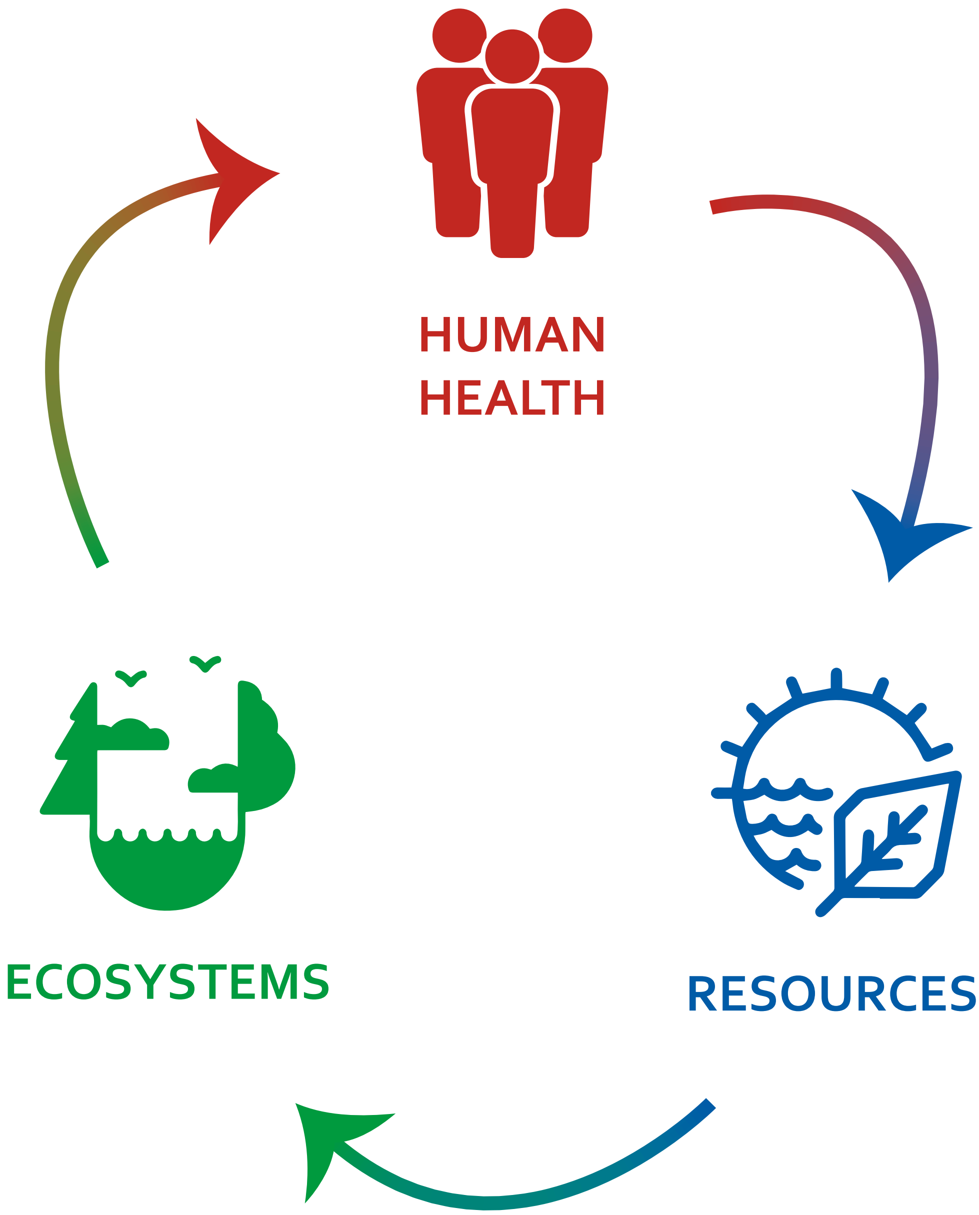
CRADLE-TO-GATE LIFE CYCLE ASSESSMENT RESULTS

detailed analisys of ActInPak's demonstrators



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INTRODUCTION

Traditional definition of sustainable development was developed by the Brundtland Commission in 1987. It states that sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development comprises three elements - economic, social and environmental - which have to be considered in equal measure in a whole life cycle of given product, service or economic process.

Active and Intelligent packaging solutions tackle sustainability in a variety of interesting ways, depending on where the interaction takes place in full packaging value chain.

During the course of COST action FP1405 ActInPak, Working Group 3 performed Life Cycle Assessments of three Active and Intelligent demonstrator products. This document presents those results.

ACTIVE AND INTELLIGENT PACKAGING

Active packaging is intended to extend the shelf life or to maintain or improve the condition of packaged food. It is designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food.

Examples of active packaging:

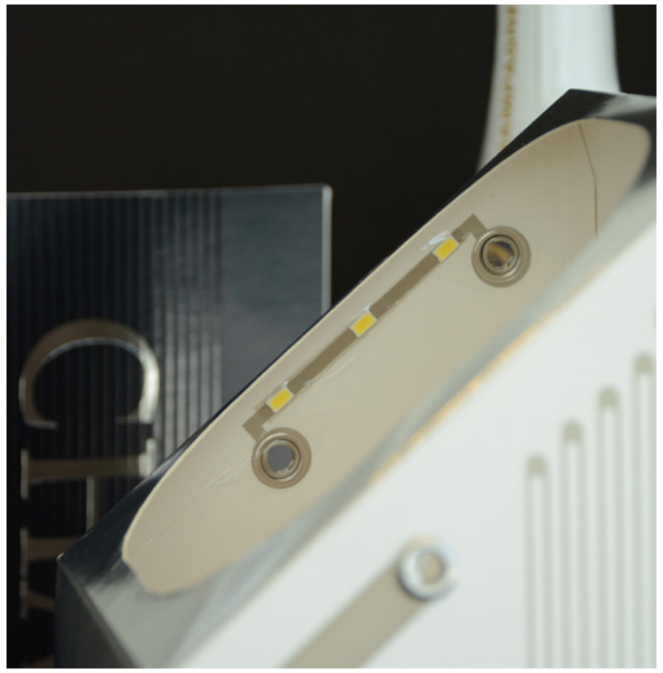
- Oxygen, moisture or ethylene scavengers
- CO2/antioxidant emitters
- Adaptors

Intelligent packaging refers to packaging systems that can inform and/or interact with the consumer about the quality, nature or production history of the packed product.

Examples of intelligent packaging:

- Oxygen sensors
- Temperature and time-temperature indicators
- Freshness indicators
- Interactive packaging

See our leaflets on active and intelligent packaging for more information.



LIFE CYCLE ASSESSMENT (LCA)

Widespread use of packaging, mostly produced from non-renewable resources, causes a noticeable increase in environmental burdens - the consumption of natural resources, emissions during production, as well as the need for management of increased waste. Increasing public awareness, more stringent legal regulations and the development of knowledge about the environmental impact of products, make the protection of the natural environment and sustainable development more and more important. More attention is paid to the type of raw materials and their impact on the environment, energy consumption, mode of transport, storage and disposal of post-consumer waste.

The activities of environmental organizations, increased awareness of residents, increasing legal requirements, and above all, the development of knowledge about the impact of many products on the state of the environment led to the development of various methods to assess this impact in the context of environmental threats.

The Life Cycle Assessment (LCA) is an example of a method effectively implemented in industrial practice, aimed at limiting the negative impact on the environment. It complies with the international standard ISO 14040 Environmental management - Life cycle assessment - Principles and structure.

