5. Conclusive summary

5.1. P2F product lines examined

In the report presented here, the environmental impact profiles of the following four innovative protein-rich food prototypes (P2F prototypes) were assessed and compared against conventional animal-based and where appropriate also against soy-based (modern) reference food alternatives:

1. Fiber-like vegetable meat alternative („VMA-fiber“)
   Conventional alternative: chicken breast meat
2. Spread-like vegetable meat alternative (“VMA-spread”)
   Conventional alternative: pork-based Leberwurst (liver paté)
3. Vegetable burger alternative („Vegetable burger“)
   Conventional alternative: beef burger
   Modern alternative: soy burger
4. Lentil protein based milk alternative („Vegetable milk“)
   Conventional alternative: cow milk
   Modern alternative: soy milk

The first prototype was examined with two different protein sources combined with two different sources of flour

1.A.1 Lupin-based VMA-fiber with Amaranth flour (“VMA-fiber AF LuPI”)
1.A.2. Lupin-based VMA-fiber with Buckwheat flour (“VMA-fiber BWF LuPI”)
1.B.1 Lentil-based VMA-fiber with Amaranth flour (“VMA-fiber AF LePI”)
1.B.2. Lentil-based VMA-fiber with Buckwheat flour (“VMA-fiber AF LuPI”)

The second prototype was examined with three different taste variants each with specific combination of ingredients:

2.A. “VMA-spread type leberwurst”
2.B. “VMA-spread type tomato”
2.C. “VMA-spread type curry”

The third prototype was examined with two different protein sources:

3.A. “Lupin Burger”
3.B. “Lentil Burger”

5.2. Important assumptions

To put the LCA results in the right perspective a couple of points should be taken into consideration.

- The P2F crop processing and food preparation data from P2F partners were at pilot or laboratory scale. For the purpose of the LCA selected parameters such as overall “protein yield per protein content of crops” and “energy efficiency” were adjusted so as to simulate operation at small/medium industrial scale. Overall this “up-scaling” was done in a conservative way to avoid an overestimation of the process performance.

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This means that well-established industrial scale operations might even perform with higher efficiencies than the simulation of up-scaled processes assumed in this study.

- Processing of P2F crops requires a number of combined process steps such as milling, de-hulling, de-oiling, protein extraction, protein precipitation, drying (from solvents or water), etc. As a consequence, a series of different by-products are created, for example hulls and shells, oil containing fractions, fiber containing fractions and starch containing fractions. Depending on the nature of these “side streams” and the composition of the P2F prototypes they are not necessarily usable in the final product despite the effort made in the project to make use of whole grains where adequate.
  Most of those side streams can be considered valuable materials though their potential/probable end-use might not be known due to the fact that they are not yet present on the market. In order to cope with this situation expert judgement of project partners was used to estimate a theoretical market value of each type of by-product. Those values then formed the basis of allocation of environmental loads between the target P2F ingredients and the by-products.

- In this project the value chain of the reference food products were also fully modelled to ensure data symmetry between P2F prototypes and reference food products. The challenge when modelling animal based food systems is the large variability of husbandry practices. Among the most influencing factors are the amount of feed required per unit of animal weight gain and the economic value associated with the particular animal parts used in the reference products. Where feasible we decided to model a very efficient and a much less efficient value chain of animal products in order to better understand the positioning of P2F prototypes if compared to a realistic range of possible environmental profiles of animal based products. The more favorable husbandry conditions were referred to as “low impact” while the less favorable ones as “high impact”. This was implemented in the following cases:

  Reference for VMA-fiber prototypes:
    a. “chicken meat low impact”
    b. “chicken meat high impact”

  Reference for VMA-spread prototypes:
    a. “Leberwurst low impact”
    b. “Leberwurst high impact”

  Reference for plant-based milk prototypes:
    a. “Cow milk low impact”
    b. “Cow milk high impact”

  It should be borne in mind that the “low impact” cases represent intensive husbandry conditions using high performance animals. These animals are “optimized” for fast growing and/or high yielding and therefore approximate the currently dominating practice of animal husbandry.
  All animal feed mix applied in the LCA models contains soy (around 25% of which assumed to come from Brazil) and – with the exception of beef feed – palm oil (assumed to come from Malaysia). The land use change associated with those feed sources has been accounted for in the carbon footprint calculations of the animal-based food products.

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- P2F prototypes were also compared to soy-based milk and burger. It is important to notice here that there are fundamental differences in the underlying crop processing steps. The P2F alternatives to animal food are built on isolated and/or concentrated proteins which in the case of VMA-fiber being combined with flour extracted from buckwheat or amaranth. Soy milk and soy burger are made from soy beans with less processing steps and with most of the proteins and flour/oil ending up in the final products. On the other hand, the nutritional value of the soy products is most likely smaller than that of the P2F prototypes. In the LCA models it was assumed that both soy milk and soy burger are made from European grown soy. This assumption is based on the fact that several large producers of e.g. soy-based milk products on the European market actually state European origin for their raw material soybean.

- Yields of P2F crops are in many cases considerably lower than feed crops for animal husbandry. This may lead to relatively high potential environmental impacts related with crop production on a product (e.g. per t crop) basis.

- In general, water requirement per crop not only depends on the crop as such but even more on the site-specific conditions. Site-specific conditions were not considered or specified in the P2F project. Therefore, in order to have a symmetric assessment of all crops agriculture of all crops (P2F crops as well as any other food and feed crop) was assumed to happen under rain fed conditions. Consequently, in the LCA no use of blue water from irrigation was accounted for.
  However, in order get an impression of the importance of future selection of P2F crop growing sites a water footprint exercise was carried-out using VMA-spread as an example. The term water footprint here refers to an approach which considers water scarcity at a watershed level.

5.3. Condensed LCA results: P2F products versus animal-based products

5.3.1. Emission-related LCA indicators

The net results regarding emission related environmental impacts are visible in figures 3-19 to 3-26 with protein content as the functional unit and in figures 3-27 to 3-34 with 100g of mass per each product as the functional unit. The potential environmental impacts of P2F prototypes in total are clearly smaller than those of the animal-based products no matter if scaled to protein content or mass of the food products. Within this general picture carbon footprint and aquatic eutrophication call for a closer look.

Carbon Footprint (CF)

On a protein content basis the carbon footprint without dLUC of all P2F prototypes is smaller than that of the animal-based products. The CF savings of the best P2F variants as compared to the animal-based product are roughly

-50% and -70% for VMA-fiber compared to chicken meat low and high impact
-45% and -60% for VMA-spread compared to Leberwurst low and high impact
-70% for P2F burger compared to beef burger
-70% and 80% for P2F milk compared to cow milk low and high impact

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If taking land use change into consideration the CF savings are even much larger. In the case of VMA-fiber and due to the fact that protein content per mass of product in VMA-fiber is higher than in chicken breast the CF advantage here becomes smaller when compared on a mass basis but is still significant.

Aquatic Eutrophication (AqEutr)

Regarding AqEutr the comparative results show a more differentiated picture. Here the P2F prototypes tend to have less impact when compared to the high-impact animal variant but give an ambiguous result when compared to the low-impact animal variant. This is explained by the relatively low crop yield per ha of the P2F crops and the assumption that nitrate leaching which is the key driver of AqEutr is a function of agricultural area. Therefore, the more crop land is needed to deliver the feed or food ingredients by functional unit the more nitrate emissions from soil are generated.

5.3.2. Resource-related LCA indicators

In this project four resource-related categories were examined. Two of those, land use and phosphate rock demand, are mostly driven by agriculture. The other two, non-renewable energy consumption and blue water use are mainly driven by processing of crops for food and feed and in the case of animal-based food by animal husbandry too.

Land use and phosphate rock demand

Land Use: The main factors triggering land use results are crop yield per ha and protein content per crop. As previously explained P2F crops have a relatively low crop yield per ha as compared to conventional feed crops such as wheat, maize and soy. Consequently, overall more arable land is required for P2F products than for animal based products, especially for the chicken and cow milk alternatives. The exception seems to be the burger case. However, here a major part of the area is related to grassland for the production of grass silage.

Phosphate rock demand: This category is environmentally relevant as phosphorus is an increasingly scarce resource while crucial for agricultural productivity and implicitly for securing human nutrition. P2F prototypes in the case of burger have a significantly smaller and in the case of milk a slightly smaller phosphorus demand. This is related to the phosphorus demand associated with roughage feed for cows (grass cultivation for silage production). In the case of VMA-fiber and VMA spread comparative results are ambiguous, as those are composed of both legume and pseudocereal ingredients. Legumes typically show lower specific phosphate rock demand due to their ability to solubilize soil-bound phosphorus, whereas pseudocereals (especially amaranth) lack this ability and thus are more in the range of feed crops with regard to specific phosphate rock demand.

Energy demand and blue water use

Water Use: The main contributions to water come from the processing of crops into ingredients and ingredients into final product and for animal-based products also from animal husbandry. Overall P2F products use less blue water than the animal based-products. The

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exception is the VMA-fiber prototype made with lupins which use more water than the low-impact chicken case. This is due to the relatively high water demand for protein extraction from lupin seeds.

Energy demand: Overall the non-renewable energy demand of P2F products is in the range of that of the reference animal based-products. The exception here is the P2F burger as the beef burger case requires a large amount of diesel fuel for the cultivation of grass for grass silage feed, e.g. for harvesting, handling of harvested grass with a relatively high water content and silage processing required.

5.4. Condensed results regarding biodiversity and water footprint

Biodiversity: given the lack of practical and operable methods for a fully quantitative biodiversity assessment a new approach was developed to meet the needs of the P2F project allowing for benchmarking protein crop based products against animal based products. The method applies five “pressure categories” which again are broken down into a number of “influencing factors”.

The results are shown in tables 4-1 to 4-4 in form of a color pattern, where *green* indicates a more favorable and *red* a less favorable impact on biodiversity. These patterns clearly indicate that P2F prototypes will have a very positive contribution to improved biodiversity.

Water Footprint: water scarcity footprints (WSF) were calculated for VMA-fiber prototypes as an example (see figure 4-6). These water footprints are based on the water scarcity factors of the so-called AWARE-method (0,1 = very low water scarcity; 100 = max. water scarcity possible). To better understand the potential ranges minimum and maximum water scarcity factors were applied for the following P2F crops:

- Buckwheat: (Min: 0,93 France; Max: 3,19 France)
- Lentil: (Min: 1,29 Bulgaria; Max: 96,67 Spain)
- Lupine: (Min: 0,93 Germany; Max: 34,95 France)

Only countries with areas suitable for cultivation of the individual crop were considered. The min and max values refer to smaller regions within each of the countries where the lowest or the highest water scarcity can be expected. The final water scarcity footprint (see figure 4-6) considers the mix of P2F crops used in the corresponding VMA-fiber prototype. The results show that for the VMA-fiber prototype made from Lupine the difference between min and max is WSF 0,5 and 4,9. In contrast for the VMA-fiber prototype made from Lentil the difference between min and max is WSF 0,5 and 58 with the latter representing a rather unfavorable WSF.

5.5. Synopsis and outlook

In the environmental assessment carried-out in the P2F project all relevant environmental topics for a comparison of the innovative plant-based prototypes with traditional animal-based products were addressed. The P2F prototypes proved to be very promising solutions to improve the sustainability of protein food supply for humans. Especially for “climate change” and “biodiversity loss” two environmental problems of high concern and public attention P2F prototypes bear a high potential for significantly reducing GHG emissions and increasing biodiversity.

A major trade-off consists in the fact that more arable land area is required to deliver the same amount of protein currently provided via animal-based food products, especially when compared to the

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strongly industrialized chicken and pig meat as well as cow milk value chains. This difference becomes clearly smaller when comparing it with more extensive animal-based value chains. Thus, extensification of food supply systems will most probably require more arable land area per protein intake. Yet, there are ways to cope with this:

0. Reduce amount of overall protein uptake of EU consumers
1. Optimize protein-efficiency in plant-based food production systems (yield of crops per ha, yield of proteins per seeds processed)

P2F prototypes build on protein concentrates and/or protein isolates. Besides increasing protein yield a further issue are the by-product side streams for which good uses, ideally in human food production, still have to be investigated and accomplished. This can be seen as a fundamental prerequisite for a beneficial environmental performance of P2F products. And it also is the major reason why soy milk and soy burger have more favourable environmental profiles than the corresponding P2F prototypes. The soy-based products with tofu, okara and oil as ingredients create much less side streams by making use of most of the bean components. Thus, it seems worthwhile to explore the increased use of e.g. starch fractions of P2F legume crops.

A third area of concern is water consumption with agriculture being the main contributor. The negative impact of water consumption can best be measured against water scarcity at a regional level. Given the generic character of the P2F project it was not possible to assess regional water scarcity at sufficient detail and consistency across the multitude of value chains. Yet, the sensitivity analysis carried-out gives a striking insight of how decisive the choice of growing locations for P2F crops could be in order to establish low pressure supply chains.

Again, this implies careful decision making in order not to discriminate against hotter regions with low precipitation. In any case the European crop map when increasing the share of P2F crops should be aimed at a stronger alignment of site-specific conditions and crop-specific requirements.

Also, regarding water consumption it is strongly recommended that crop processing for protein extraction should be operated with closed water circles. This would help minimize fresh water input at the processing stage (currently dominating blue water use of the P2F value chains) largely and thus contribute to a strongly optimized blue water profile of P2F prototypes.

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6. Delays and difficulties

The deadline of this deliverable had to be shifted (in agreement with the EU project officer) by 4 months (from M42 to M46). This was due to additional wishes regarding the scope of the deliverable as a result of the review meeting in May 2018. However, the overall timeline of the P2F project (including timelines of future deliverables) will not be affected by this delay.

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8. Appendix

8.1. Sensitivity Analysis Functional Units – mass and energy

8.1.1. Sensitivity analysis: VMA-fiber

The following table 8-23 summarizes the product reference mass flows related to the alternative functional units.

Table 8-1: Comparison of FUs, VMA-fiber and reference systems

Reference flow of food product / Functional Units	Innovative: VMA-fiber[9]	Traditional: Chicken meat
Energy content (136 kcal) *	100 g (~1360 kcal/kg)	114.3 g (~1190 kcal/kg)
Protein content (30 g) *	100 g (~300 g protein/kg)	140.2 g (~214 g protein/kg)
Mass (100 g)	100 g	100 g

The following figures (Figure 8-1 to Figure 8-4) illustrate sensitivity results of VMA-fiber.

[9] VMA-FIBER = vegetable meat alternative, fiber-like

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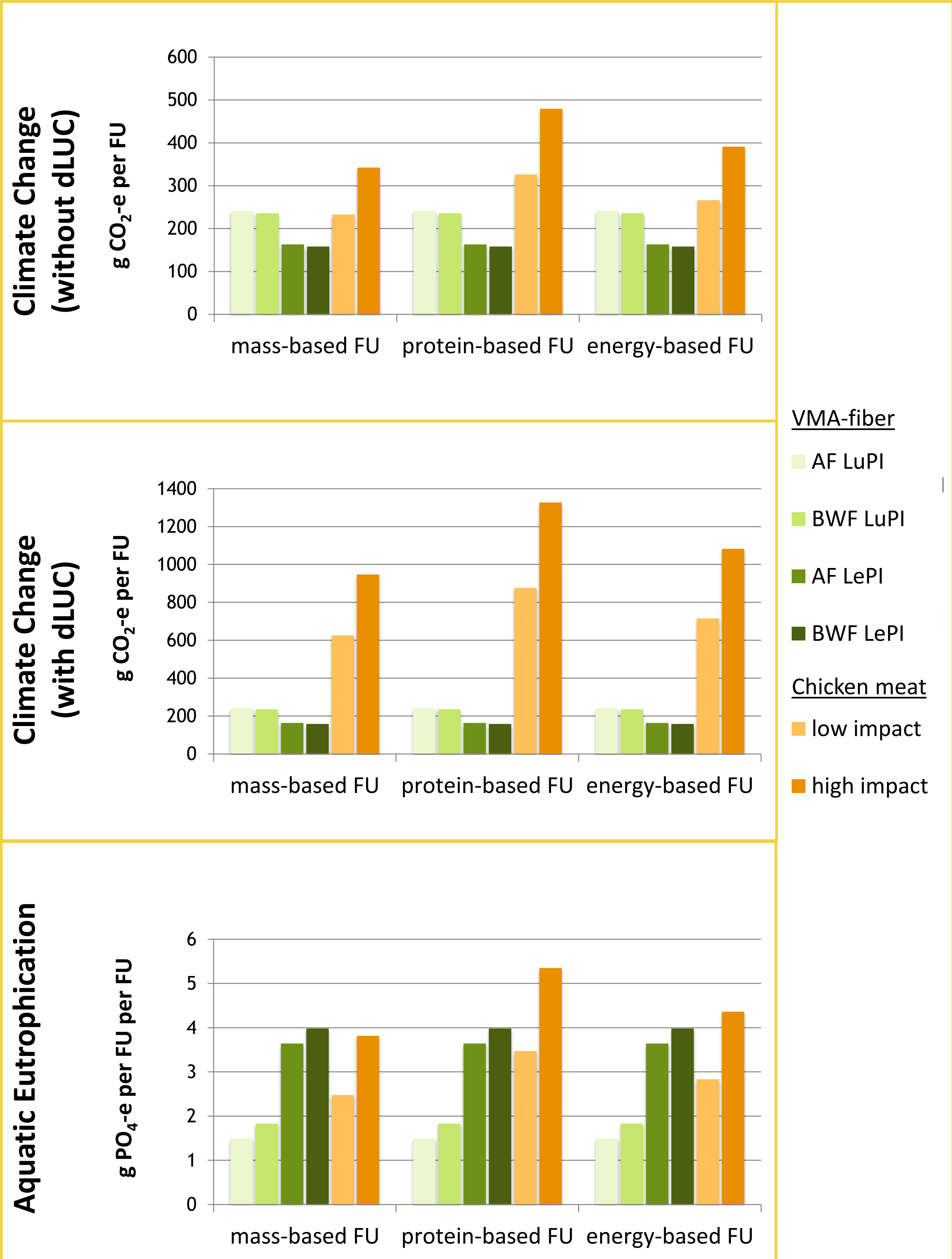

Figure 8-1: sensitivity results of VMA-fiber, indicators: Climate Change (with dLUC), Climate Change (without dLUC), and Aquatic Eutrophication

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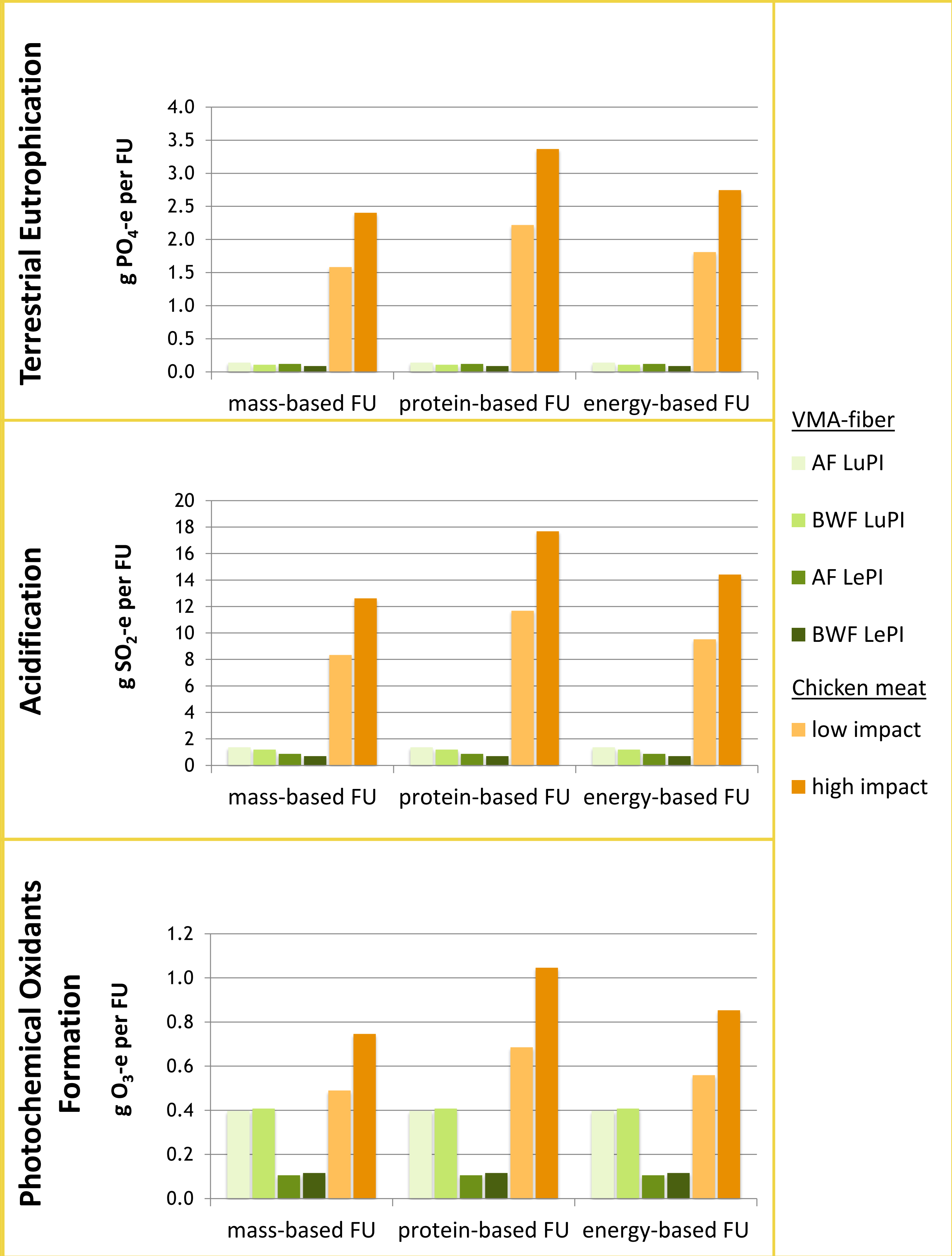

