for clarification.	Units added in all graphs in the y-axis.	OK
30	Chapter 3.10 Page 34	ED		Still missing units on y-axis. See comment 29.	See 29	OK

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31	Chapter 3.11 Page 39	TE		You also need to consider the cat. Results. They are not mentioned or shown in the report. **Round 2:** The impacts from "Human toxicity – non-cancer organics" to "Ecotoxicity freshwater metals" should be excluded since they are not part of the standard and the impacts have already been report earlier in the same table.	Corrected so in the Table the characterised results for the most relevant categories are presented. In a separate table, the weighted results are presented. **Round 2**: Results for these impact categories delated from the table.	OK
32	Chapter 3.11 Page 39	GE		PEF weighted results shall be excluded from table. See comment 1.	See 31	OK
33	Chapter 3.11 Page 42	TE		Sensitivity check should be presented as shown in ISO 14044 section B.3.3 **Round 2:** Has all assumptions been changed during in the same calculation? To probably see the effects only one should be changed at a time.	Modified the sensitivity check tables to present the information as shown in ISO 14044 section B.3.3. **Round 2:** The sensitivity analysis checks the valorization rate, so almost all inventory data are affected by this change. This is the main assumption	OK

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					for the period 2019-2021. Added this sentence as clarification: "The change on the valorization rate (kg of flour/kg of processed BSG), affects all inventory data, as all processes are allocated to the quantity of flour produced."	
34	Chapter 3.11 Page 44	TE		See comment 33. **Round 2:** I have trouble seeing what you are trying to convey in table 16. Please explain.	See 33 **Round 2:** Added "na" to the empty cells in all Sensitivity analysis tables and added clarification in the text after Table 16 of what we are comparing.	OK
35	Chapter 4.2 Page 46	ED		No units on y-axis, but mentions in table text	Corrected	OK
36	Chapter 4.2 Page 47	GE		Again, GHG does not equal CO2e emissions	Corrected	OK

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37	Whole report	GE		General comments: 1. The LCI needs more detail. 2. The characterized data is absent from the report. 3. All comparison should be done on an objective basis, like fx characterized data. 4. LCIA section is not clear. 5. Interpretation and LCIA sections are mixed together. **Round 2:** Data quality section is not complete. Some processes related to packaging is still missing from the DQA.	LCI data have been clarified in report with a new Table. And auditors have access to data not indexed. LCIA section has been added including characterized, normalized and weighted results. In the comparisons we now clearly indicate when it's done for the characterized results (always first) and when it refers to the weighted results. **Round: 2** Added in Table 7 all datasets considered to model the scenarios and the cradle to retail assessments.	OK
38	Intro to report	GE		A conclusion can not be made on the weighted scores, since these are not allowed according to ISO 14044 section 4.4.5: "weighting, as described in 4.4.3.4, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public"	See 1	OK

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39	Summary	GE		See comment 38	In the summary references to the weighting are indicated to be not conformant with ISO 14044.	OK
40	Summary	GE		See comment 38	See 39	OK
41						
42	Chapter 2.2	GE		If the geography of the process from Ecoinvent is China it will not be "Very good" Geographical representativeness	See 11	OK
43	Chapter 2.2	GE		See comment 42	See 11	OK
44	Intro to report	GE		It is recommended to select a representative period of 1 year, or mention in the functional unit that data are collected over a 4 year period. It would be difficult to compare Agrains' with other grains' environmental footprint that are based on a time period of 1 year, unless data for every process is collected are based on the 4 year timeframe. Due to the COVID period, the production yield and sales of grain is affected, so it is recommended to use the representative timeframe based on normal operation i.e. 2022-2023. By having a 4 year timeframe affects also the data quality assessment i.e. a dataset that is of 0-3 years old has a quality rating of 'Very Good'. More details in the data quality assessment section.	The purpose of the current assessment is to assess a representative product. Added new section 1.2.1.1 justifying it and explaining how it is calculated (average of the 4 years). In the future, only single years will be assessed, once we confirm that the process is stable.	OK