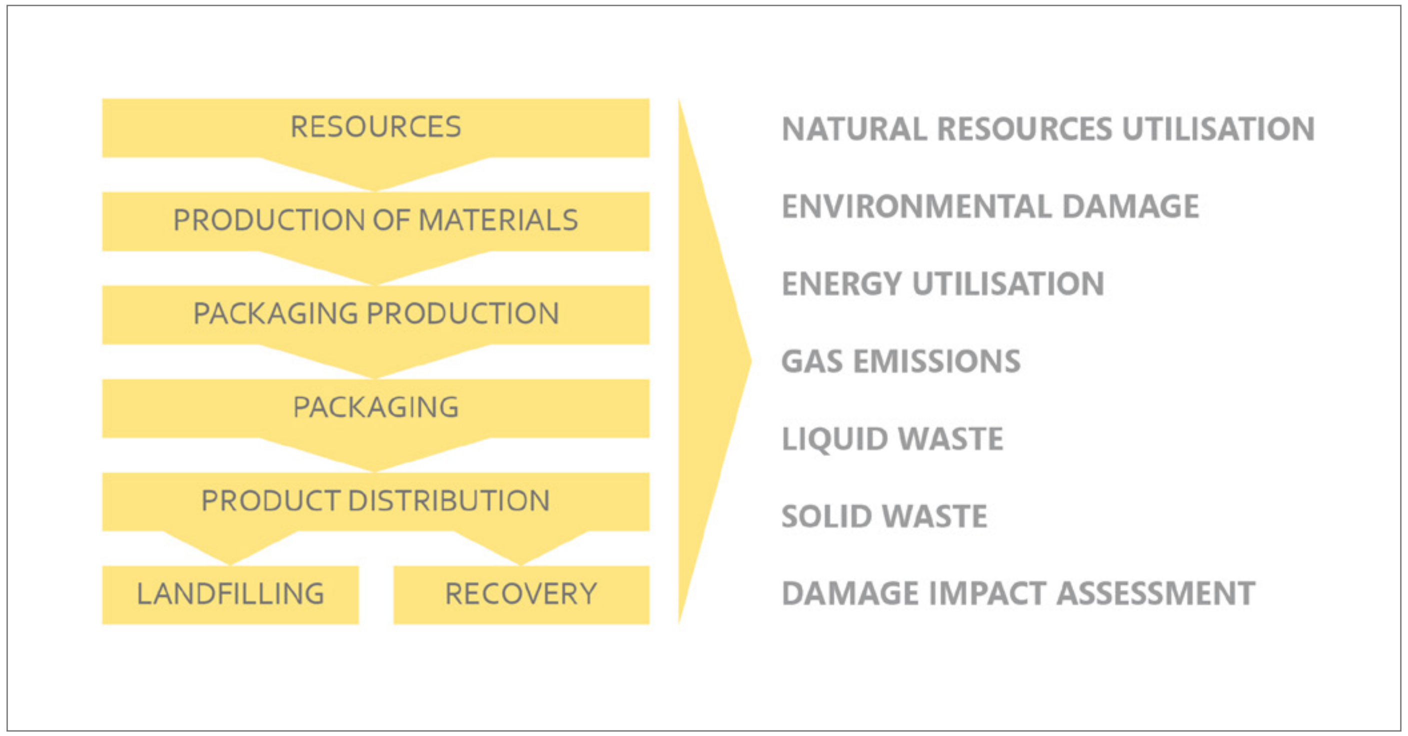


Figure 1. Simplified process tree of a packaging, with examples of environmental threats that can occur throughout the life cycle. (Source: COBRO)

The LCA method seems to be a natural development of both the environmental management system and the waste management strategy. The life cycle assessment analyses the environmental hazards associated with the product throughout its life, including: extraction and processing of raw materials, production (production process), distribution, transport, use, and waste management [1].

The life cycle is defined as subsequent, interrelated processes - from the collection of raw materials to the production of materials, through the production and distribution phase, up to the stage of waste generation and the processes of their recovery and / or disposal [2]. In the case of packaging, the Life Cycle Analysis (LCA) enables assessment of environmental impacts resulting from all stages of packaging life, including: extraction and processing of raw materials, production (production process), distribution, transport, usage re-use, recycling or other methods of waste recovery, final disposal of waste.

The LCA method should form part of the concept of extended producer responsibility for the product and be used by industry as a basic factor supporting the decision-making process related to the selection of packaging for specific product groups.

Packaging tests incorporating the LCA method rely on the recording of environmental burdens in the particular stages of their life cycle (system boundaries). According to this, it is possible to depict the impact of the assessed packaging on individual categories of environmental mechanisms based on life science (like for example quality of soil, use of minerals, water, air, animals and plants, landscape and climate). Knowledge on this subject allows making choices more beneficial for the environment, and thus enables rational management of resources in accordance with the principle of the sustainable development [3]. If the environmental impacts of specific packaging are known, strategies can be defined to reduce them, for example through material changes, technological development, better process management, etc. [4].

LCA can be used to rate and compare a product with another product of similar functionality, in terms of its environmental impact throughout its life cycle. LCA method consists of different criteria of evaluation in all life cycle stages of a selected product. LCA study can present full view on specific products influence on the environment starting from mining of resources, ending on recycling or waste treatment. Potential environmental influence of every life cycle process of a chosen product is quantitatively recorded in categories such as: health, ecosystem quality and resources consumption. Potential impacts that a given product can have on an environment are: carcinogenic factors, organic and inorganic compounds emission, climate changes, radiation, ozone layer damage, ecotoxicity, acidifications/ eutrophication, terrain usage, natural resources and fossil fuel consumption.

DEMONSTRATOR PRODUCTS

Illustrations of demonstrator products are presented below on figures 2-4 For the purposes of ActInPak, three demonstrator products were chosen:

Intelligent indicator for meat products – assumptions that the indicator is binary – it either shows that the meat is fresh, or not.

Packed bread active packaging – bread in active packaging does not have preservatives, and therefore its best before date can be identical to a standard bread with preservatives.

Fruits/Vegetables active corrugated box – strawberries chosen as the packed product.