Figure 8-2: sensitivity results of VMA-fiber, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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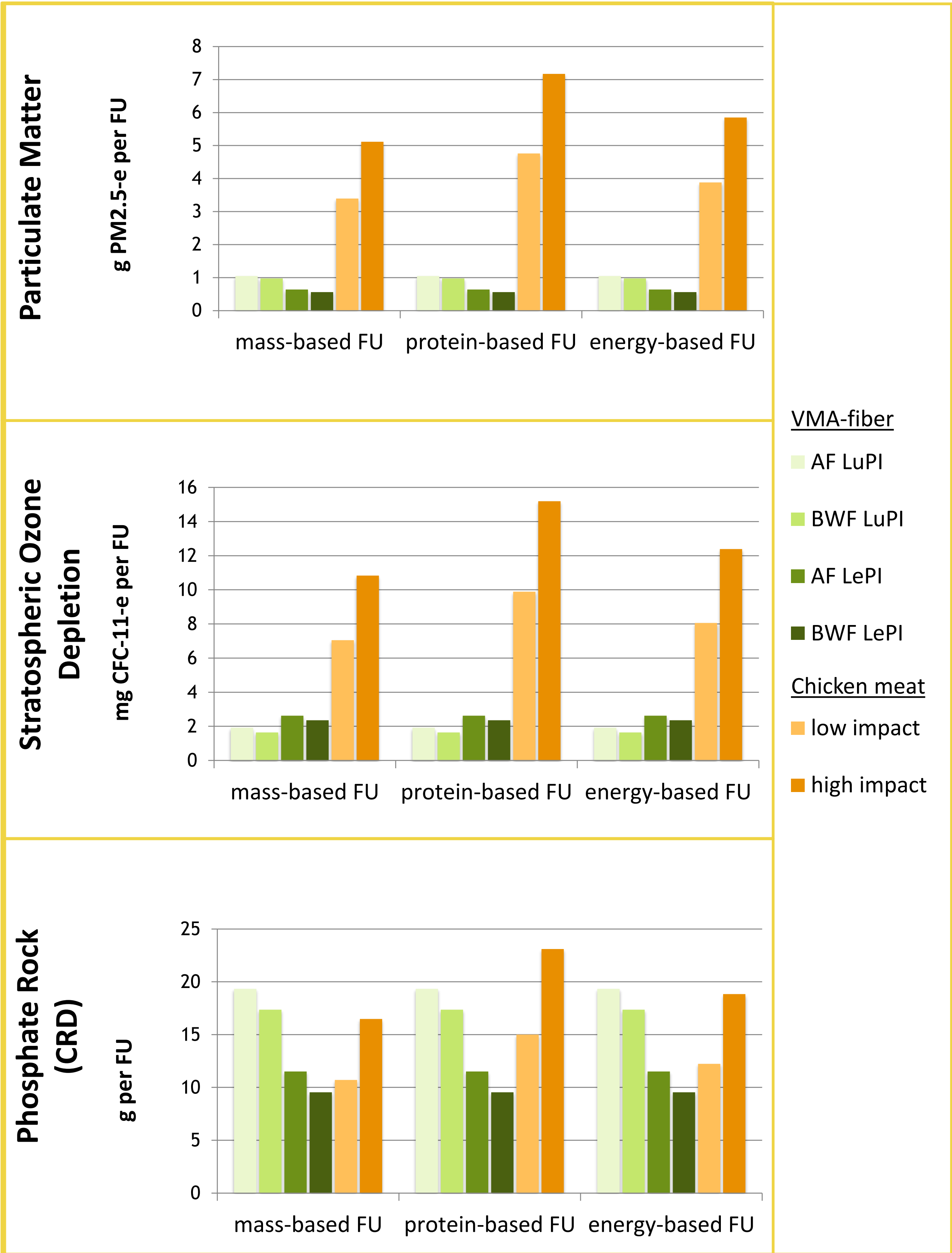

Figure 8-3: sensitivity results of VMA-fiber, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate Rock (CRD)

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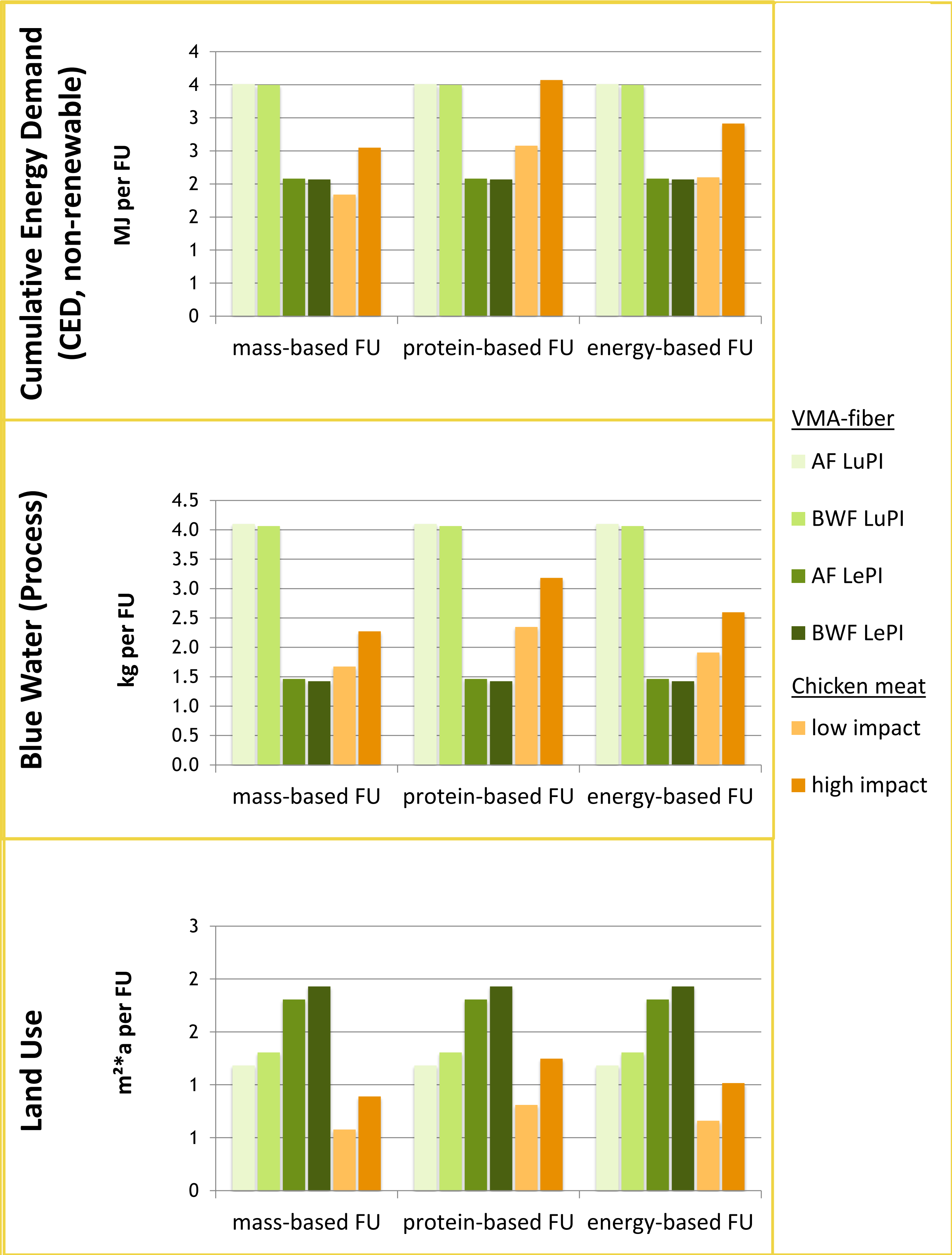

Figure 8-4: sensitivity results of VMA-fiber, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process), Land Use

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8.1.2. Sensitivity analysis: VMA-spread

The following table 8-24 summarizes the product reference mass flows related to the alternative functional units.

Table 8-2: Comparison of FUs, VMA-spread and reference systems

Reference flow of food product / Functional Units	Innovative: VMA-SPREAD	Traditional: Leberwurst
Energy content (247.3 kcal) *	100 g (~2473 kcal/kg)	77.3 g (~3200 kcal/kg)
Protein content (12.5 g) *	100 g (~125 g protein/kg)	83.3 g (~150 g protein/kg)
Mass (100 g)	100 g	100 g

The following figures (**Figure 8-5** to Figure 8-8) illustrate sensitivity results of VMA-spread.

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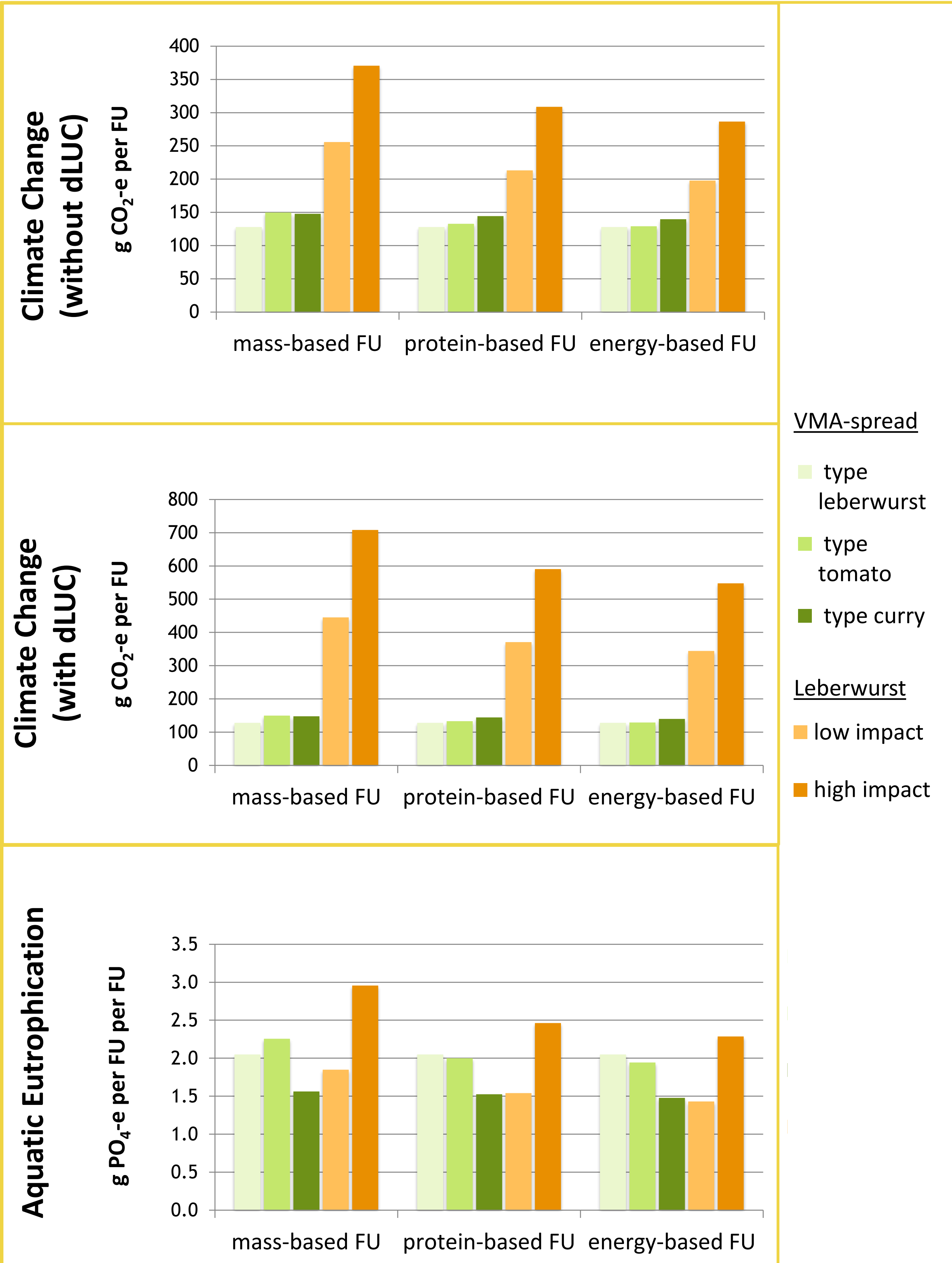

Figure 8-5: sensitivity results of VMA-spread, indicators: Climate Change (with dLUC), Climate Change (without dLUC), and Aquatic Eutrophication

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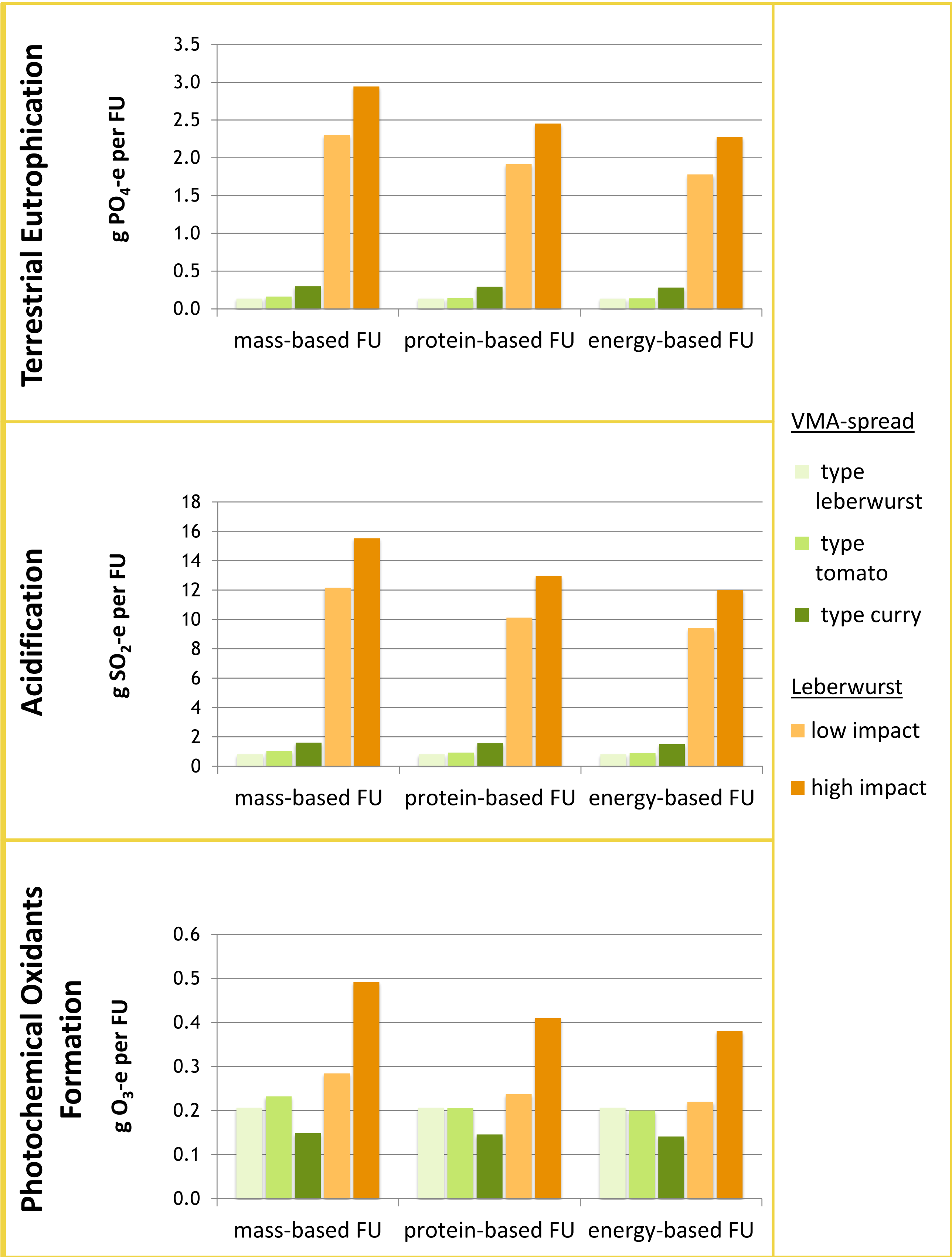

Figure 8-6: sensitivity results of VMA-spread, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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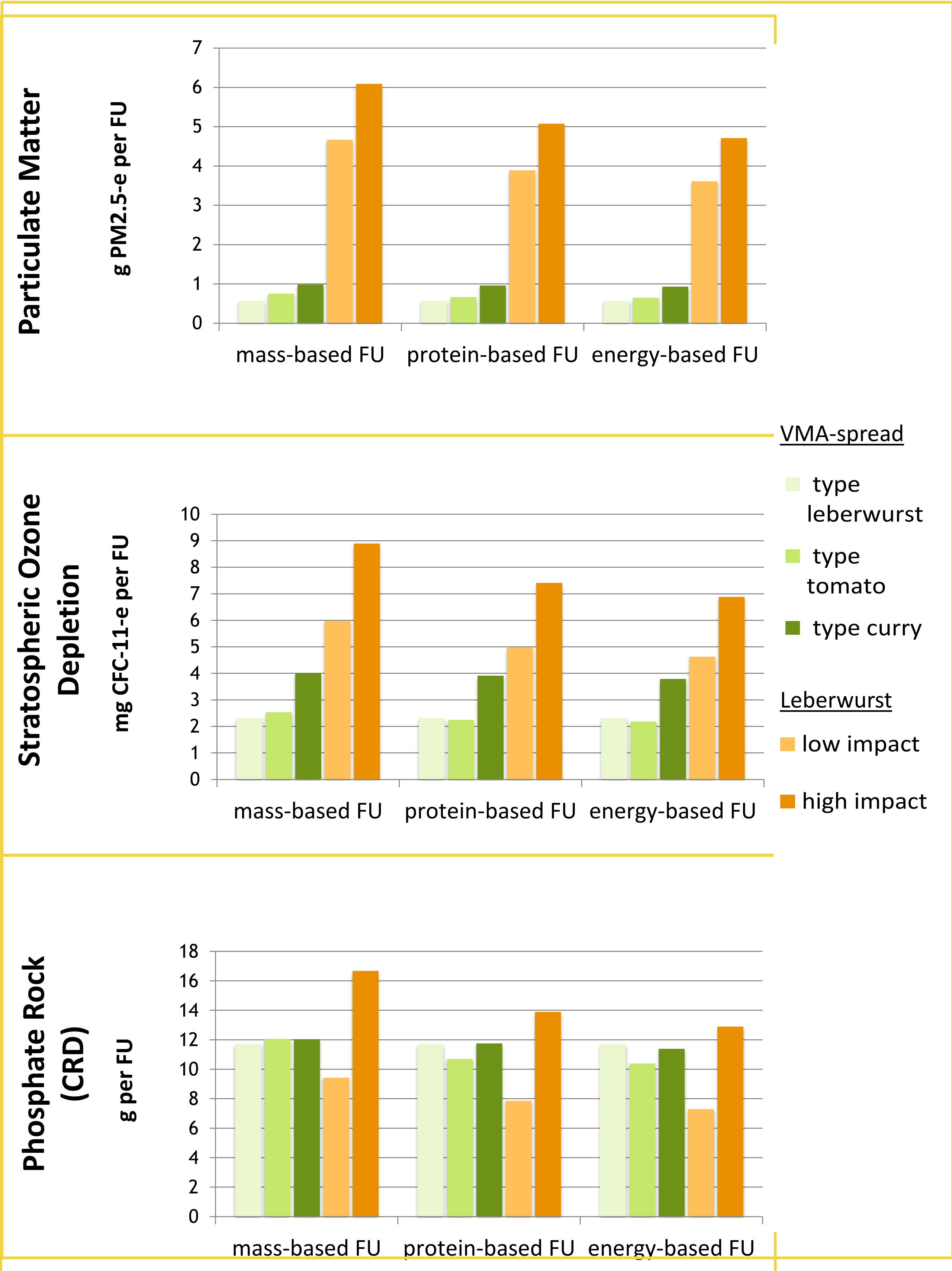