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45	Summary	ED		Very interesting potential and insightful comment made, but since we can not verify the information, please remove any judging words, so the text is more neutral for the audience.	Done	OK
46	Summary	GE		Please provide full address for transparency in the 'Introduction', here it is fine to mention only the location in Denmark.	Done	OK
47	Summary	ED		Please remove judging words.	Done	OK
48	Summary	ED		*good manner is meant here?	Corrected	OK
49	Summary	GE		How is this derived, as a sum of the above 4 strategies reduction % potential? Please clarify and show in the meeting.	It is the total reduction in Weights when all four strategies are implemented. It's modelled at the inventory data level, where allocations between the flour and the liquid takes place, so it is not the sum of the previous strategies.	OK
50	Summary	ED		Please remove judging words to make a moderate statement.	Done	OK
51	Chapter 1.1	GE		It is good that you are aware of the difference in single years, but the average scenario reflects an average product, not a precise single year. This makes it difficult to be consise with data collection by having multiple data entries for 4 years and moving	See 44	OK

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				forward with future control and verification checks on the fiscal year.		
52	Chapter 1.2.1, Table 1	GE		Is the agrain flour nutritional content measured in the lab or with stoichiometric formulas? Just be clear and transparent that Wheat, Maize, Barley, Buckwheat, Rice, Soy, Spelt come from the FRIDA database if that is the case.	Measured by external authorized lab (Lab=ALS global).	OK
53	Chapter 1.2.3	GE		Please specify the cut-off criterion. Usually a maximum 1% of the renewable and non-renewable primary energy use and maximum 1% of the total mass input of a specific unit process are allowed to be cut-off (excluded). However, it should be noted, that all relevant processes that could be included are included.	Added new chapter (1.2.4) detailing the specific percentages considered as cut-off criteria.	OK
54	Chapter 1.2.4	GE		Good assessment with reference to beer PEFCR, but please describe 3 step allocation procedure, as in below: Allocation in this LCA is performed according to ISO 14044, which is done in the following order of priority: Step 1 – Avoid allocation by dividing the unit processes into sub-processes or expanding the product system to include additional functions.	The 3 steps described in section 1.2.5 of Allocation	OK

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				Step 2 – Partitioning the inputs and outputs of the system between its different products or functions in a way that reflects the underlying physical relationships between them. Examples of this is mass or energy, if the revenue is small, pleases show that it is below 25% variation. Step 3 – Partitioning the inputs and outputs of the system between its different products or functions in a way that reflects other relationships between them. Examples of this is economic value.		
55	Chapter 1.2.4	GE		Good that you mention the burden free rationale, but explain why by Adding that the system boundary follows The polluter pays principle. Processes of waste processing shall be assigned to the product system that generates the waste until the end-of-waste state is reached. Add a 'Description of the polluter pays principle section'. ''For all generic data the system model 'Allocation, cut-off by classification - unit' is used apart from manual datasets shown in Section 5.5. This model is based on the approach that primary production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. The	Added in section 1.2.5 that we follow the polluter pays principle and added new subsection 1.2.5.1 with the description provided.	OK

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				consequence is that recyclable materials are available burden-free to recycling processes and secondary (recycled) materials bear only the impacts of the recycling processes. Also, producers of wastes do not receive any credit for the recycling or re-use of products resulting out of any waste treatment.''		
56	Chapter 1.2.5	GE		Is next year expected to take into account only the year 2023 or again the 2019,2020,2021,2022,2023 5year period? This question highlights the need for a reference year assessment, but not an average of 4-5 year period of data collection.	If the Agrain production has been stabilized, a one year period can be used. In 2023 Agrain has initiated data collection on a monthly basis on elecricty, gas, water, incoming BSG and flour production and will therefore be able to analyze to which degree the production setup has been stabile across the year.	OK
57	Chapter 1.2.5, table 2	GE		I understand that you may want to hide the production figures, but pplease show in a meeting as the index can be a little confusing.	Reviewers have been shown full data. Explained how indexes are calculated.	OK
58	Chapter 1.2.7	GE		Add ISO 14071:2016	Added	OK
59	Chapter 2.1	GE		Show during meeting. The internal flow, water and carbon water flows in SimaPro.	Aspects made available to the reviewers during the meeting.	OK