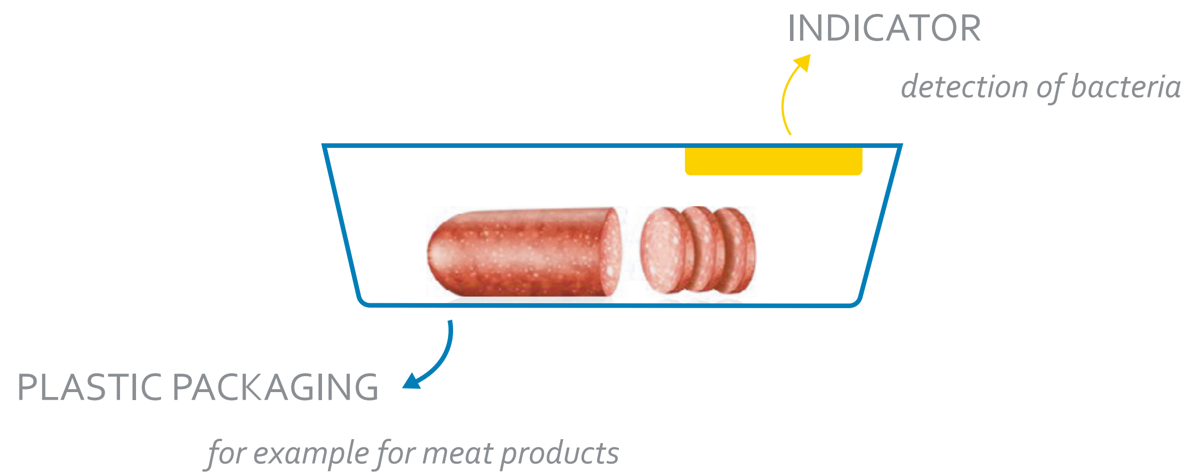
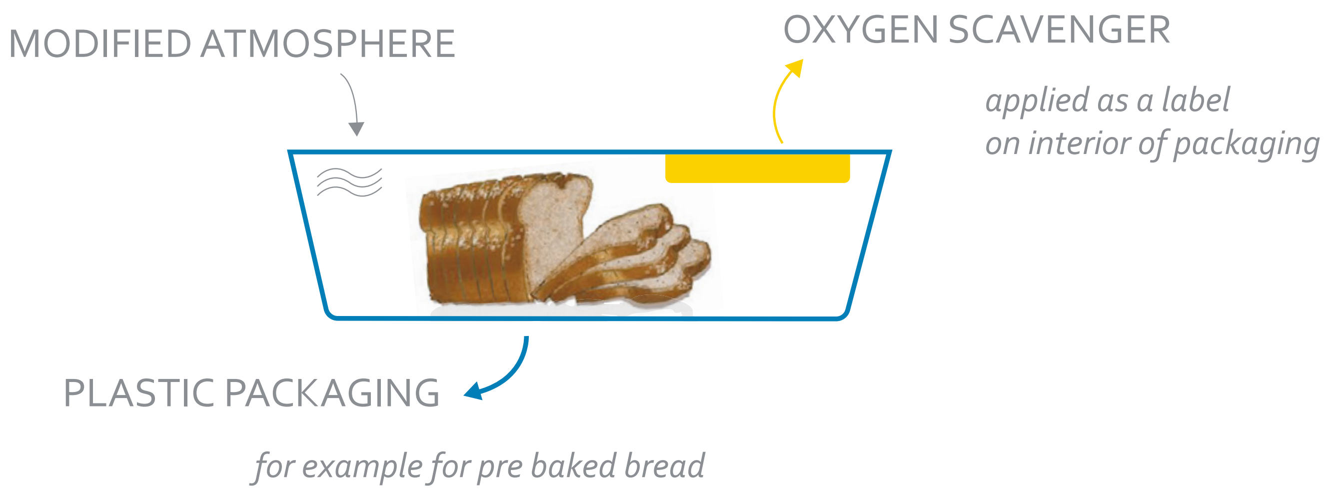


Figure 2. Demonstrator product 1 – Intelligent packaging for meat with indicator – detection of bacteria

Figure 3. Demonstrator product 2 – Active packaging for bread with oxygen scavenger



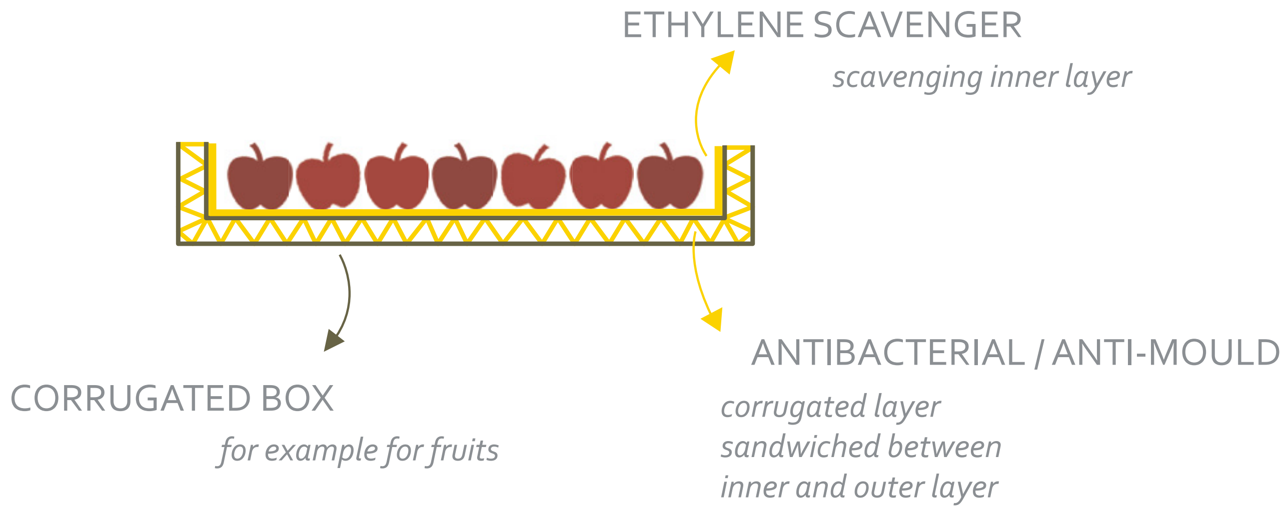


Figure 4. Demonstrator product 3 – Active packaging for strawberries with ethylene scavenger and antibacterial/anti-mould layers sandwiched between inner and outer layer of corrugated board

LIFE CYCLE ASSESSMENT STANDARDS AND SOFTWARE

Life Cycle Assessment is a standardised method. ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework, provides a clear overview of the practice, applications and limitations of LCA to a broad range of potential users and stakeholders, including those with a limited knowledge of life cycle assessment. While ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines, is designed for the preparation of, conduct of, and critical review of life cycle inventory analysis. It also provides guidance on the impact assessment phase of LCA and on the interpretation of LCA results, as well as the nature and quality of the data collected.

This study uses both standards, and the LCA examples presented here follow the internal LCA guidelines of ISO 14044:2006.

SimaPro 8 software was used for calculations. SimaPro 8 is LCA assessment tool in line with ISO 14040:2006. SimaPro 8 software allows to create full LCA's, LCA reports, export results, calculate uncertainty and most importantly includes numerous databases with input and output data of thousands of feedstock products, processes, transport and energy mixes. For the purpose of this study SimaPro 8 software and the EcoInvent 3 database were used.

IMPACT ASSESSMENT METHODS

For the interpretation of lists of emitted chemical substances, this study utilizes the ReCiPe EndPoint v1.13 method. It was chosen on the merit of giving opportunity to assess individual categories of environmental impacts and enabling to recalculate these inflows into categories of environmental damages. Detailed descriptions of method used, can be found below – literature concerning this method is in line with the most recent official SimaPro 8 Methods Manual from May 2017 and therefore describe the current state of methodology research:

ReCiPe METHOD

ReCiPe is the successor of the Eco-indicator 99 and CML-IA methods. The purpose at the start of the development was to integrate the 'problem oriented approach' of CML-IA and the 'damage oriented approach' of Eco-indicator 99. The 'problem oriented approach' defines the impact categories at a midpoint level. The uncertainty of the results at this point is relatively low. The drawback of this solution is that it leads to many different impact categories which makes the drawing of conclusions with the obtained results complex. The 'damage oriented approach' of Eco-indicator 99 results in only three impact categories, which makes the interpretation of the results easier. However, the uncertainty in the results is higher. ReCiPe implements both strategies and has both midpoint (problem oriented) and endpoint (damage oriented) impact categories. The midpoint characterization factors are multiplied by damage factors, to obtain the endpoint characterization values. ReCiPe comprises two sets of impact categories with associated sets of characterization factors. At the endpoint level, most of these midpoint impact categories are multiplied by damage factors and aggregated into three endpoint categories: The three endpoint categories are normalized, weighted, and aggregated into a single score.

Figure 5 portrays relations between the 18 midpoint categories, and the 3 endpoint categories [5,6].