Figure 8-7: sensitivity results of VMA-spread, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate Rock (CRD)

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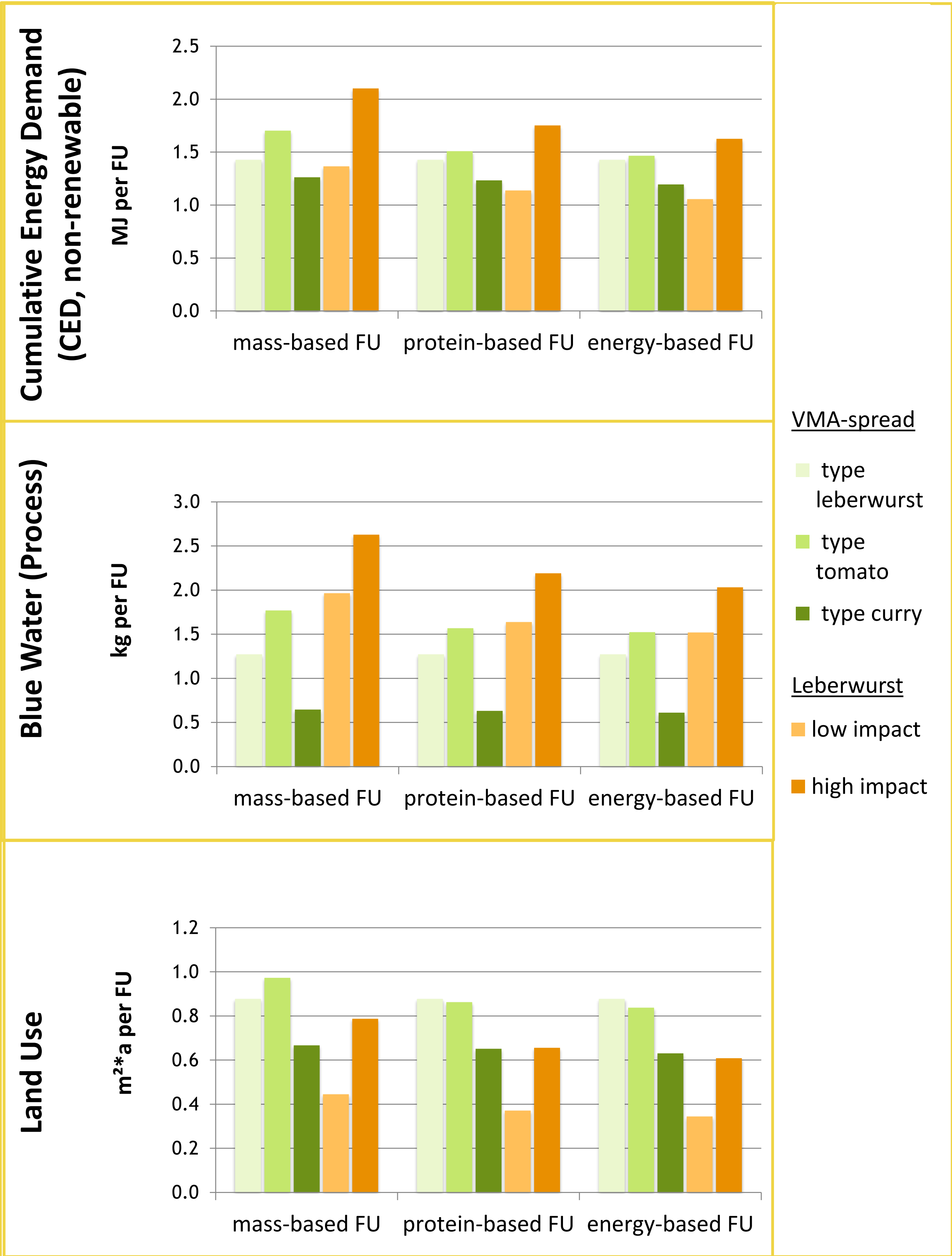

Figure 8-8: sensitivity results of VMA-spread, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process), Land Use

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8.1.3. Sensitivity analysis: Vegetable milk

The following table 8-25 summarizes the product reference mass flows related to the alternative functional units.

Table 8-3: Comparison of FUs, vegetable milk and reference systems

Reference flow of food product / Functional Units	Innovative: vegetable milk	Traditional: cow milk
Energy content (54 kcal) *	100 g (~540 kcal/kg)	80.6 g (~670 kcal/kg)
Protein content (3.3 g) *	100 g (~33 g protein/kg)	100 g (~33 g protein/kg)
Mass (100 g)	100 g	100 g

The following figures (**Figure 8-9** to Figure 8-12) illustrate sensitivity results of milk.

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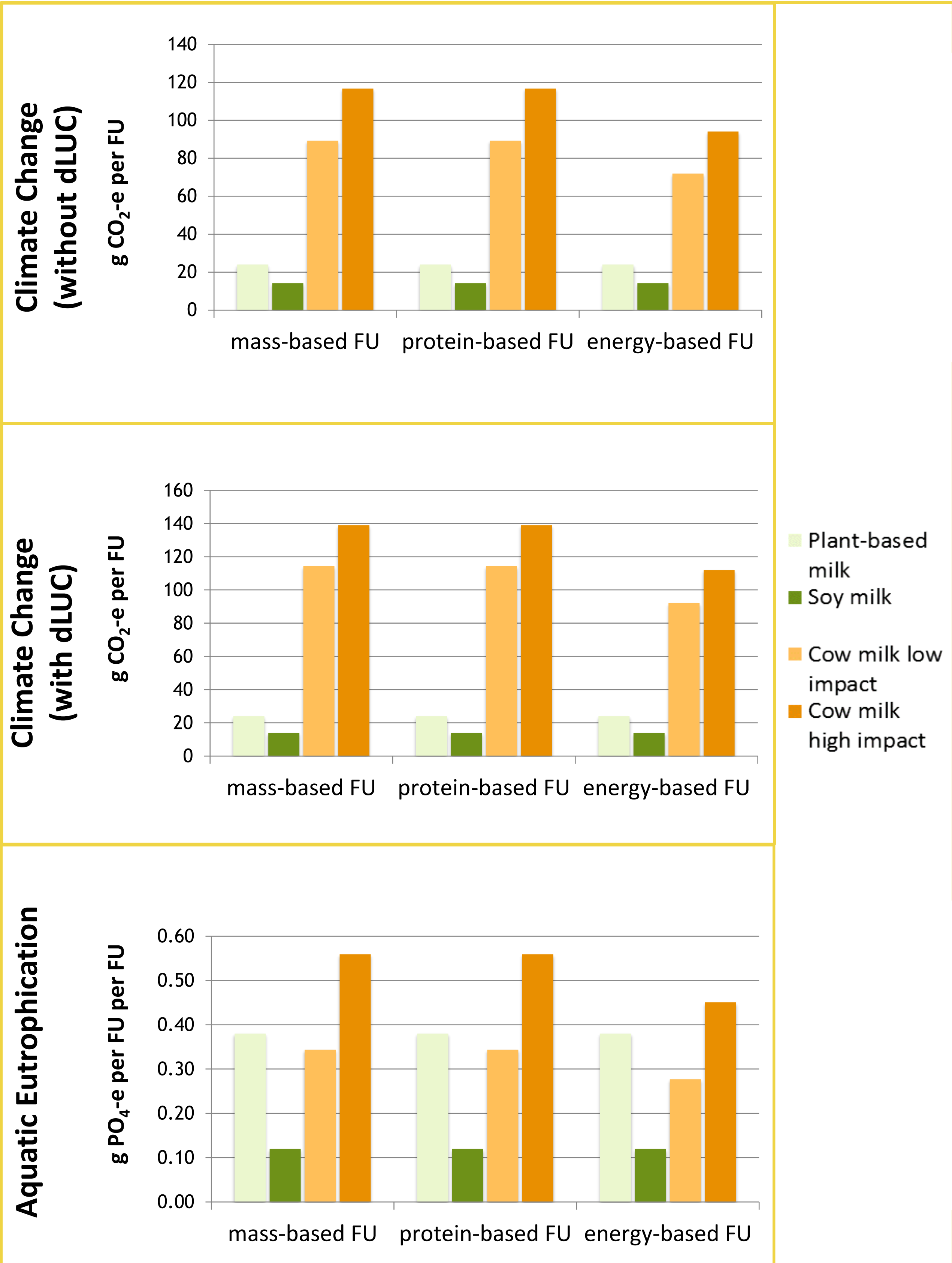

Figure 8-9: sensitivity results of milk, indicators: Climate Change (with dLUC), Climate Change (without dLUC), and Aquatic Eutrophication

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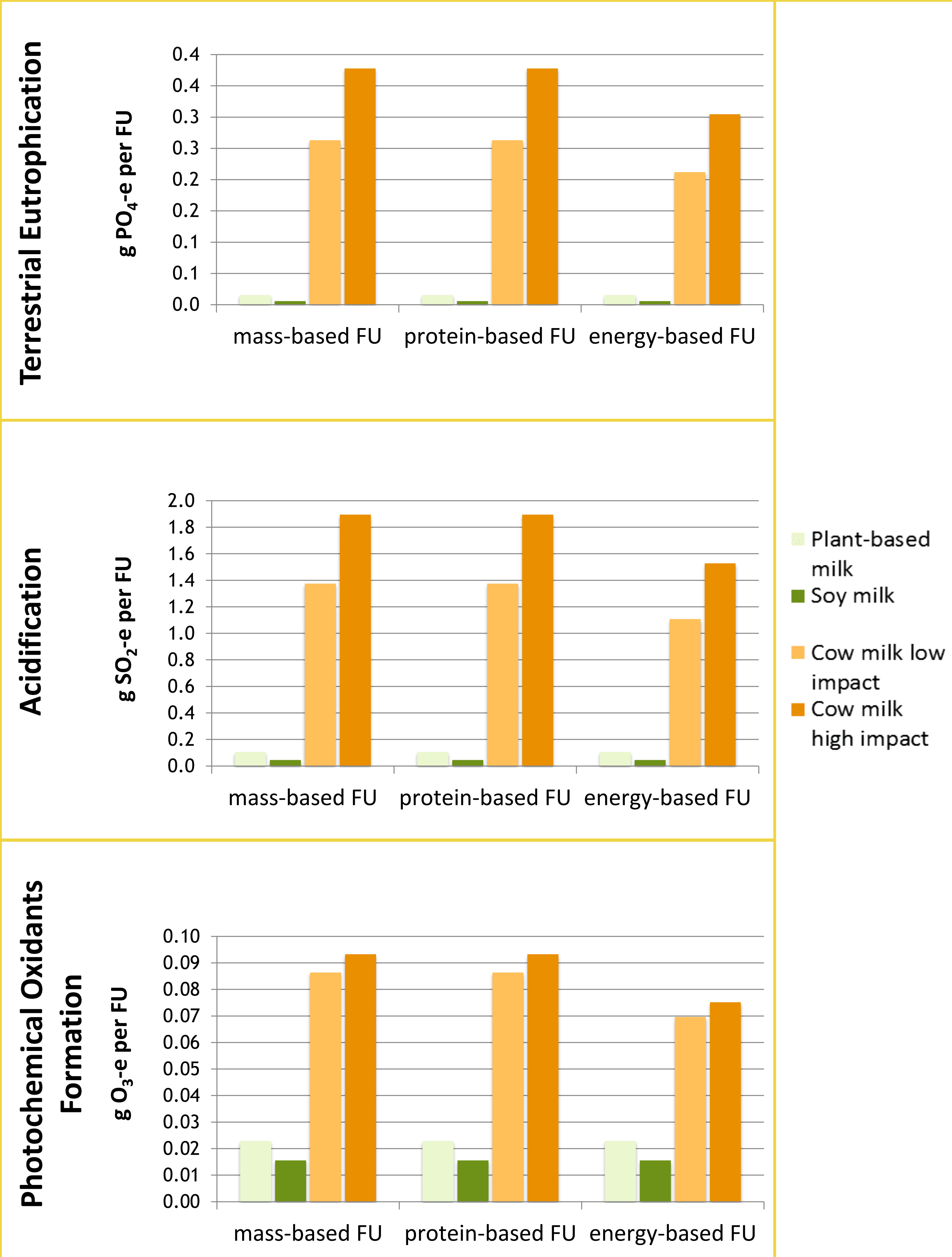

Figure 8-10: sensitivity results of milk, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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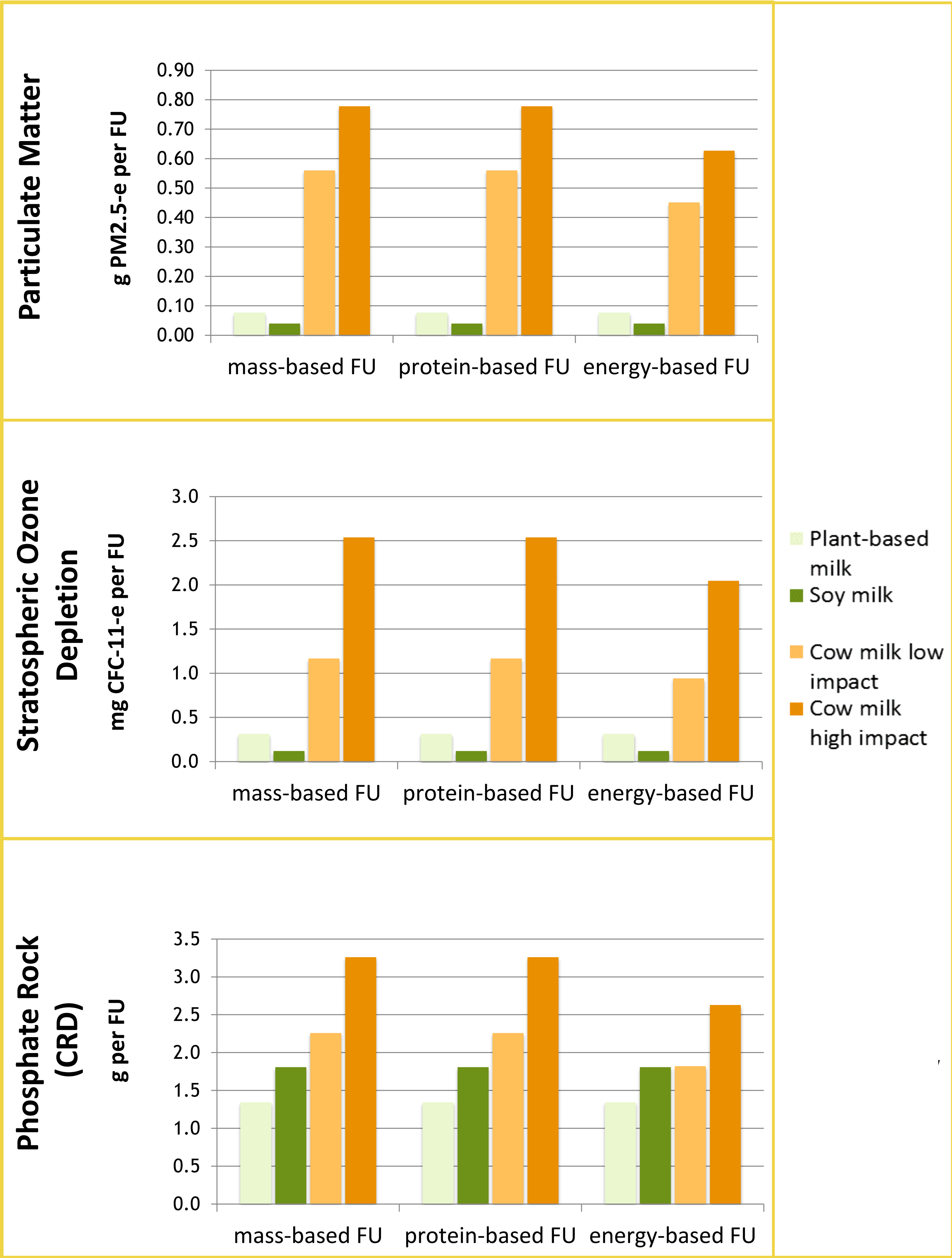

Figure 8-11: sensitivity results of milk, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate Rock (CRD)

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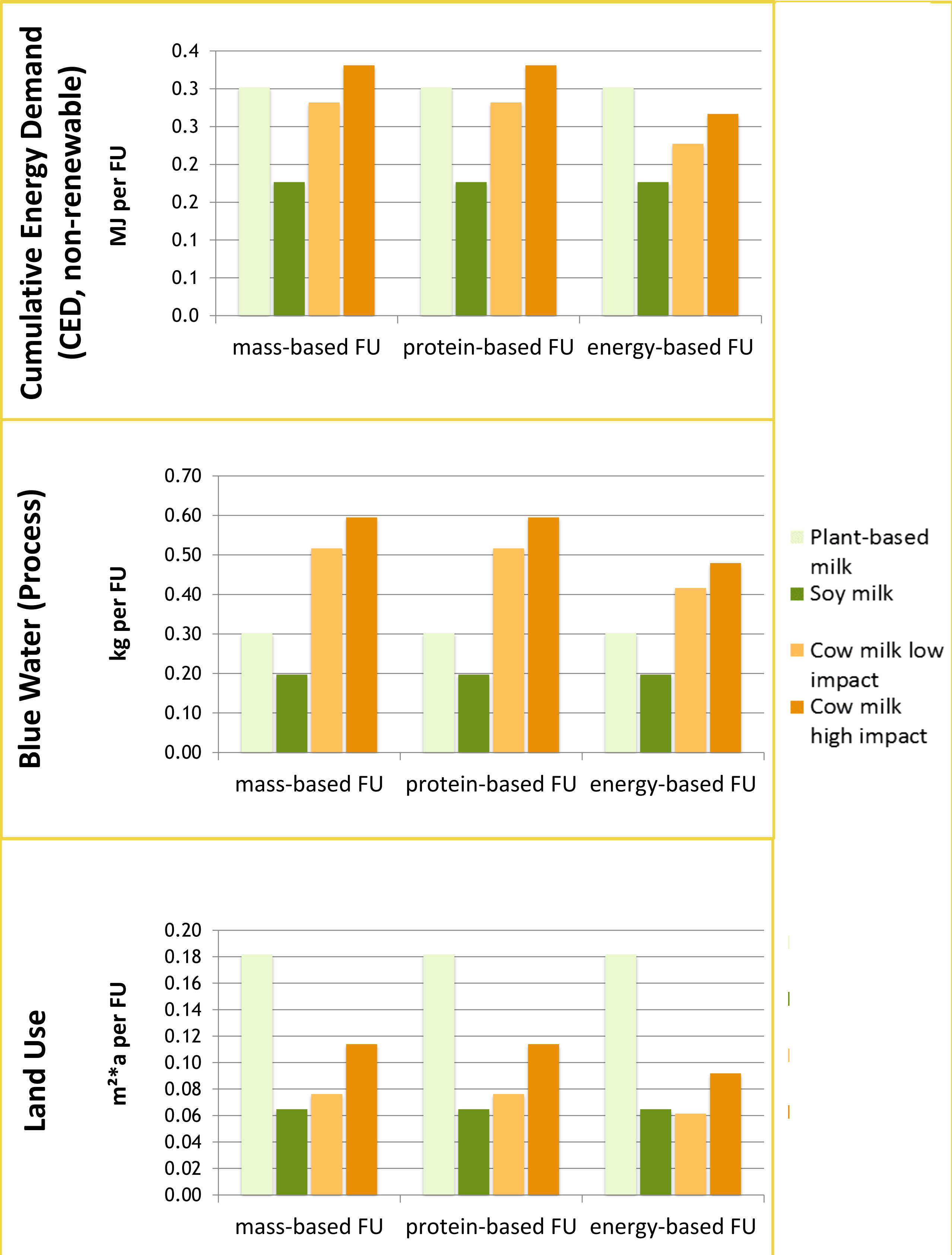

Figure 8-12: sensitivity results of milk, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process), Land Use

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635727.