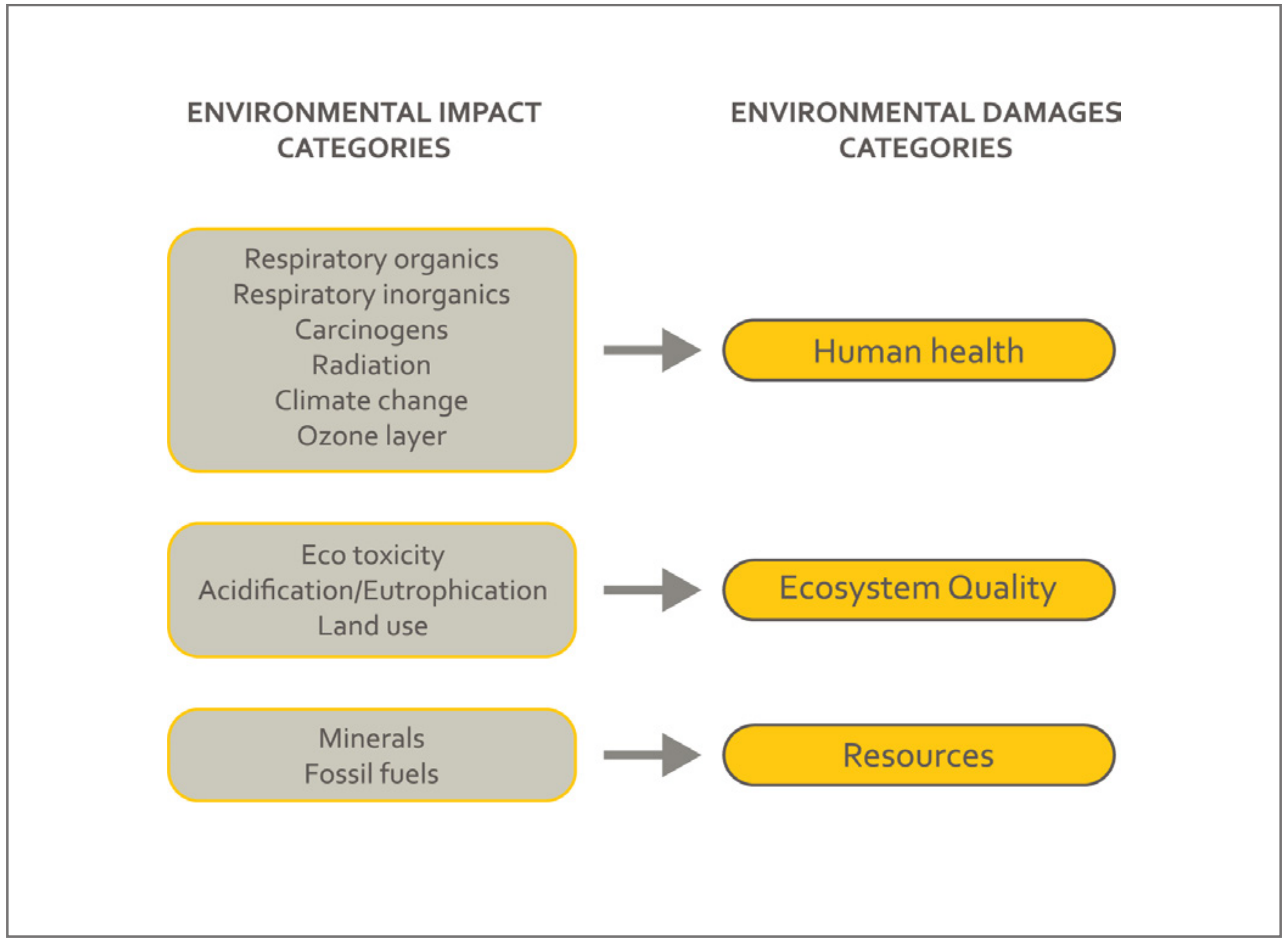


Figure 5. Environmental impact categories and damages according to ReCiPe method [3]

GOAL AND SCOPE

SAMPLES AND FUNCTIONAL UNIT

All demonstrator products were based on average products of their respective types. Products were collected from the market and assumptions and certain data was taken from literature. Based on WG3 members' discussions, the functional units for the demonstrator products were assigned to the actual products that are packed. This way of selecting functional unit allows to compare A&I packaging to its traditional counterpart and show different behavior of products in A&I packaging with regards to shelf life and, in the case of bread, difference in product formulation (preservatives). Functional unit and scenarios for comparison are described in table 1.

SYSTEM BOUNDARIES

CRADLE TO GATE SCENARIO

The LCA study considers standard system boundaries scenario. This scenario takes into account all the raw feedstock materials of packaging, its processing, transport and finally packaging components production and their assembly into the final packaging. It also takes into account all processes of food production (beef, bread and strawberries). The end of this scenario – so called 'gate' - is the moment that the finished packaging along with its contents is ready to be transported to the next participant of the value chain distributor, wholesaler or end-consumer etc.

DATA COLLECTION

There were 2 main sources of the data used for this study:

Primary data - physical samples were obtained from the market. Processing data was collected from selected companies. Information about A&I components was accessed directly from ActInPak members.

Secondary data - ata from EcoInvent 3 database concerning feedstock materials, granulates, additional processing and food production. Data from literature concerning the energy use of various manufacturing equipment. Where possible, data from the database was changed to reflect primary data.

RESULTS

Results are presented according the following scheme for each demonstrator product:

- Process trees with single score results
- Damage assessment – process contribution
- Weighting – process contribution
- Weigthing – end-point – process contribution
- Weigthing – end-point – process contribution – single score results
- Comparison of scenarios – weigthing
- Comparison of scenarios – damage assessment – end-point
- Comparison of scenarios – weighting – end-point
- Comparison of scenarios – Single Score

Demonstrator 1 Tray for beef	Demonstrator 2 Bag for bread	Demonstrator 3 Corrugated board tray
100kg beef consumed	100kg packed bread sold	100kg strawberries consumed
Scenarios: • Beef in standard packaging • Beef with freshness indicator – fresh 1 extra day after best before date • Beef with freshness indicator – fresh 2 extra days after best before date	Scenarios: • Packaging without active component – bread with preservatives • Packaging with active component – bread without preservatives	Scenarios: • Strawberries in standard packaging • Strawberries in active packaging – 35% waste reduction • Strawberries in active packaging – 70% waste reduction

Table 1. Functional units and scenarios for demonstrator products.