8.1.4. Sensitivity analysis: Vegetable burger

Table 8-4: Comparison of FUs, vegetable burger and reference systems

Reference flow of food product / Functional Units	Innovative: vegetable burger	Traditional: beef burger
Energy content (159.8 kcal) *	100 g (~1598 kcal/kg)	61.5 g (~2600 kcal/kg)
Protein content (13.6 g) *	100 g (~136 g protein/kg)	97.1 g (~140 g protein/kg)
Mass (100 g)	100 g	100 g

The following figures (**Figure 8-13** to Figure 8-16) illustrate sensitivity results of vegetable and beef burger.

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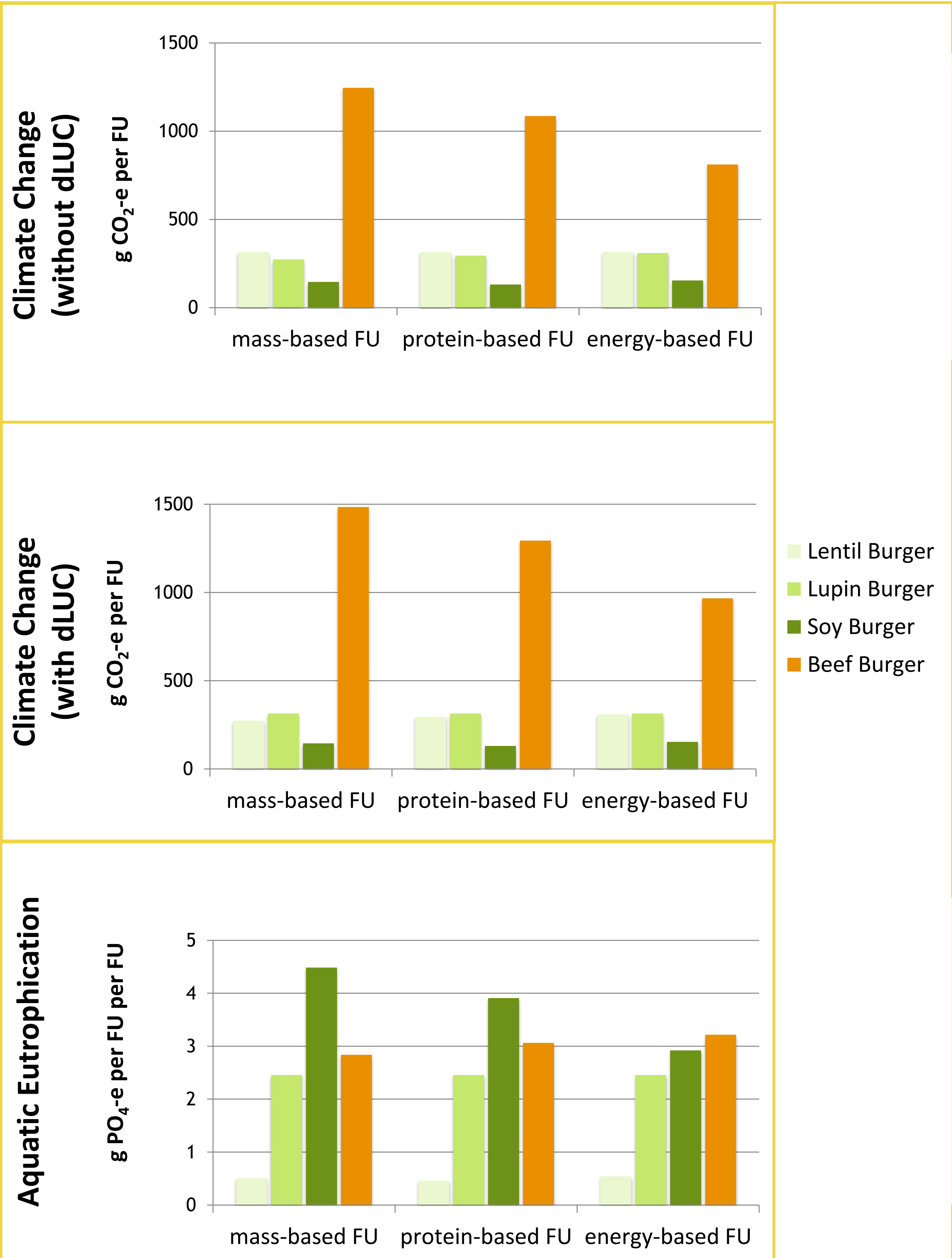

Figure 8-13: sensitivity results of vegetable and beef burger, indicators: Climate Change (with dLUC), Climate Change (without dLUC), and Aquatic Eutrophication

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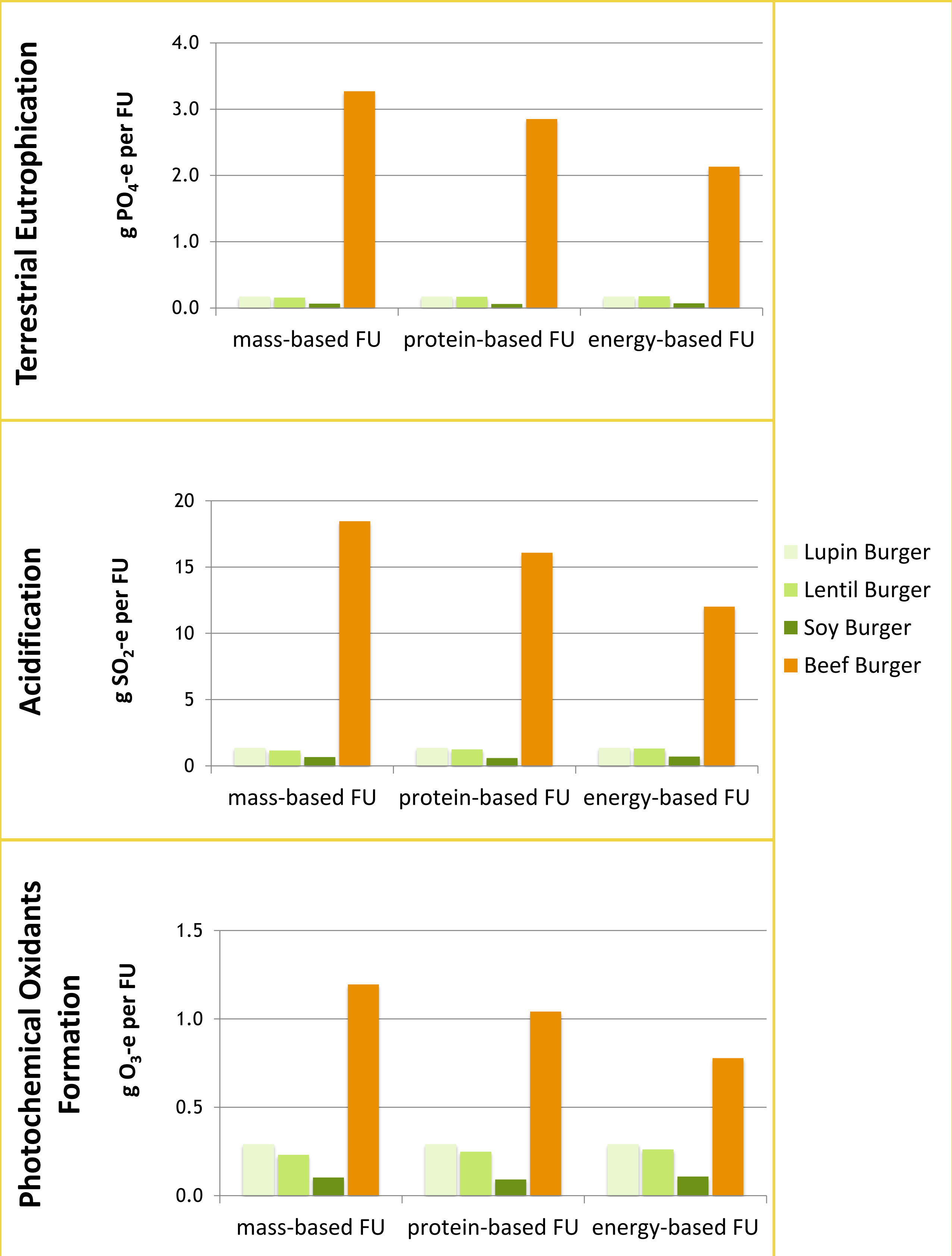

Figure 8-14: sensitivity results of vegetable and beef burger, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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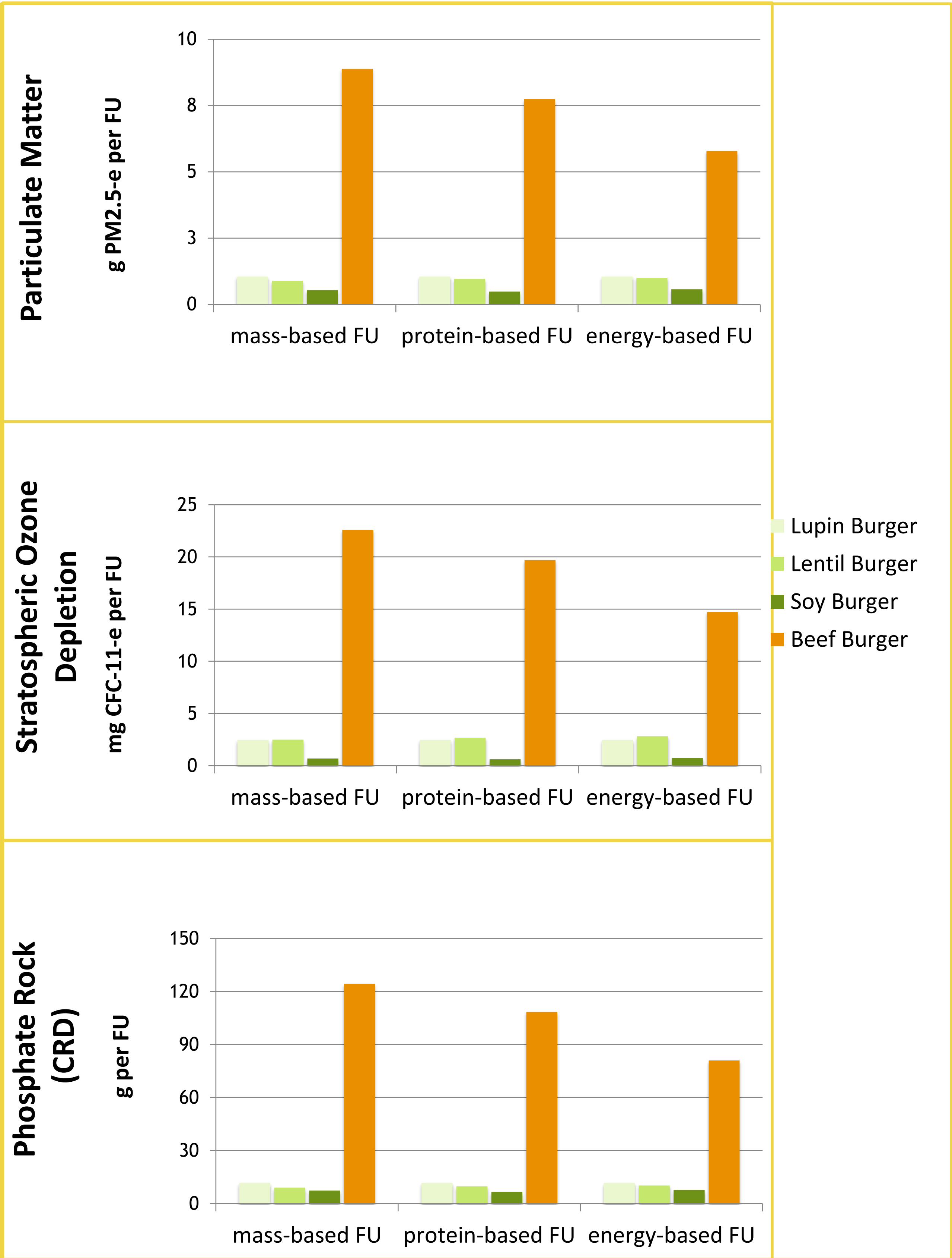

Figure 8-15: sensitivity results of vegetable and beef burger, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate Rock (CRD)

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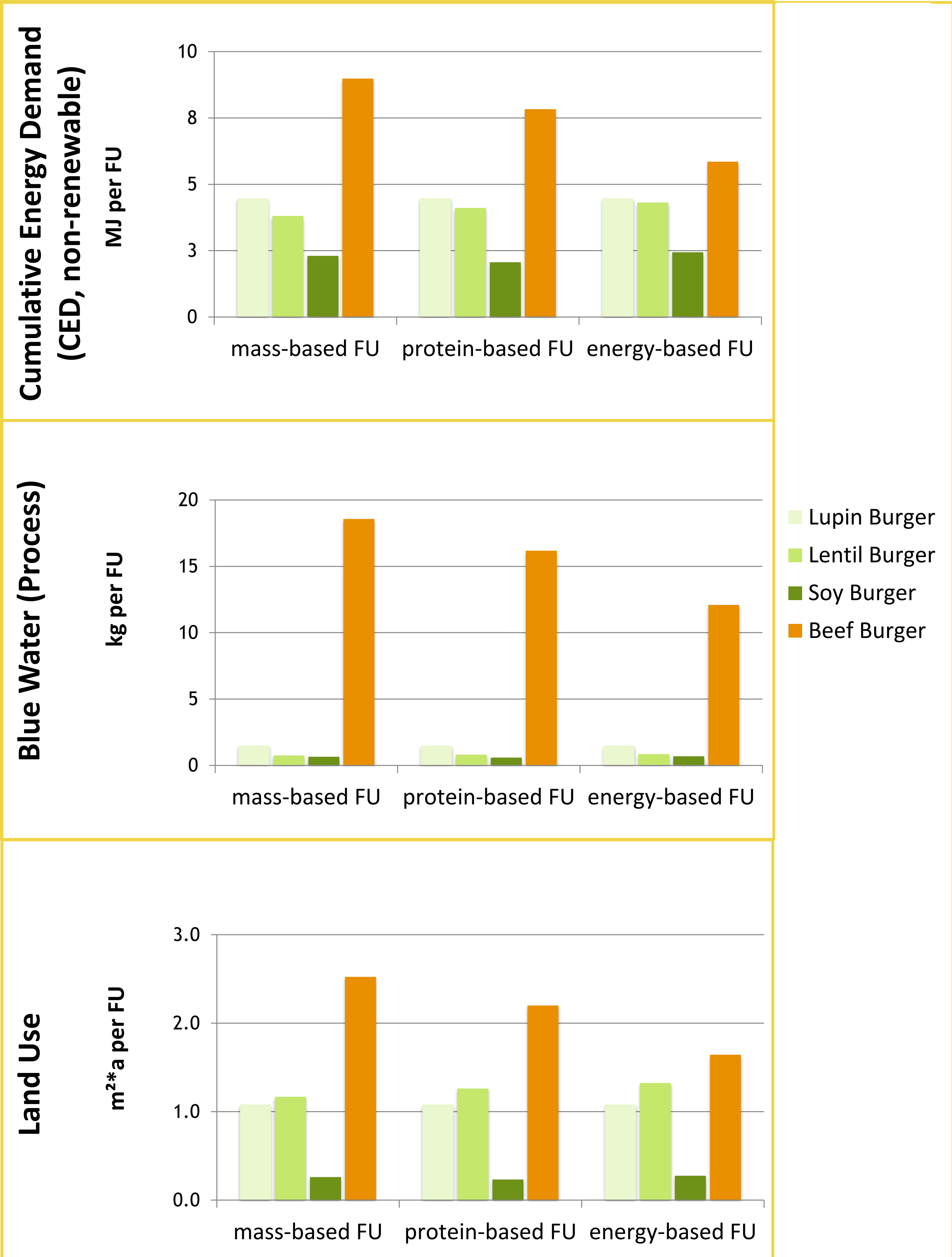

Figure 8-16: sensitivity results of vegetable and beef burger, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process), Land Use

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8.2. LCA results of further product groups (pasta & bread)

8.2.1. P2F fresh vegetable pasta and corresponding reference product

Table 8-5: Composition and corresponding nutrition values for P2F prototype fresh vegetable pasta

Composition	per 100 g
Water [g]	23
Wheat flour [g]	59
Buckwheat flour [g]	12
Fababean flour [g]	4
Lupin protein isolate [g]	2
Average nutrition values	
Total energy [kcal]	245.6
Total fat content [g]	1.4
Total carbohydrate content [g]	46.2
Total protein content [g]	13.9

*Note: composition values are rounded and thus may not add up to 100 g

Table 8-6: Composition and corresponding nutrition values for reference product: traditional fresh egg pasta*

Composition	per 100 g
Water [g]	20
Semolina [g]	65
Egg [g]	15
Average nutrition values	
Total energy [kcal]	310
Total fat content [g]	2.7
Total carbohydrate content [g]	58
Total protein content [g]	12.4

*Composition and nutrition based on Alamprese (2005) and Bevilacqua (2007)
*Note: composition values are rounded and thus may not add up to 100 g

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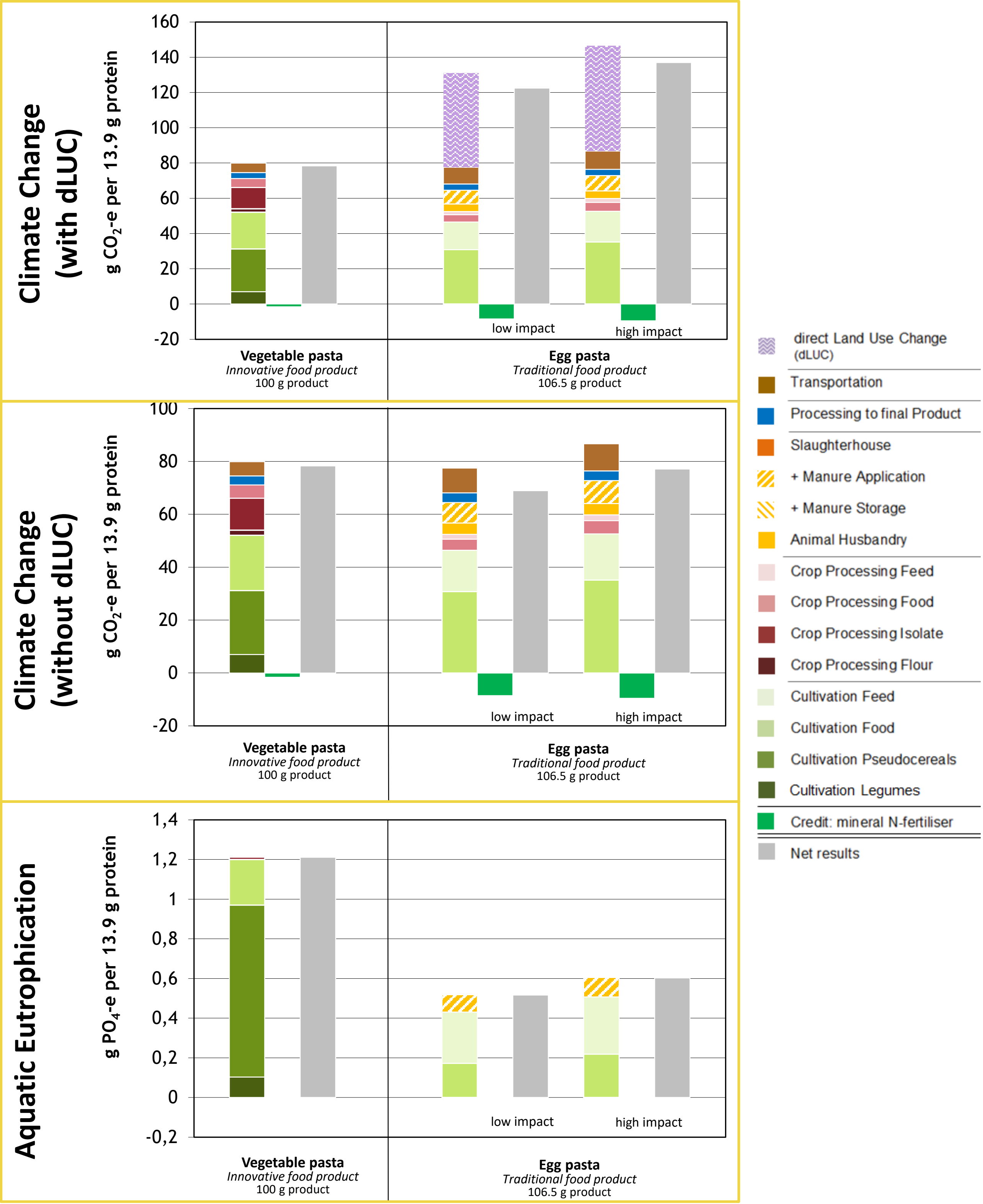