ASSUMPTIONS

Assumptions	Demonstrator 1 Tray for beef	Demonstrator 2 Bag for bread	Demonstrator 3 Corrugated board tray
Packaging with indicator or active component	• Some loss before best before date (due to non-optimal storage conditions) • Savings after best before date – indicator not activated after x days after best before date = increased consumption	Bread in active packaging does not have preservatives, and therefore its best before date can be identical to a standard bread with preservatives • Bread without preservatives • Shelf life is the same as in packaging without active component	• Direct impact on a shelf life- shelf life is longer • Normally 3-7 days refrigerated -> 5 days on average -> 30% + 5 days = 6,5 days
Packaging without indicator or active component	• Certain loss after best before date	• Bread with preservatives • Shelf life is the same as in packaging with active component	• Shelf life is normal • 3-7 days refrigerated -> 5 days on average
Chosen product	Fresh Beef – 500 g • Usual best before date if refrigerated is 3-5 day -> 4 days on average • According to http://www.eatbydate.com, fresh meat can last 1 to 2 days PAST its best before date before it begins to spoil	Loaf – 500 g Packaging – PP film Bread preservative – Propionic Acid - MAX allowed - 2000 mg/kg	Dimensions: 300 mm x 400 mm (FEFCO CF standard) Mass: 0,4 kg Max capacity: 3,6 kg
Scenarios	• Indicator will show that the meat went bad 1 day after best before date • Indicator will show that the meat went bad 2 days after best before date There is a possibility that the indicator will show that meat went bad BEFORE best before date (due to bad storing conditions or bad packaging, other error along the value chain) -Assumption is that this will happen in 10% of cases. According to different sources about 15-30% of beef is wasted (20% on average), therefore: 4 days average best before date 1 extra day = 25% more time to eat 2 extra days = 50% more time to eat Adjusting to 10% chance of accidental early indicator showing the beef is no longer fresh: 1 extra day = 15% more time to eat 2 extra days = 40% more time to eat	/	• Additional shelf life allow us to reduce the wastage by 70% • Additional shelf life allow us to reduce the wastage by 35% With 30% of strawberries being wasted the functional units for the three scenarios is following: Strawberries in normal packaging: 142,85 kg produced for consumption of 100 kg Strawberries with active packaging - 35% waste reduction: 127,85 kg produced for consumption of 100 kg Strawberries with active packaging - 70% waste reduction: 115 kg produced for consumption of 100 kg
Final functional unit calculation Waste assumtions	With 20% of beef being wasted the functional units for three cases are following: Beef in normal packaging: 125 kg produced for consumption of 100 kg Beef with freshness indicator – 1 extra day: 121,25 kg produced for consumption of 100 kg Beef with freshness indicator – 2 extra days: 115 kg produced for consumption of 100 kg	/	30% of strawberries is wasted Increased shelf life will not ensure that there will not be any more waste
Data limitations	Unfortunately there is no specific data about the actual indicator – however, given that the mass share of indicator in whole product (packaging + meat) will be less than 1%, for the purposes of this study it is assumed that the impact of the indicator is negligible.	Data about Oxygen Scavenger obtained from ActInPak members However – processing data – energy consumption – is still missing – for the purposes of the study it is considered negligible. In addition data about bread preservatives processing is also missing – i.e. how and when the preservative is inserted into the flour.	Unfortunately there is no specific data about the actual active component – however, given that the mass share of active components in whole product (packaging + strawberries) will be less than 1%, for the purposes of this study it is assumed that the impact of active components is negligible.

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

PROCESS TREE WITH SINGLE SCORE RECORDS

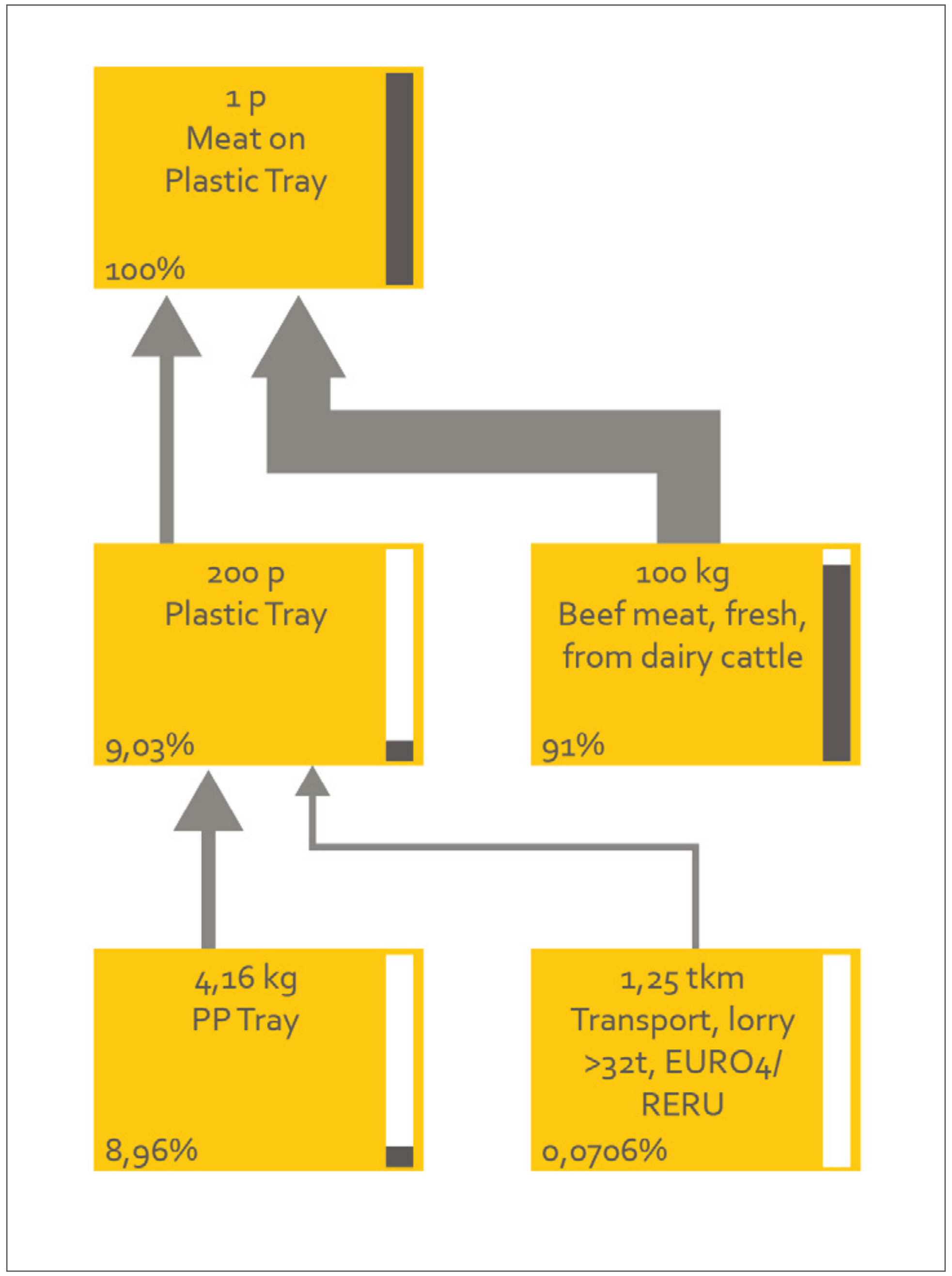


Figure 6. Process tree for beef packaging.