Figure 8-17: sectoral LCA results of pasta, indicators: Climate Change (with and without dLUC), and Aquatic Eutrophication

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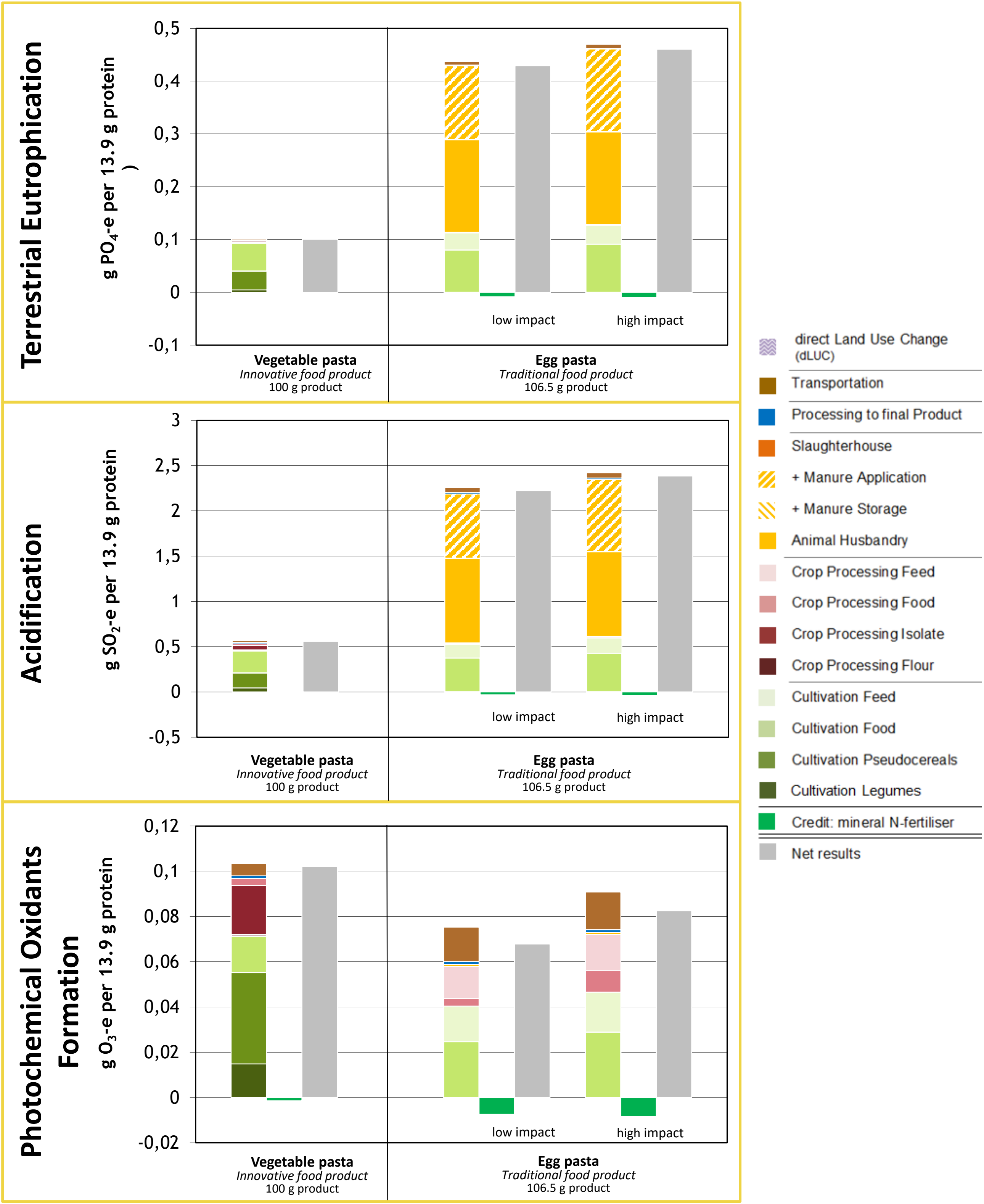

Figure 8-18: sectoral LCA results of pasta, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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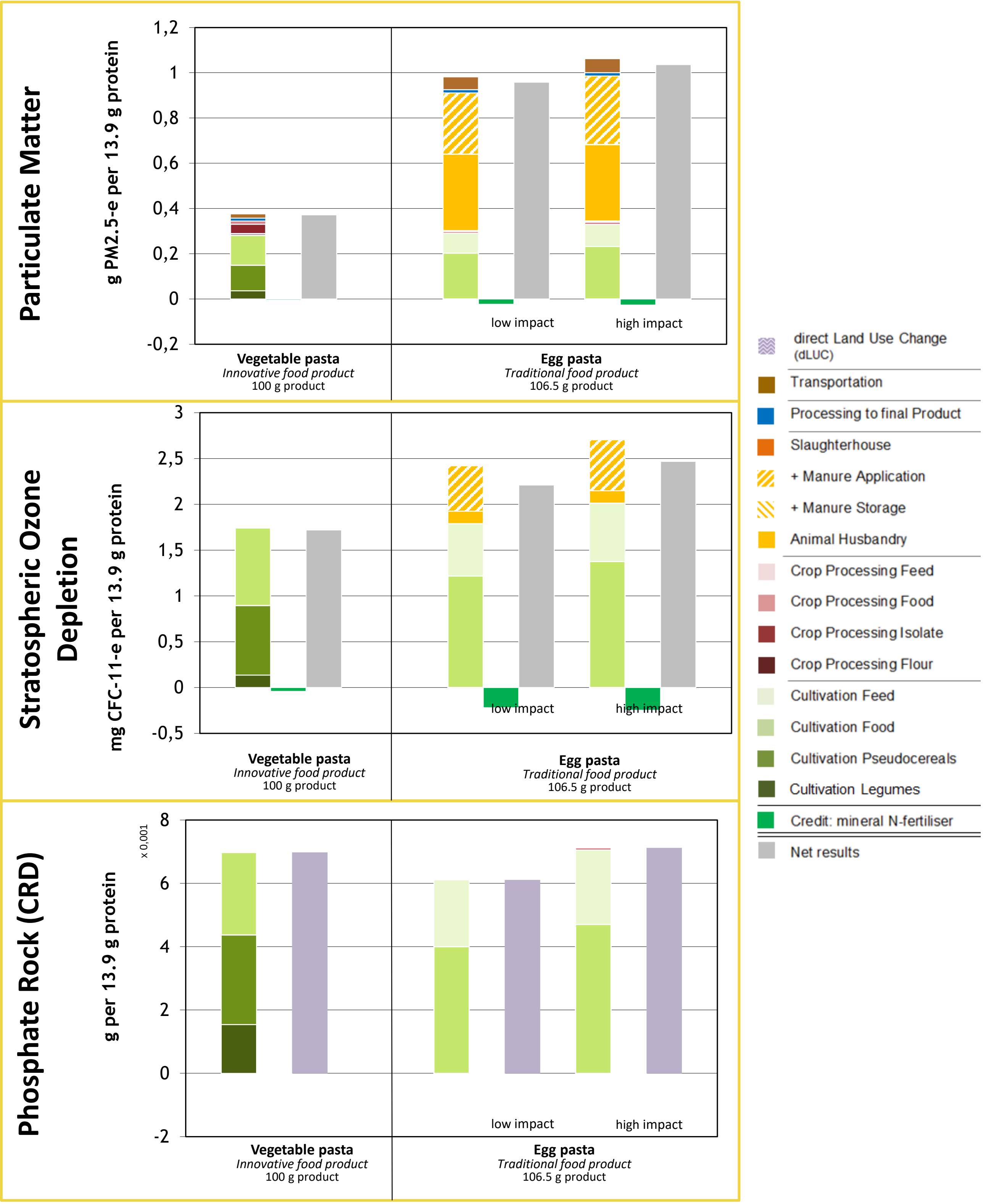

Figure 8-19: sectoral LCA results of pasta, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate rock

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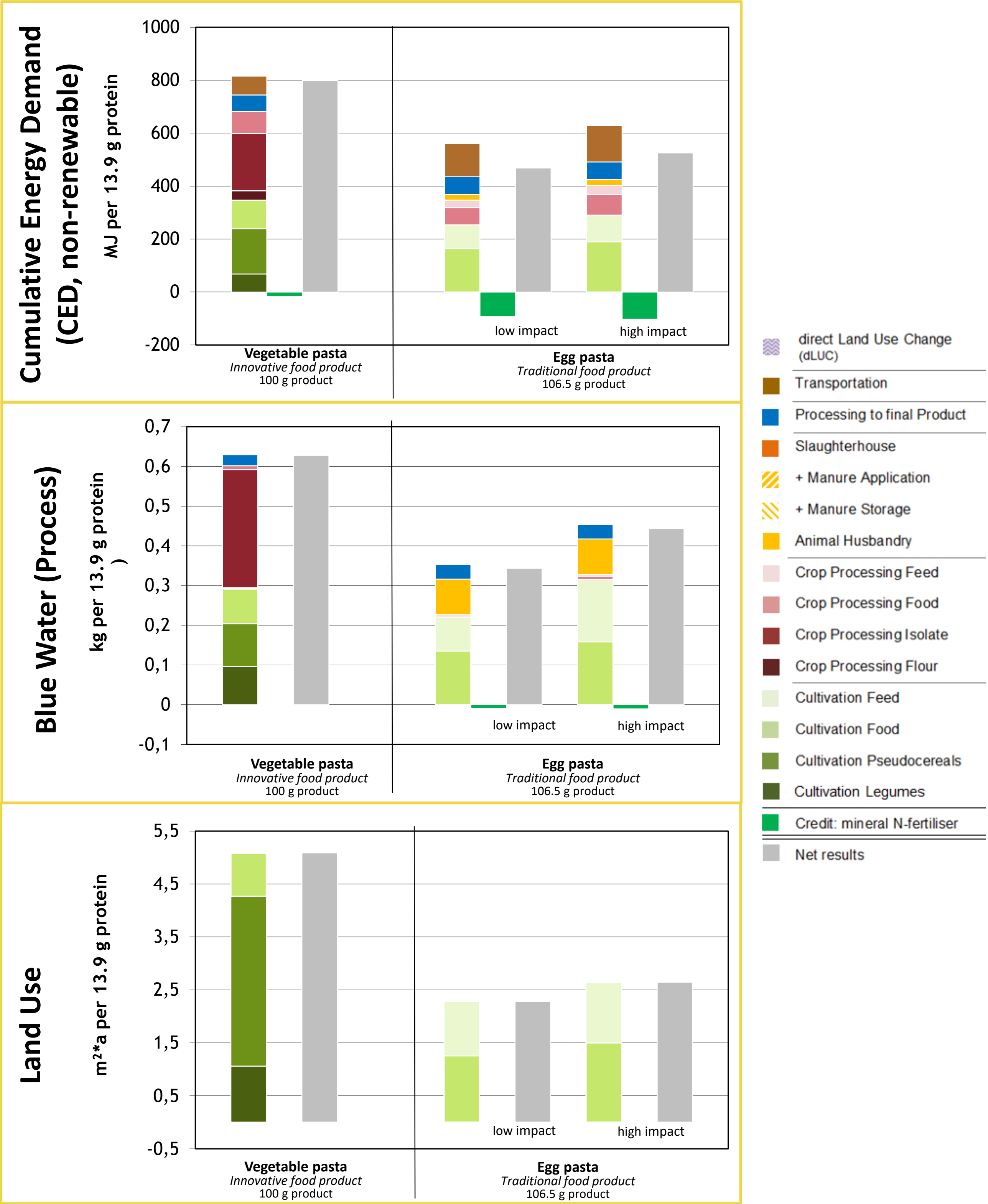

Figure 8-20: sectoral LCA results of pasta, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process) and Land Use

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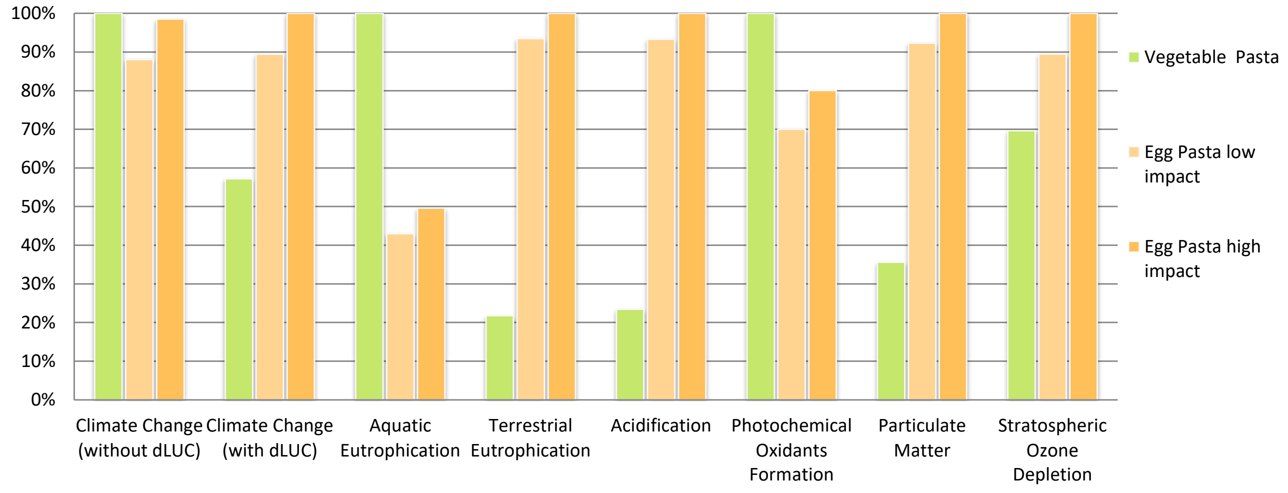

Figure 8-14: Comparative results of the innovative pasta versus traditional egg pasta, functional unit protein (part 1)

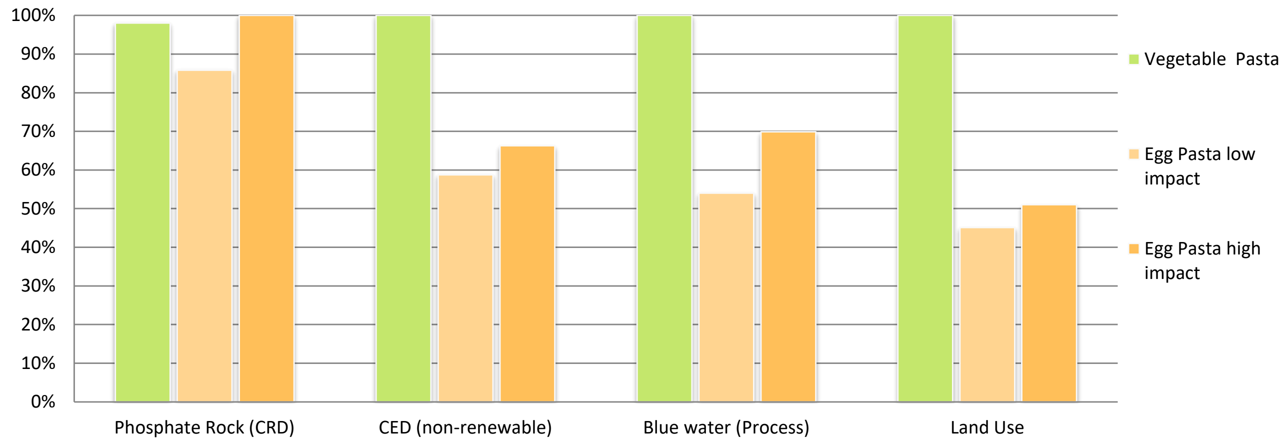

Figure 8-15: Comparative results of the innovative pasta versus traditional egg pasta, functional unit protein (part 2)

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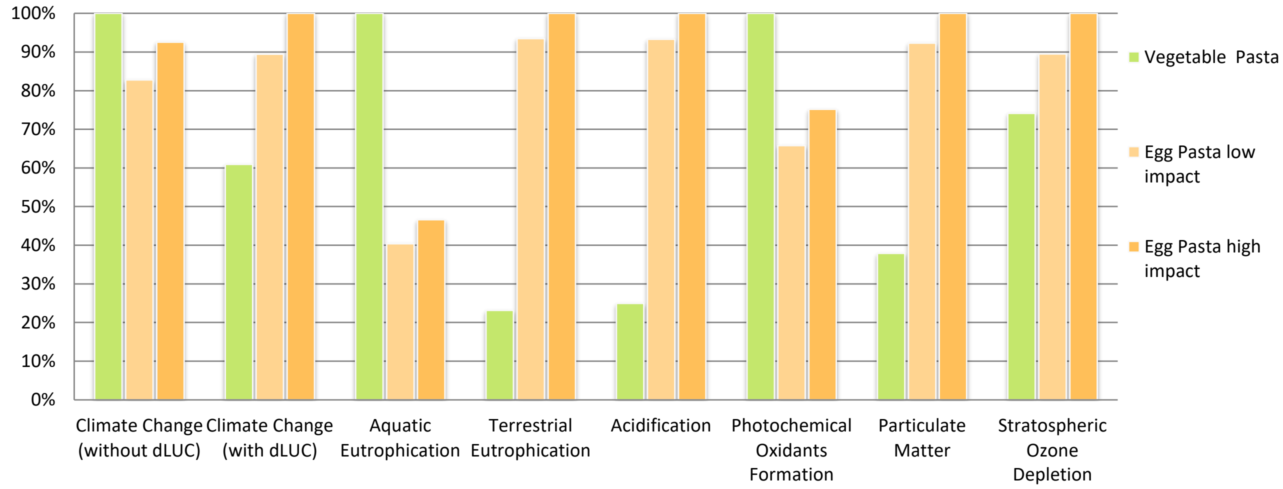

Figure 8-14: Comparative results of the innovative pasta versus traditional egg pasta, functional unit mass (part 1)

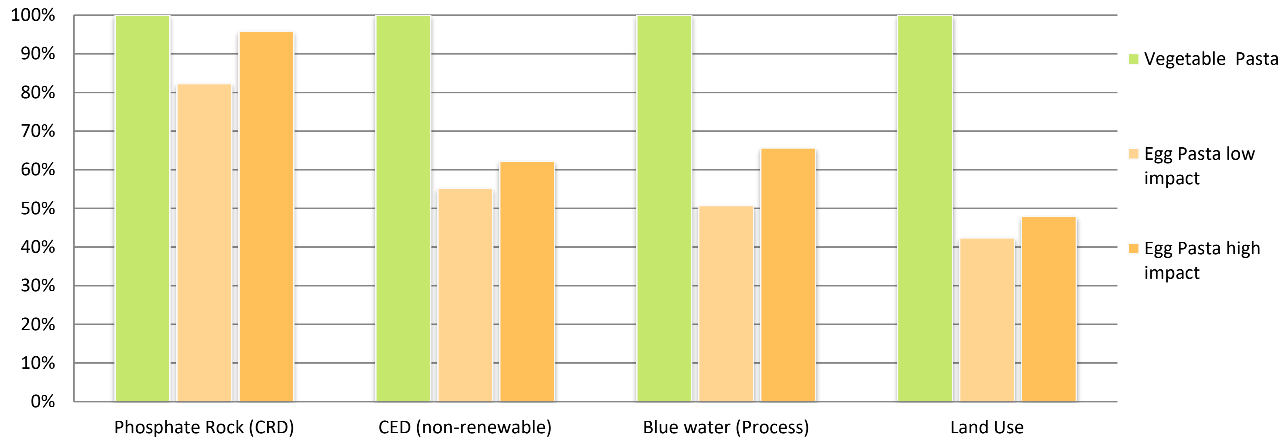

Figure 8-15: Comparative results of the innovative pasta versus traditional egg pasta, functional unit mass (part 2)

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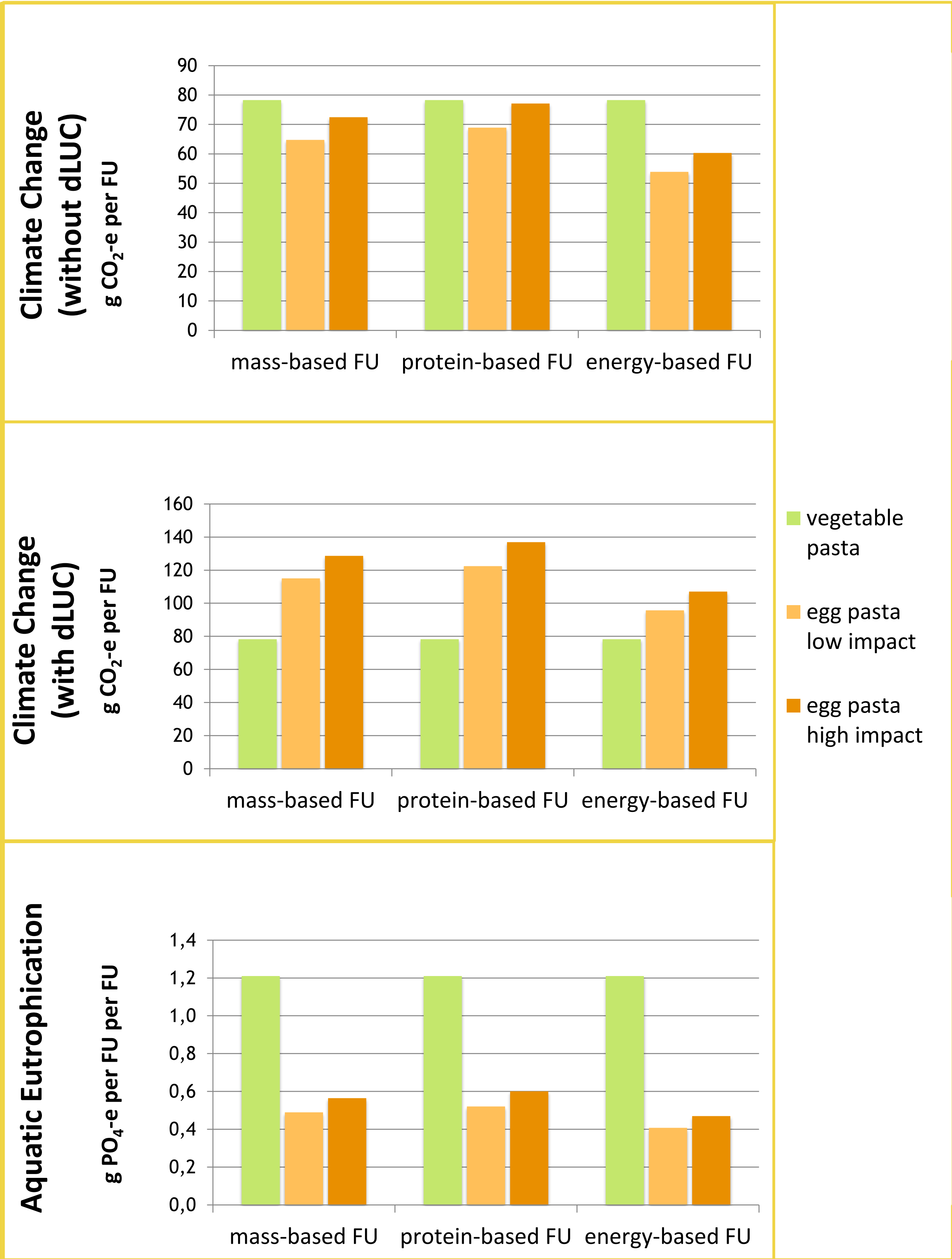

Figure 8-14: sensitivity LCA results of pasta, indicators: Climate Change (with dLUC), Climate Change (without dLUC), and Aquatic Eutrophication

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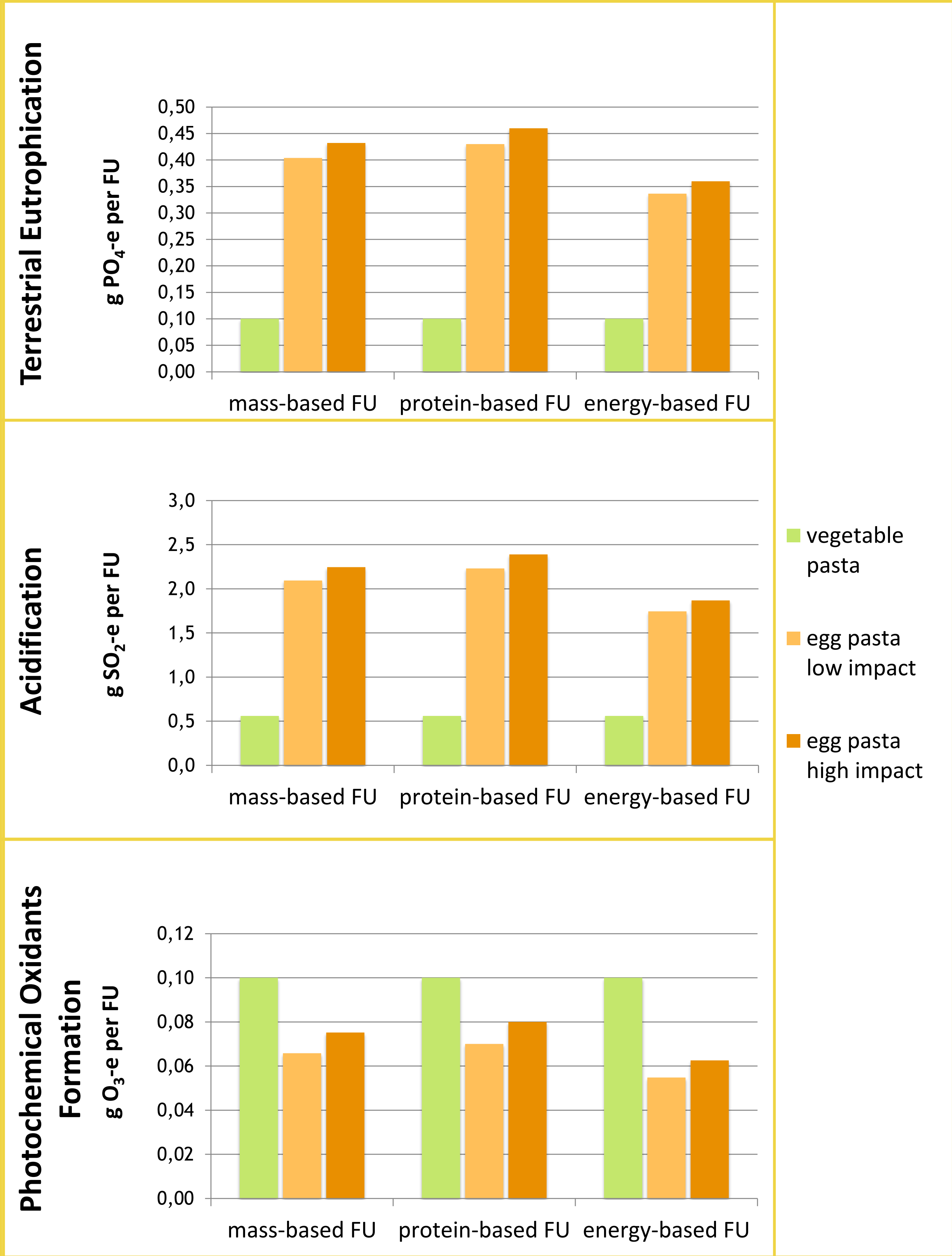

Figure 8-15: sensitivity LCA results of pasta, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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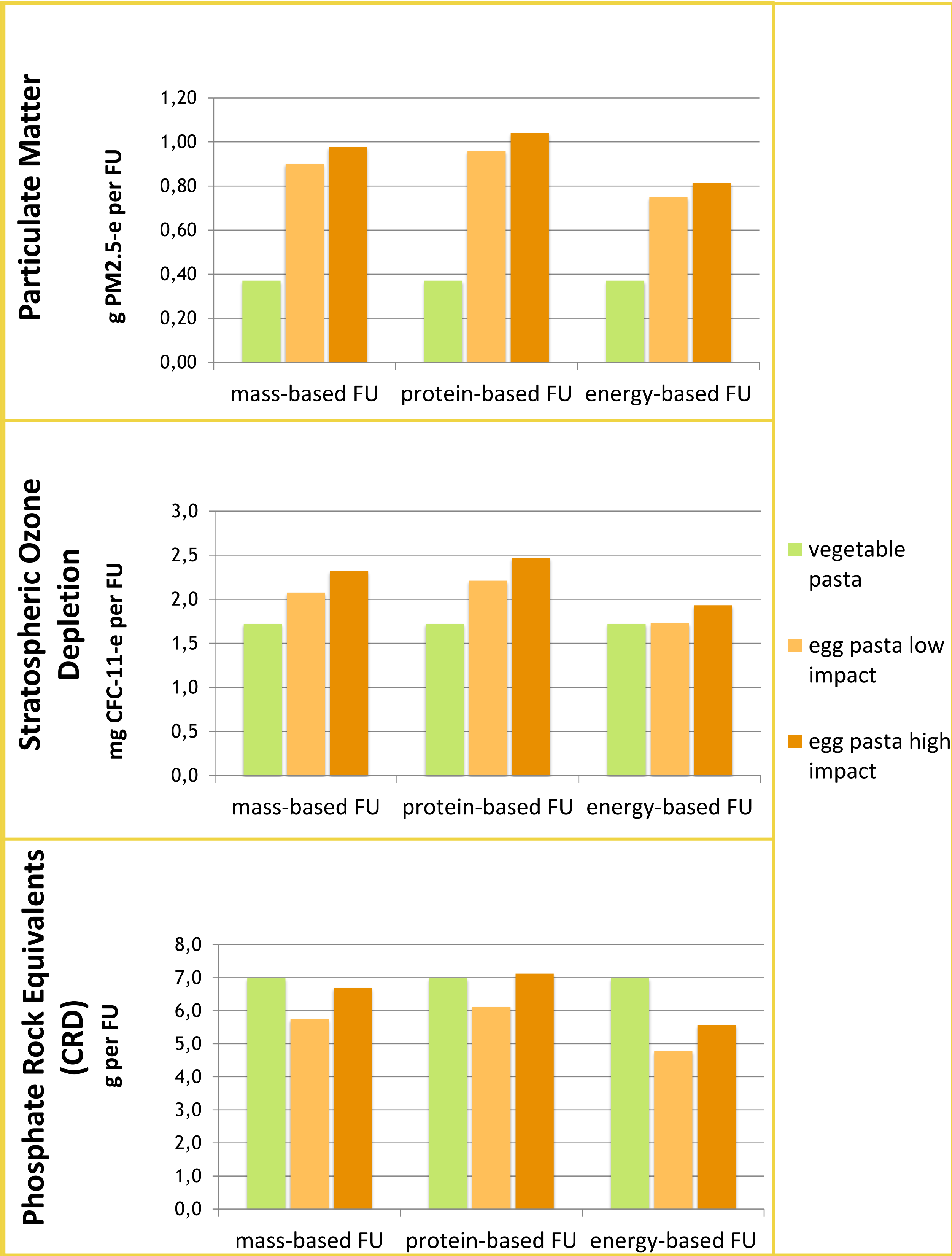

Figure 8-16: sensitivity LCA results of pasta, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate rock,

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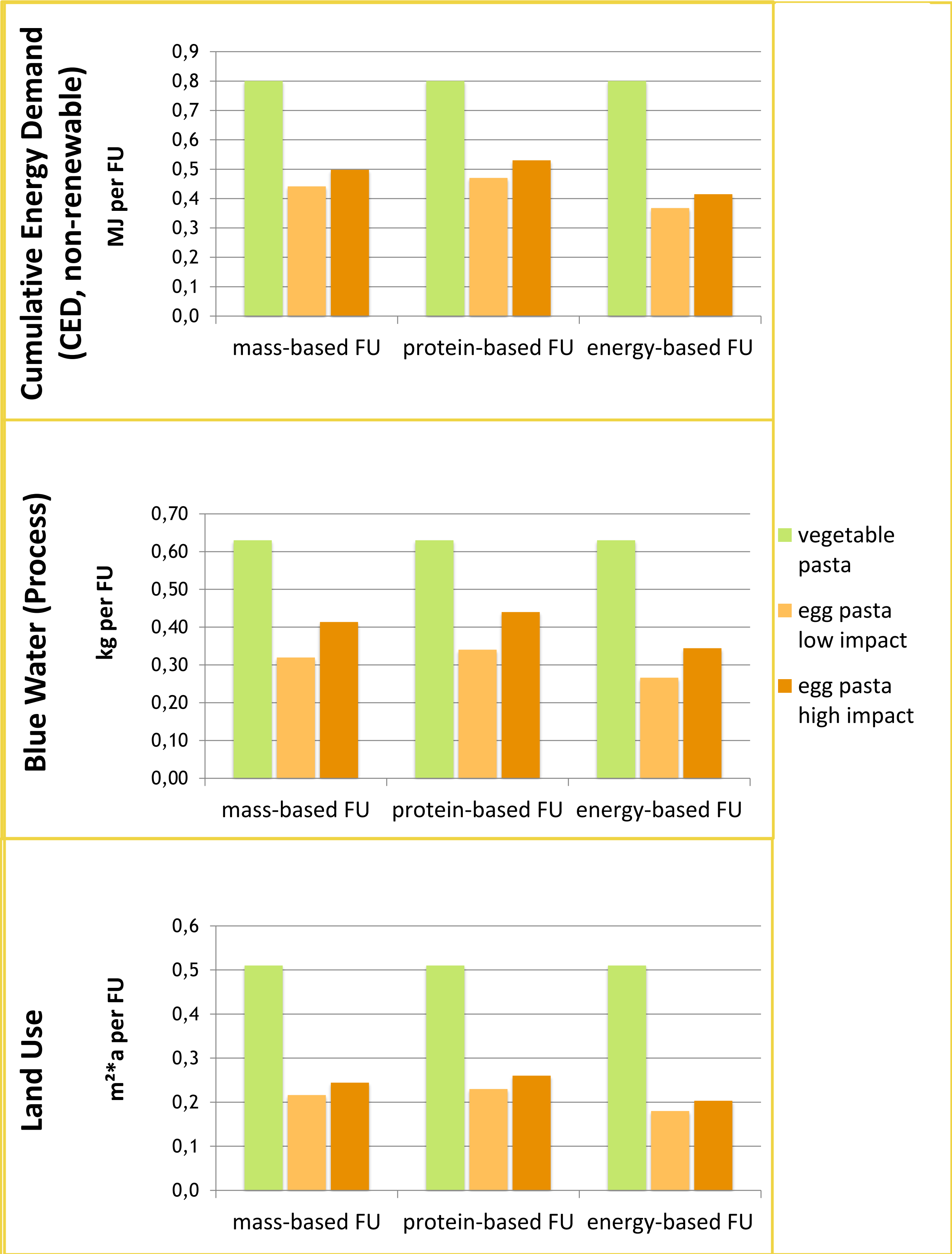

Figure 8-17: sensitivity LCA results of pasta, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process), Land Use

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8.2.2. P2F protein-rich bread

Table 8-7: Composition and corresponding nutrition values for P2F prototype bread

Composition	**per 100 g**
Wheat (wholemeal flour) [g]	49
Water [g]	39.5
Lupin Protein Isolate [g]	4.5
Faba bean flour [g]	4.5
Yeast [g]	1
Oil [g]	1
Salt [g]	0.5
Average nutrition values	
Total energy [kcal]	224.69
Total fat content [g]	3
Total carbohydrate content [g]	42.68
Total protein content [g]	12

*Note: composition values are rounded and thus may not add up to 100 g

Table 8-8: Composition and corresponding nutrition values for traditional wheat bread

Composition	**per 100 g**
Wheat (wholemeal flour) [g]	58
Water [g]	39.5
Yeast [g]	1
Oil [g]	1
Salt [g]	0.5
Average nutrition values	
Total energy [kcal]	222.76
Total fat content [g]	3
Total carbohydrate content [g]	41.68
Total protein content [g]	8.8

*Note: composition values are rounded and thus may not add up to 100 g

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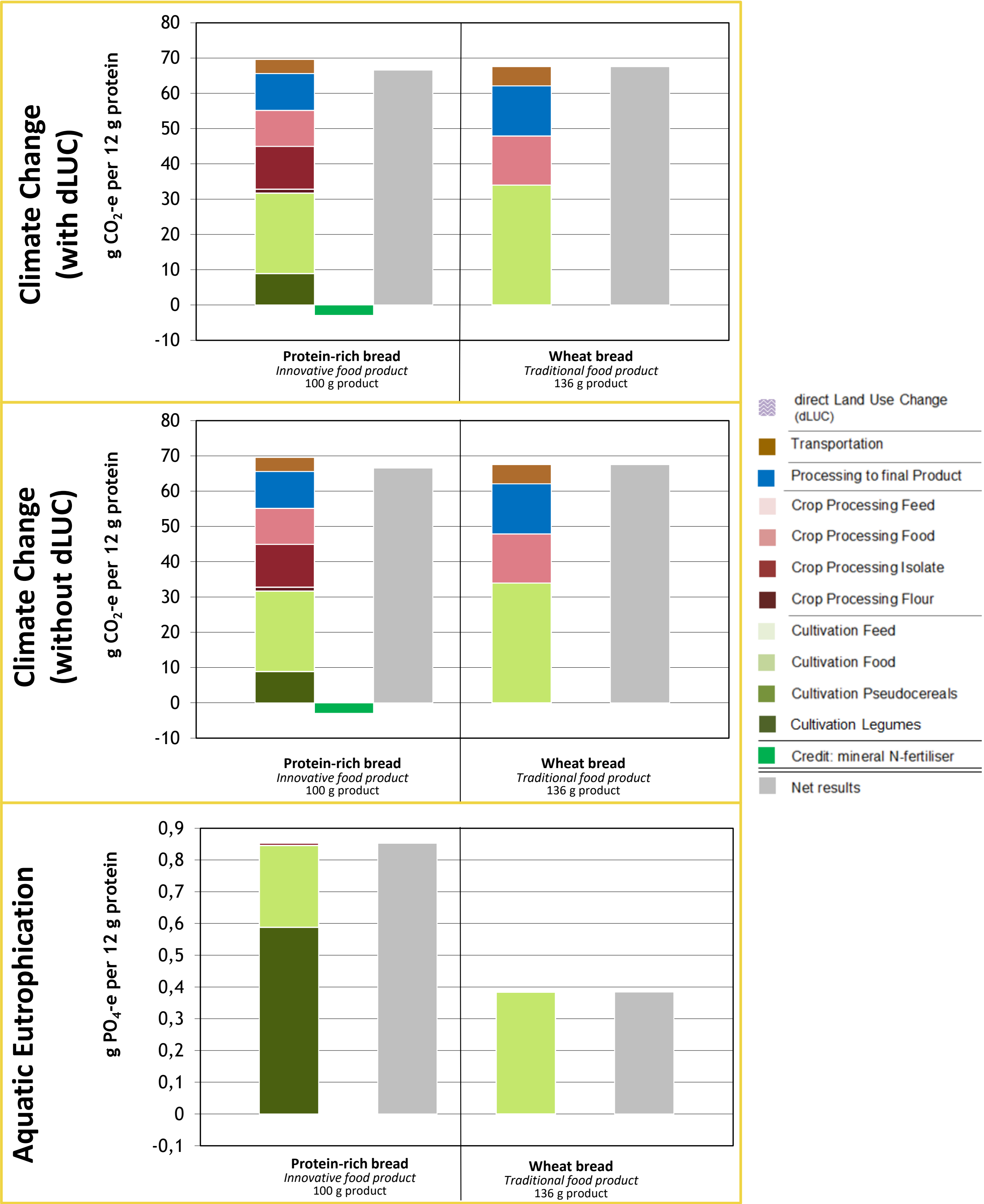