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

DAMAGE ASSESSMENT – PROCESS CONTRIBUTION

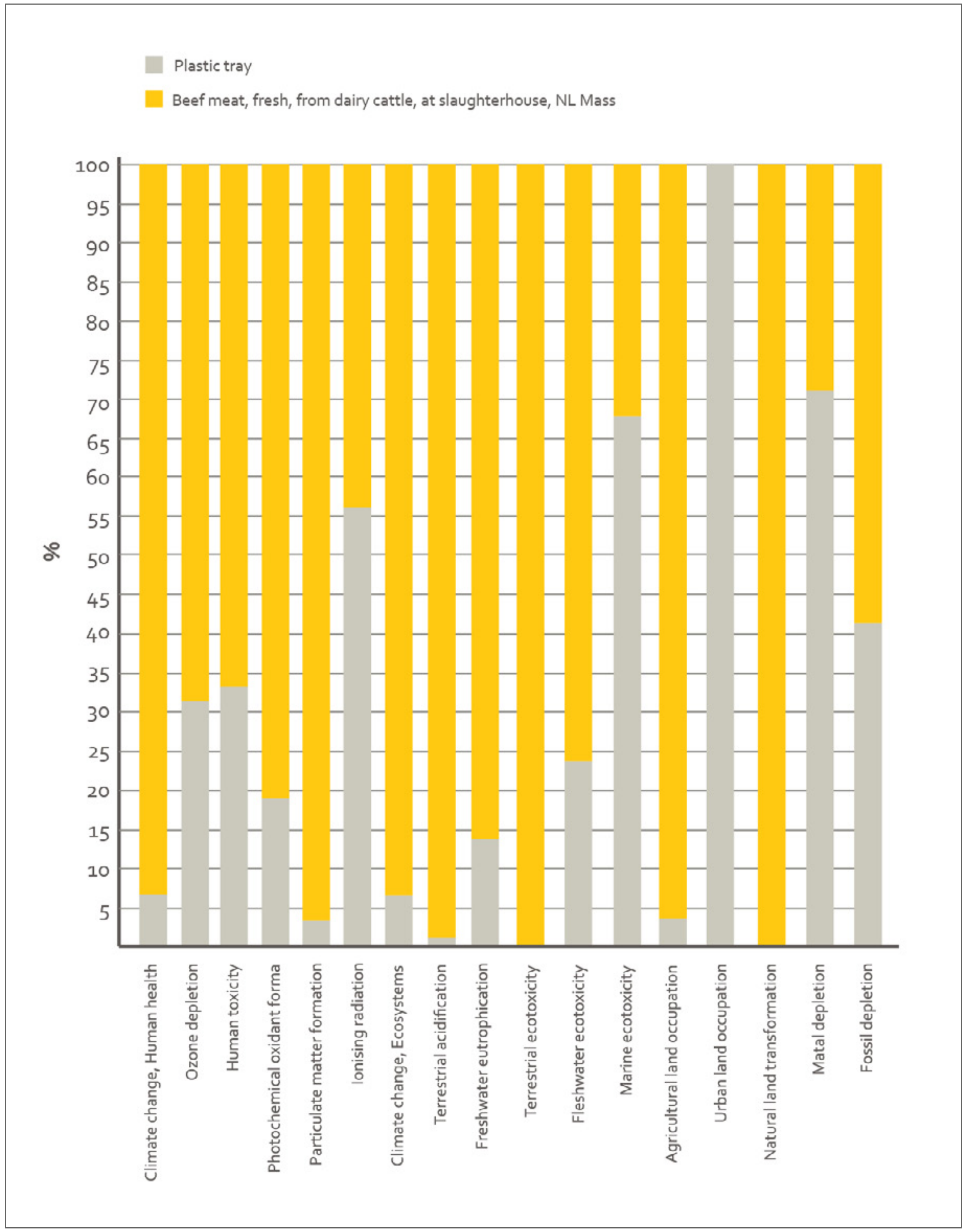


Figure 7. Damage assessment of beef packaging – process contribution

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

WEIGHTING – PROCESS CONTRIBUTION

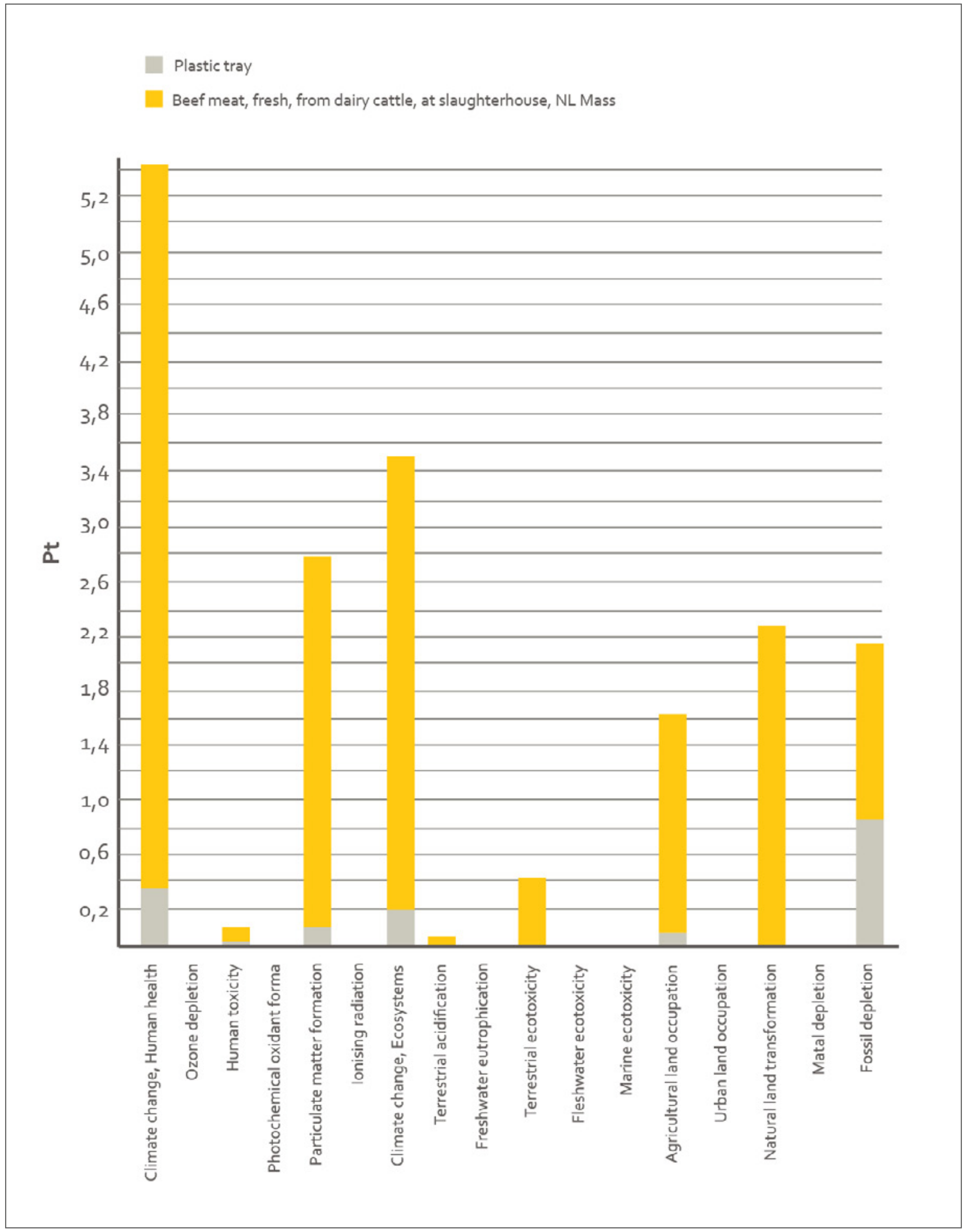


Figure 8. Weighting of beef packaging – process contribution

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