Figure 8-21: sectoral results of bread, indicators: Climate Change (with dLUC), Aquatic Eutrophication, and Stratospheric Ozone Depletion

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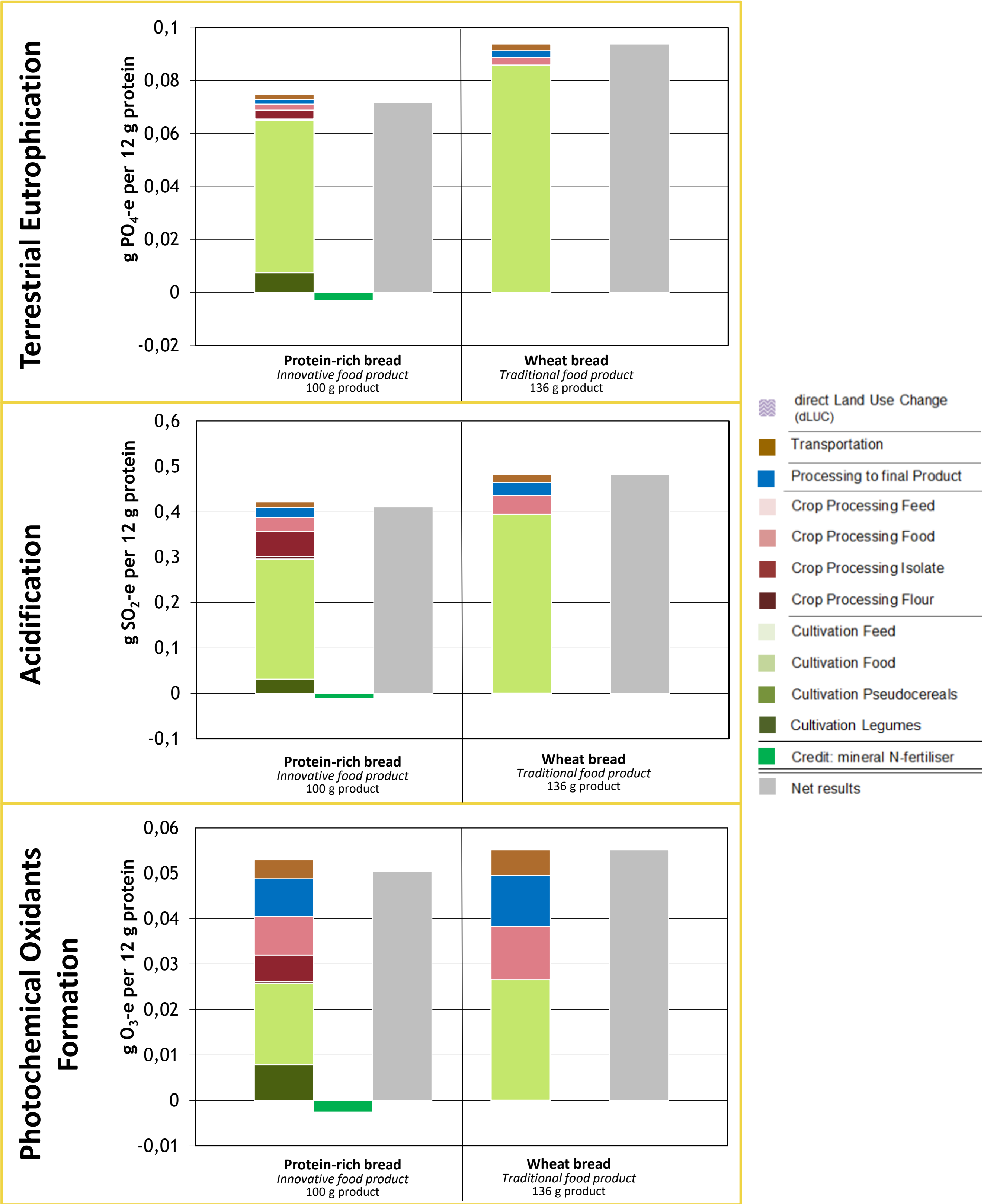

Figure 8-22: sectoral results of bread, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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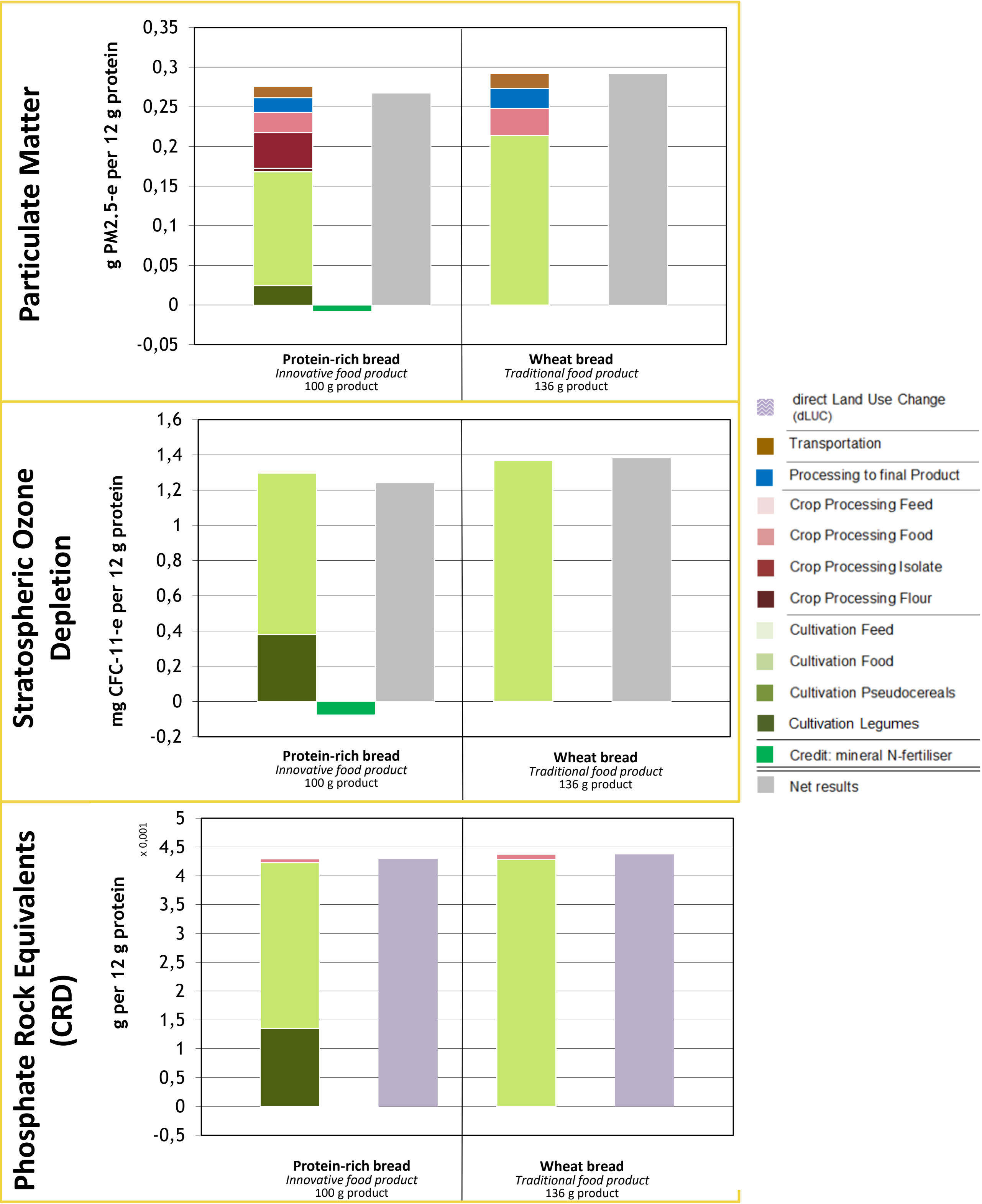

Figure 8-23: sectoral results of bread, indicators: Particulate Matter, Phosphate rock, Climate Change (without dLUC)

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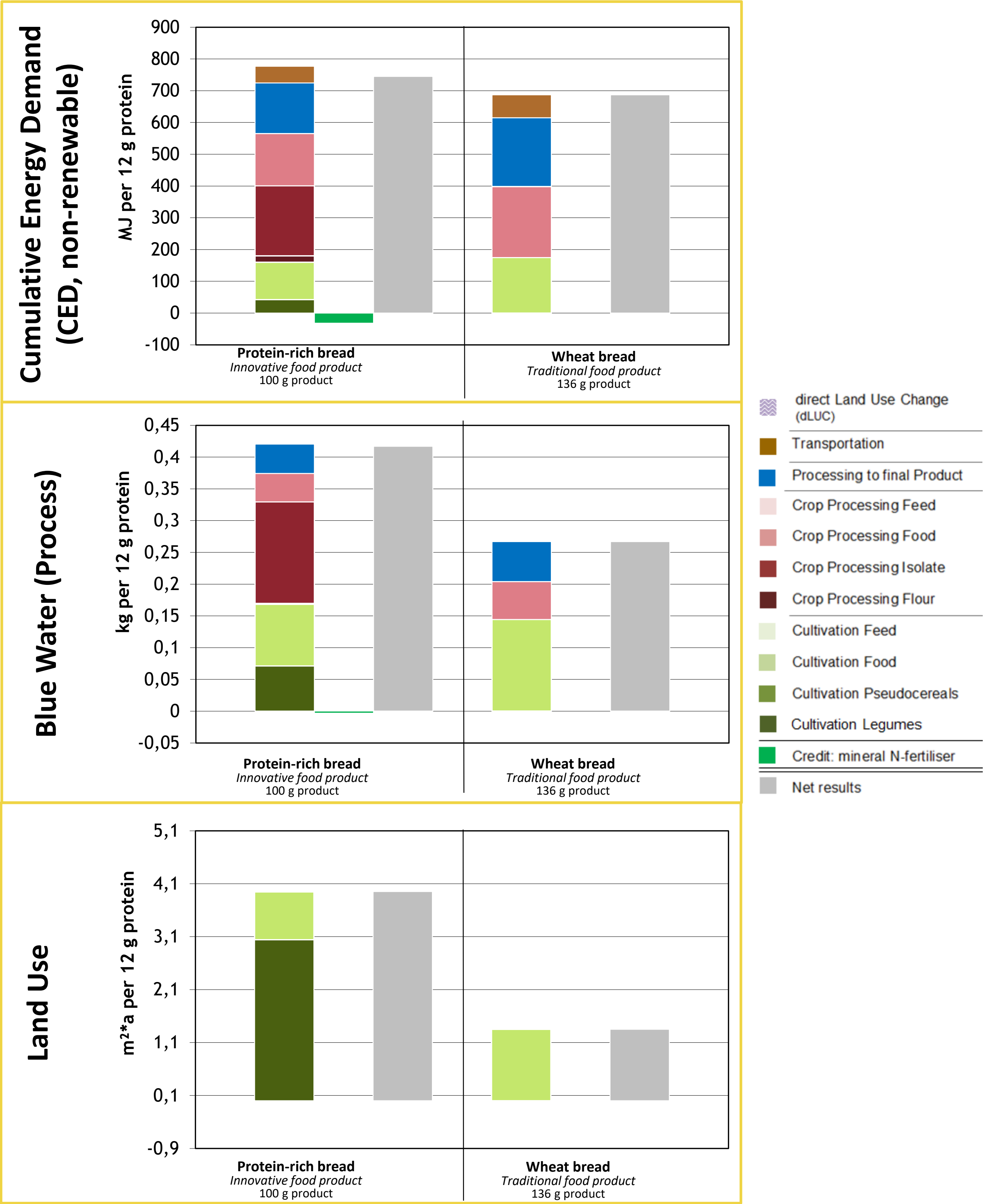

Figure 8-24: sectoral results of bread, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process) and Land Use

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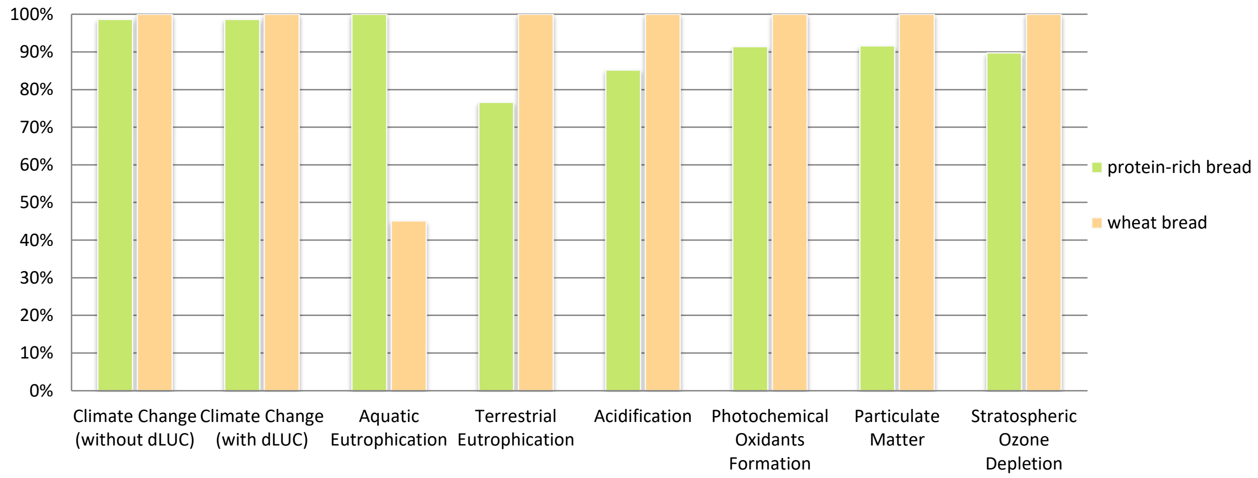

Figure 8-14: Comparative results of the innovative protein-rich bread versus traditional wheat bread, functional unit protein (part 1)

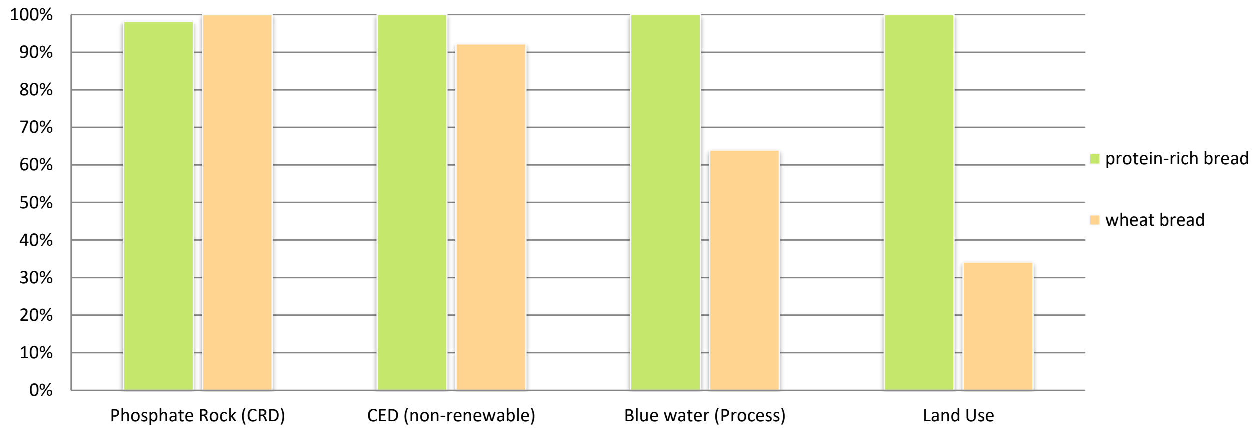

Figure 8-15: Comparative results of the innovative protein-rich bread versus traditional wheat bread, functional unit protein (part 2)

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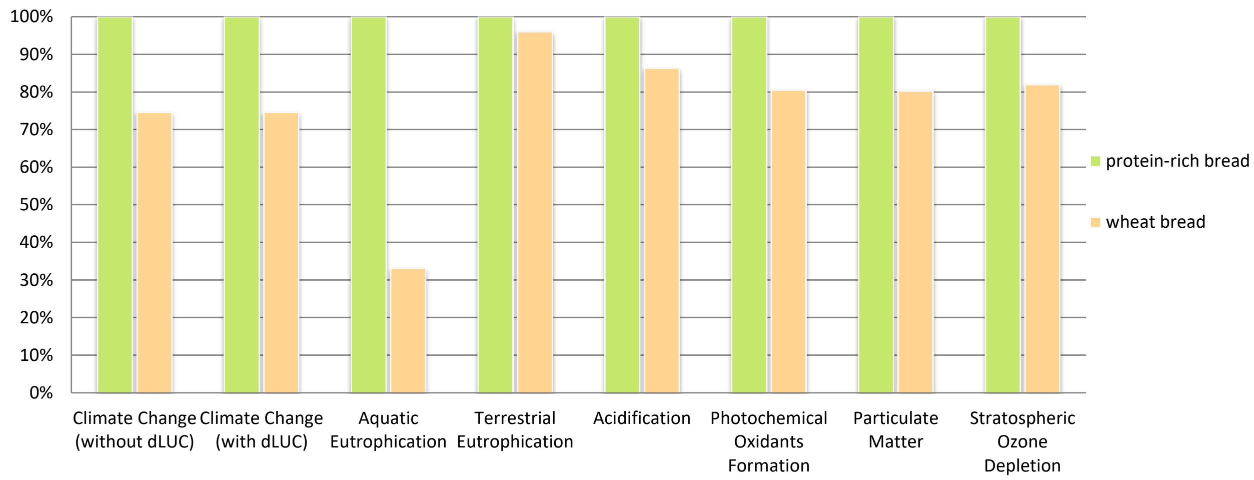

Figure 8-14: Comparative results of the innovative protein-rich bread versus traditional wheat bread, functional unit mass (part 1)

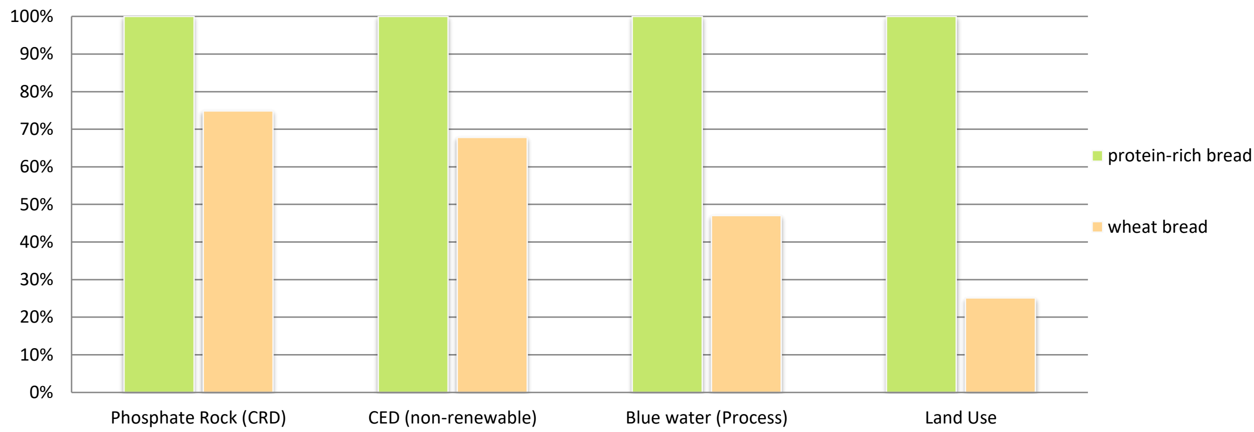

Figure 8-15: Comparative results of the innovative protein-rich bread versus traditional wheat bread, functional unit mass (part 2)