WEIGTHING – END-POINT – PROCESS CONTRIBUTION

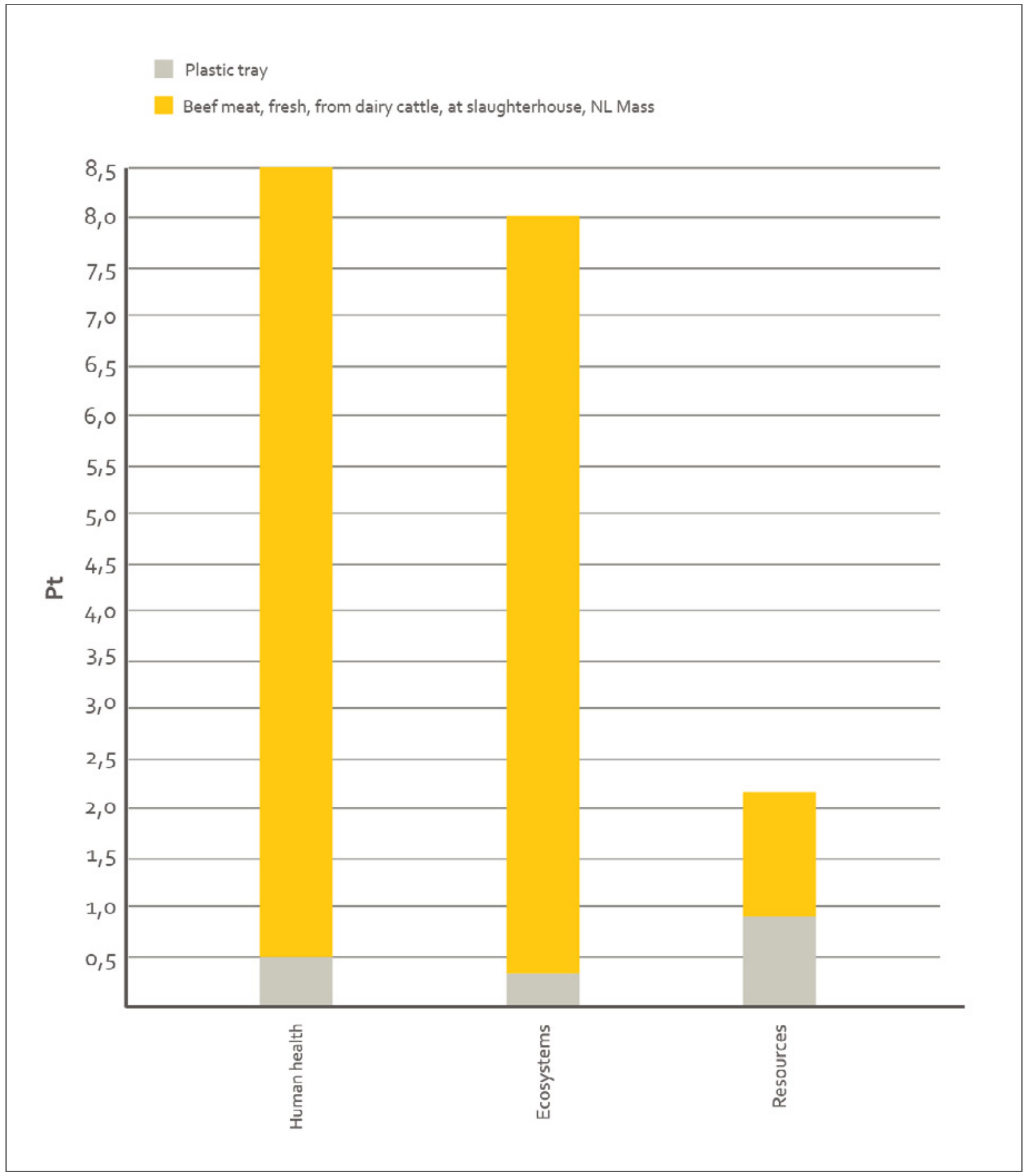


Figure 9. Weighting of beef packaging – end-point results

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

WEIGTHING – END-POINT – PROCESS CONTRIBUTION – SINGLE SCORE RESULTS

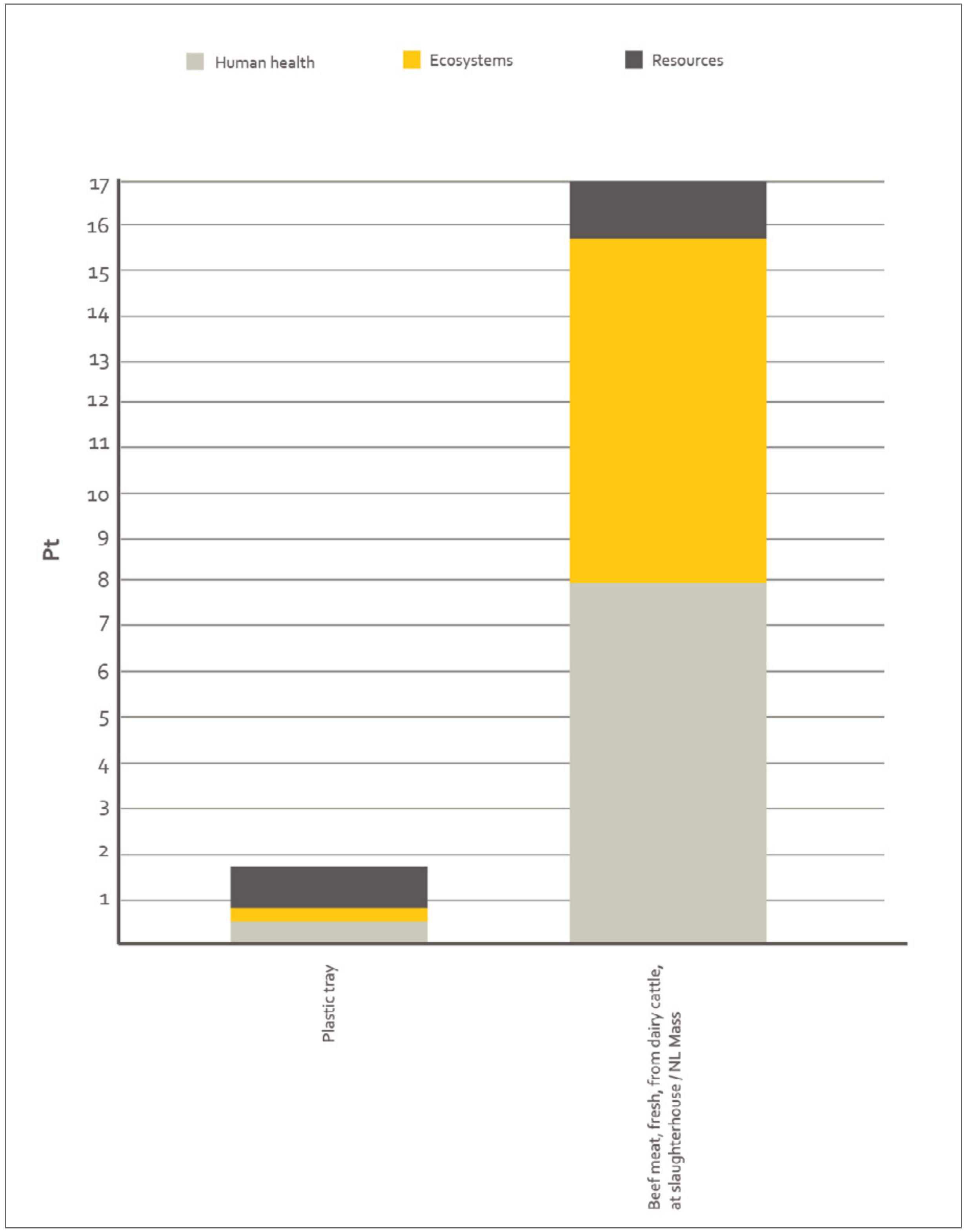


Figure 10. Single score of beef packaging – process contribution

RESULTS

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

COMPARISON OF SCENARIOS – WEIGTHING