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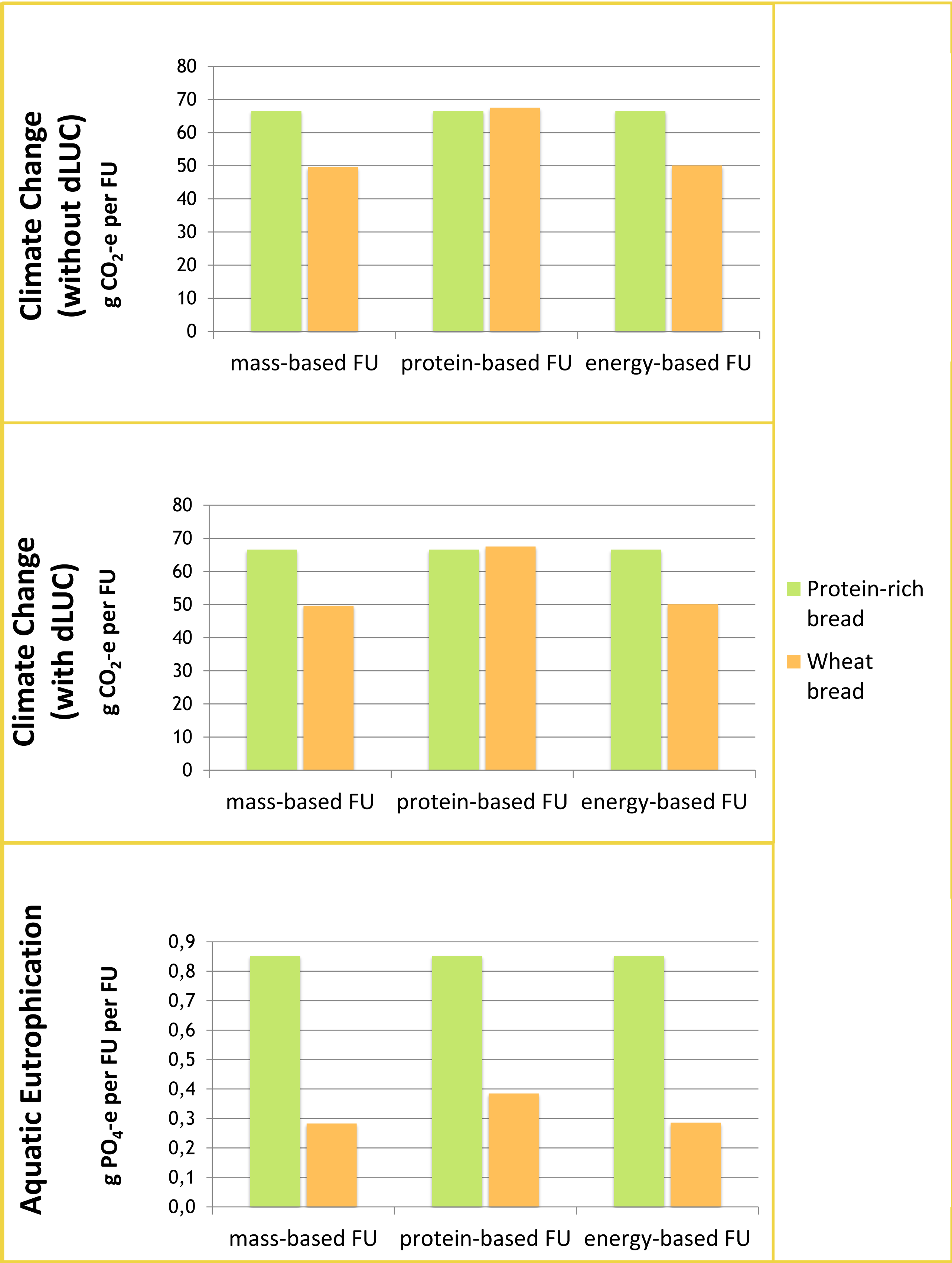

Figure 8-14: sensitivity LCA results of bread, indicators: Climate Change (with dLUC), Climate Change (without dLUC), and Aquatic Eutrophication

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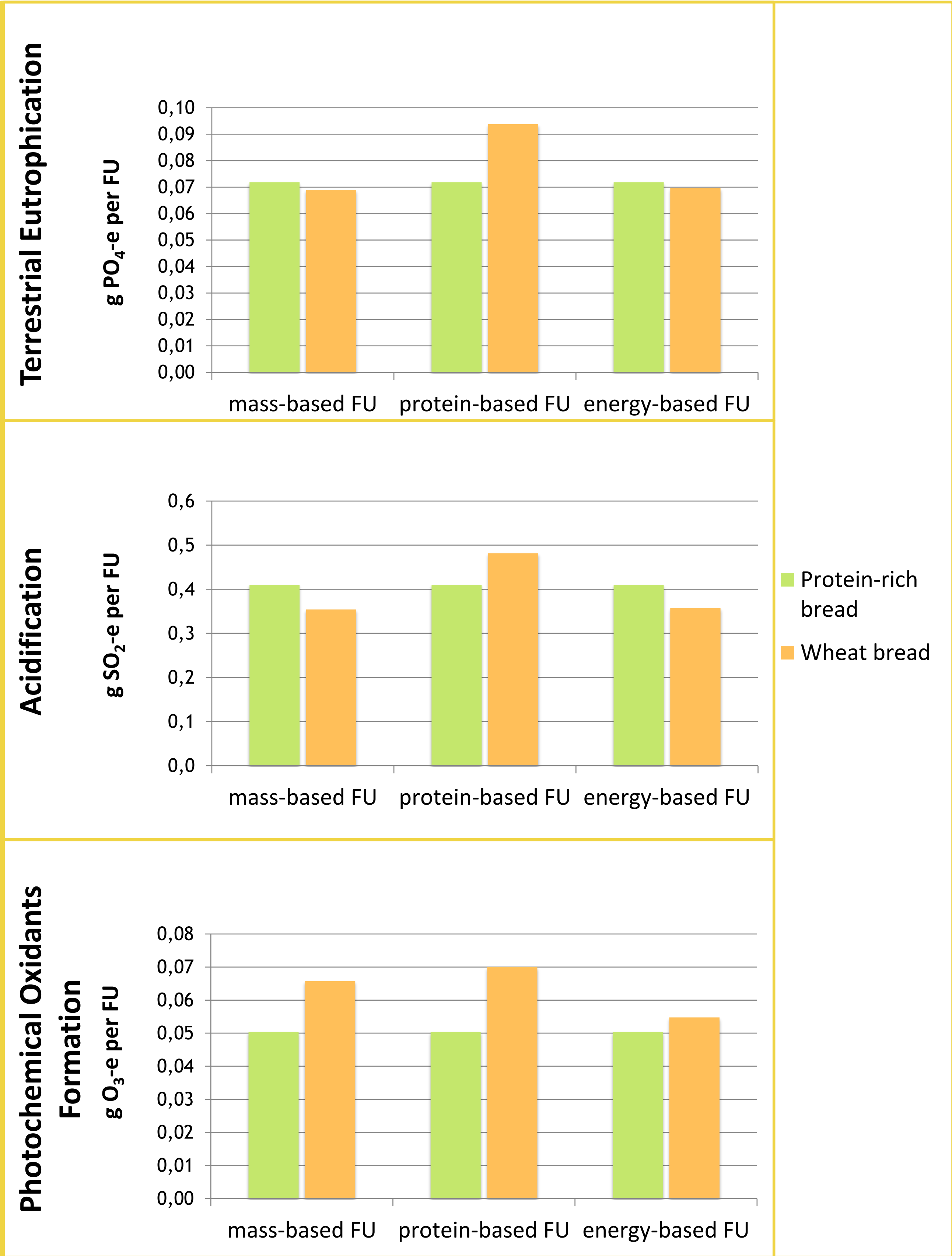

Figure 8-15: sensitivity LCA results of bread, indicators: Terrestrial Eutrophication, Acidification, and Photochemical Oxidants Formation

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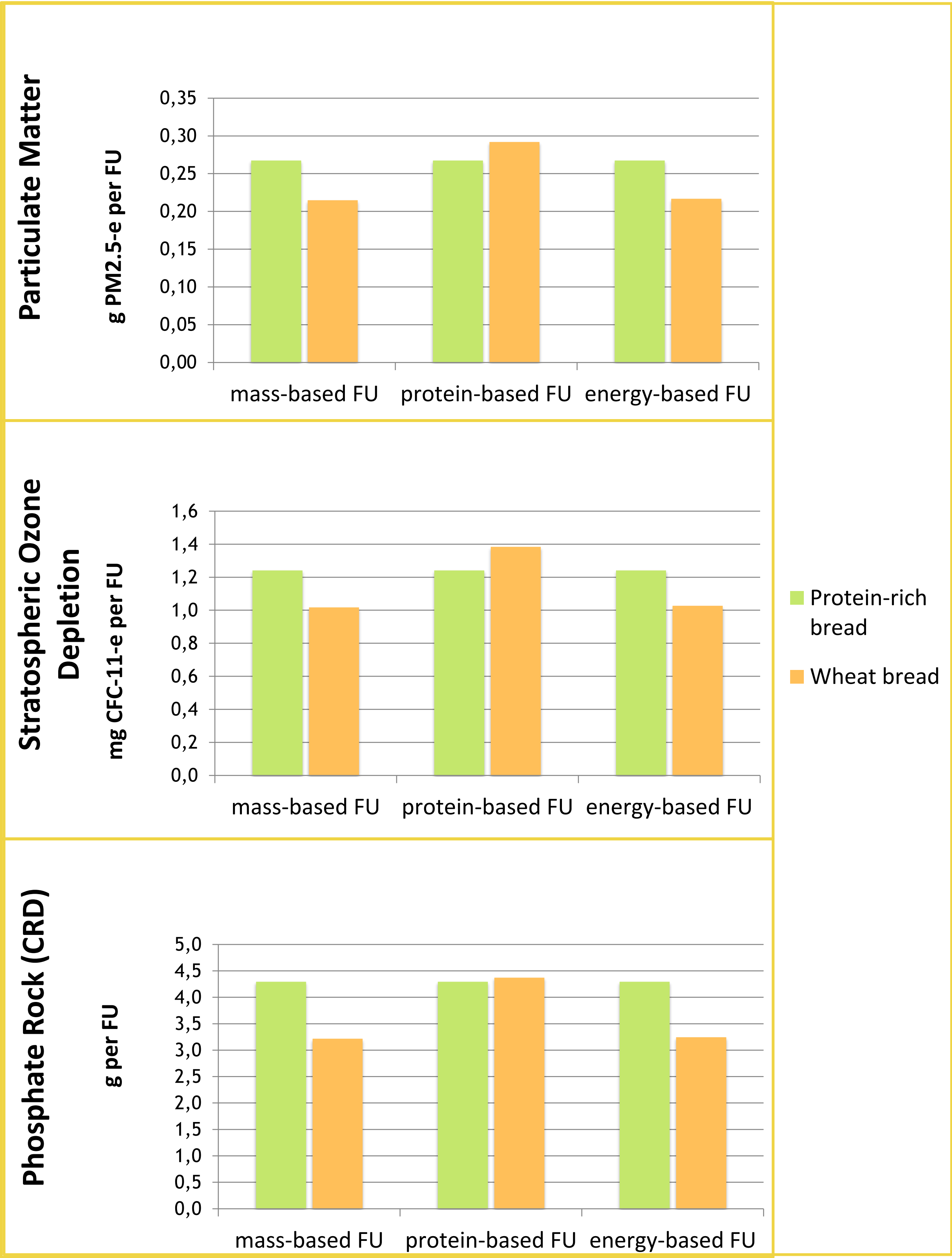

Figure 8-16: sensitivity LCA results of bread, indicators: Particulate Matter, Stratospheric Ozone Depletion, and Phosphate rock

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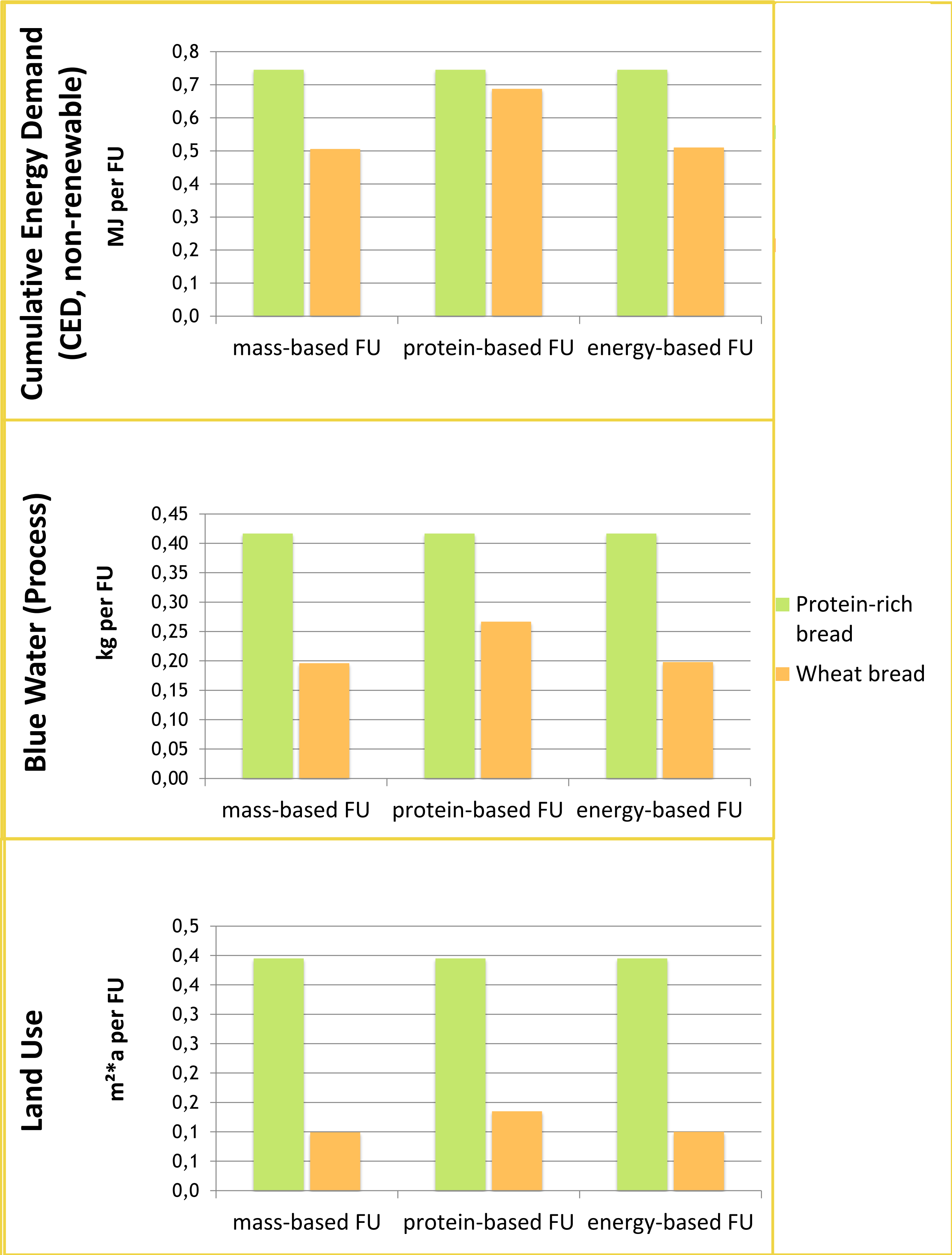

Figure 8-17: sensitivity LCA results of bread, indicators: Cumulative Energy Demand (CED, non-renewable), Blue Water (Process), Land Use

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8.3. Environmental impact profiles of P2F prototypes at farm-to-fork level

Table 8-9: Farm-to-fork LCA results P2F prototype VMA-fiber

Indicator	VMA-Fiber				Chicken	
Per 100 g	AF LuPI	BWF LuPI	AF LePI	BWF LePI	low impact	high impact
Climate Change (excl dLUC)	271	265	187	181	262	380
Climate Change (incl dLUC)	271	265	187	181	686	1034
Aquatic Eutrophication	1,61	1,98	3,93	4,30	2,67	4,12
Terrestrial Eutrophication	0,15	0,12	0,13	0,10	1,71	2,60
Acidification	1,51	1,33	0,98	0,80	9,04	13,66
Photochemical Oxidant Formation	0,43	0,44	0,11	0,12	0,53	0,81
Particulate matter	1,17	1,09	0,72	0,64	3,70	5,56
Stratospheric Ozone Depletion	2,08	1,78	2,85	2,55	7,62	11,71
Phosphate Rock	20,88	18,74	12,43	10,29	11,56	17,80
Cumulative Energy Demand (CED, non-renewable)	3,97	3,95	2,42	2,41	2,16	2,93
Blue water (process)	4,43	4,39	1,58	1,54	1,81	2,45
Land Use	1,28	1,41	1,95	2,08	0,62	0,96

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Table 8-10: Farm-to-fork LCA results P2F prototype VMA-spread

Indicator	**VMA-Spread**			**Leberwurst**	
Per 100 g	type leberwurst	type tomato	type curry	low impact	high impact
Climate Change (excl dLUC)	149	172	170	287	411
Climate Change (incl dLUC)	149	172	170	491	776
Aquatic Eutrophication	2,21	2,44	1,69	2,00	3,19
Terrestrial Eutrophication	0,15	0,18	0,32	2,49	3,18
Acidification	0,92	1,18	1,77	13,16	16,81
Photochemical Oxidant Formation	0,22	0,25	0,16	0,31	0,53
Particulate matter	0,65	0,85	1,10	5,08	6,61
Stratospheric Ozone Depletion	2,51	2,74	4,34	6,47	9,62
Phosphate Rock	12,65	13,03	13,00	10,18	18,02
Cumulative Energy Demand (CED, non-renewable)	1,72	2,02	1,54	1,65	2,45
Blue water (process)	1,37	1,91	0,70	2,12	2,84
Land Use	0,95	1,05	0,72	0,48	0,85

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Table 8-11: Farm-to-fork LCA results P2F prototype vegetable milk

Indicator				
Per 100 g	vegetable milk	cow milk low impact	cow milk high impact	soy milk
Climate Change (excl dLUC)	37	110	140	27
Climate Change (incl dLUC)	37	138	165	27
Aquatic Eutrophication	0,42	0,38	0,62	0,13
Terrestrial Eutrophication	0,02	0,29	0,42	0,01
Acidification	0,16	1,56	2,14	0,09
Photochemical Oxidant Formation	0,03	0,10	0,10	0,02
Particulate matter	0,13	0,66	0,90	0,08
Stratospheric Ozone Depletion	0,35	1,30	2,82	0,14
Phosphate Rock	1,49	2,50	3,61	2,00
Cumulative Energy Demand (CED, non-renewable)	0,51	0,49	0,54	0,37
Blue water (process)	0,33	0,57	0,66	0,22
Land Use	0,20	0,08	0,13	0,07

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Table 8-12: Farm-to-fork LCA results <u>P2F prototype vegetable burger</u>

Indicator				
Per 100 g	Innovative lupin burger	Innovative lentil burger	Traditional beef burger	Soy burger
Climate Change (excl dLUC)	351	305	1356	167
Climate Change (incl dLUC)	351	305	1614	167
Aquatic Eutrophication	2,65	3,06	4,84	0,55
Terrestrial Eutrophication	0,18	0,17	3,53	0,07
Acidification	1,50	1,28	19,97	0,75
Photochemical Oxidant Formation	0,31	0,25	1,29	0,11
Particulate matter	1,17	0,99	9,62	0,61
Stratospheric Ozone Depletion	2,67	2,69	24,41	0,74
Phosphate Rock	12,60	9,69	134,33	7,82
Cumulative Energy Demand (CED, non-renewable)	5,01	4,29	9,88	2,66
Blue water (process)	1,59	0,79	20,05	0,69
Land Use	1,17	1,26	2,73	0,28

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8.4. Raw data for identification of most relevant countries for agricultural production)

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