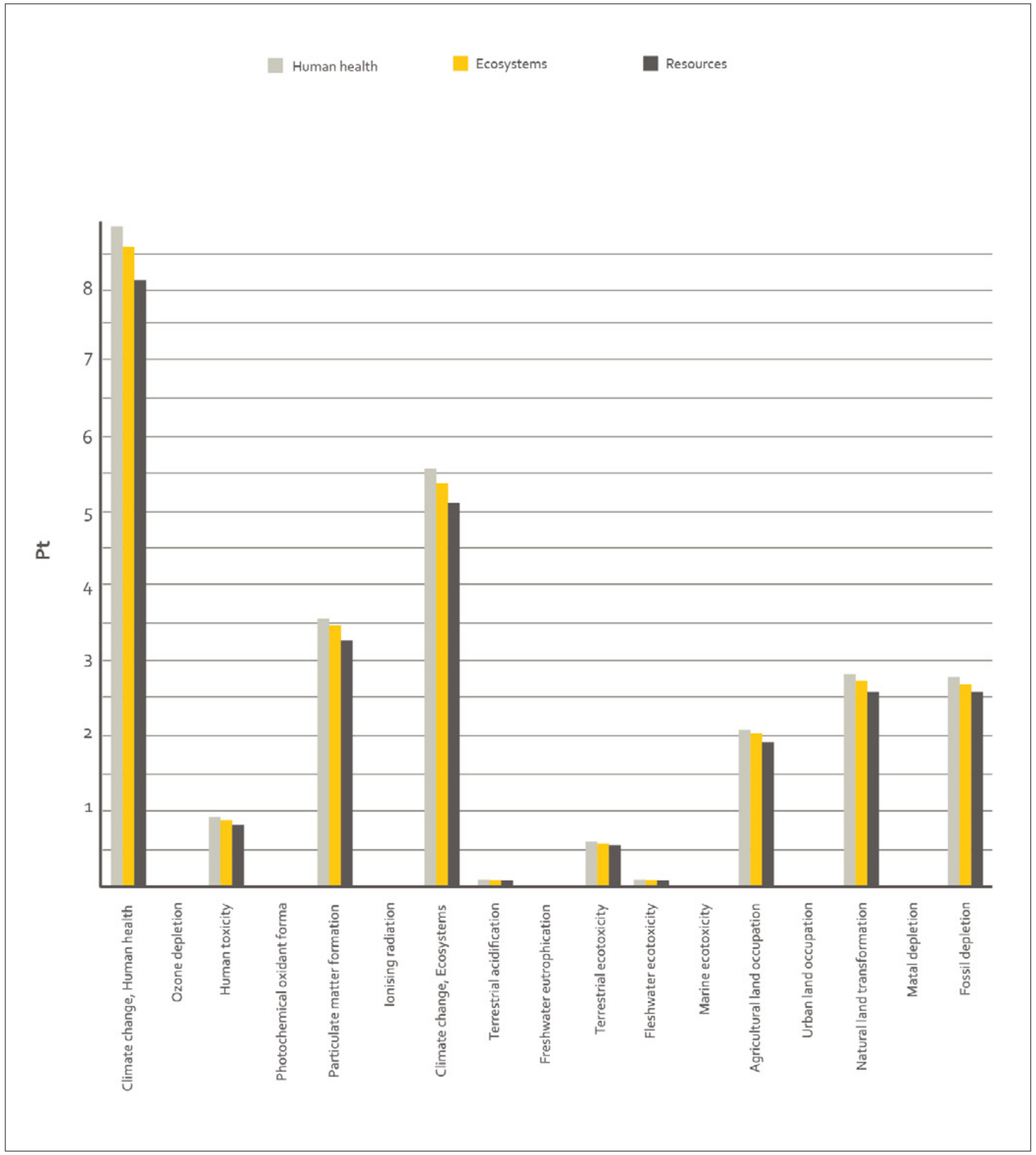


Figure 11. Comparison of beef packaging scenarios – weighting

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

COMPARISON OF SCENARIOS – DAMAGE ASSESSMENT – END-POINT

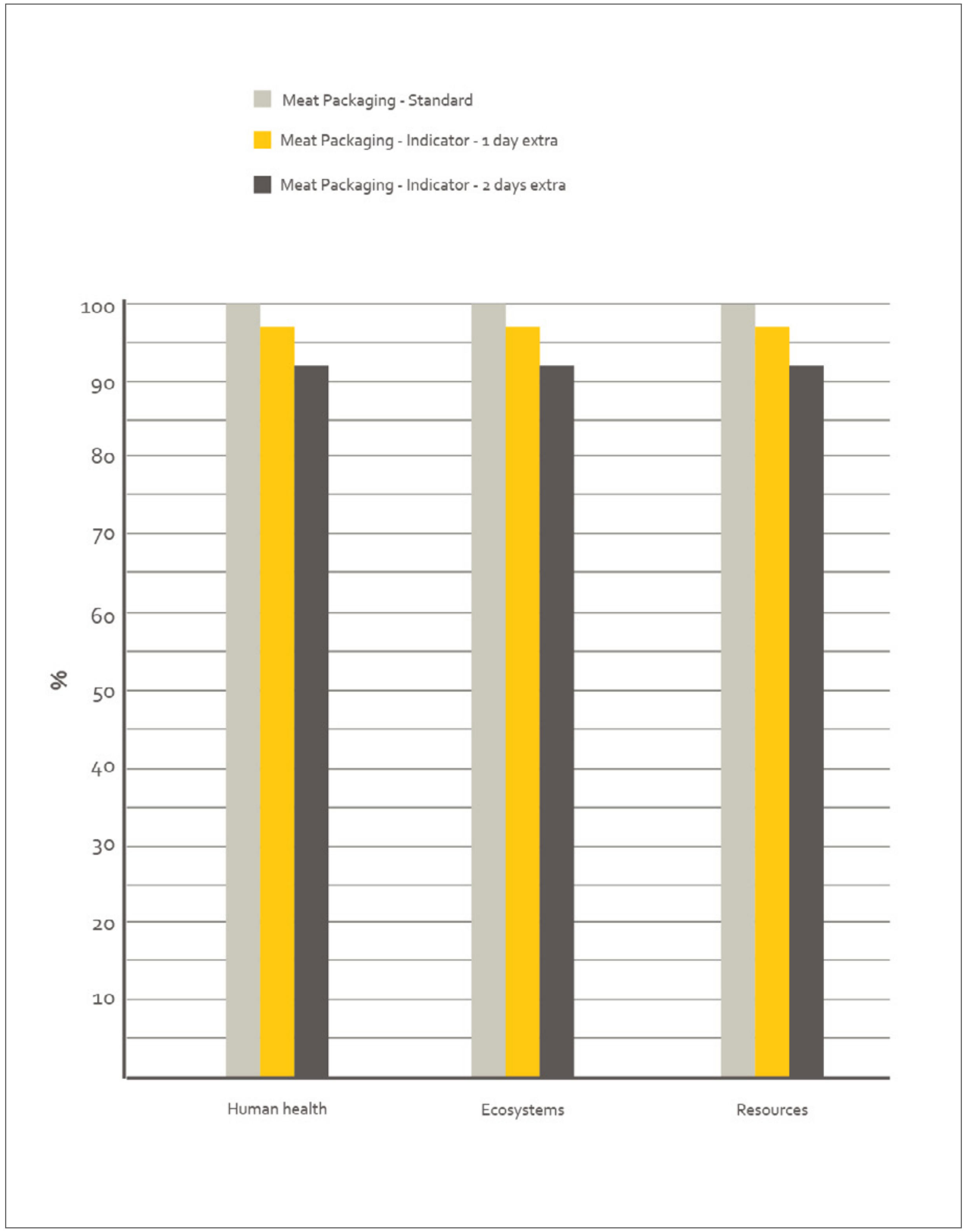


Figure 12. Comparison of beef packaging scenarios – end-point – damage assessment

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

COMPARISON OF SCENARIOS – WEIGHTING – END-POINT

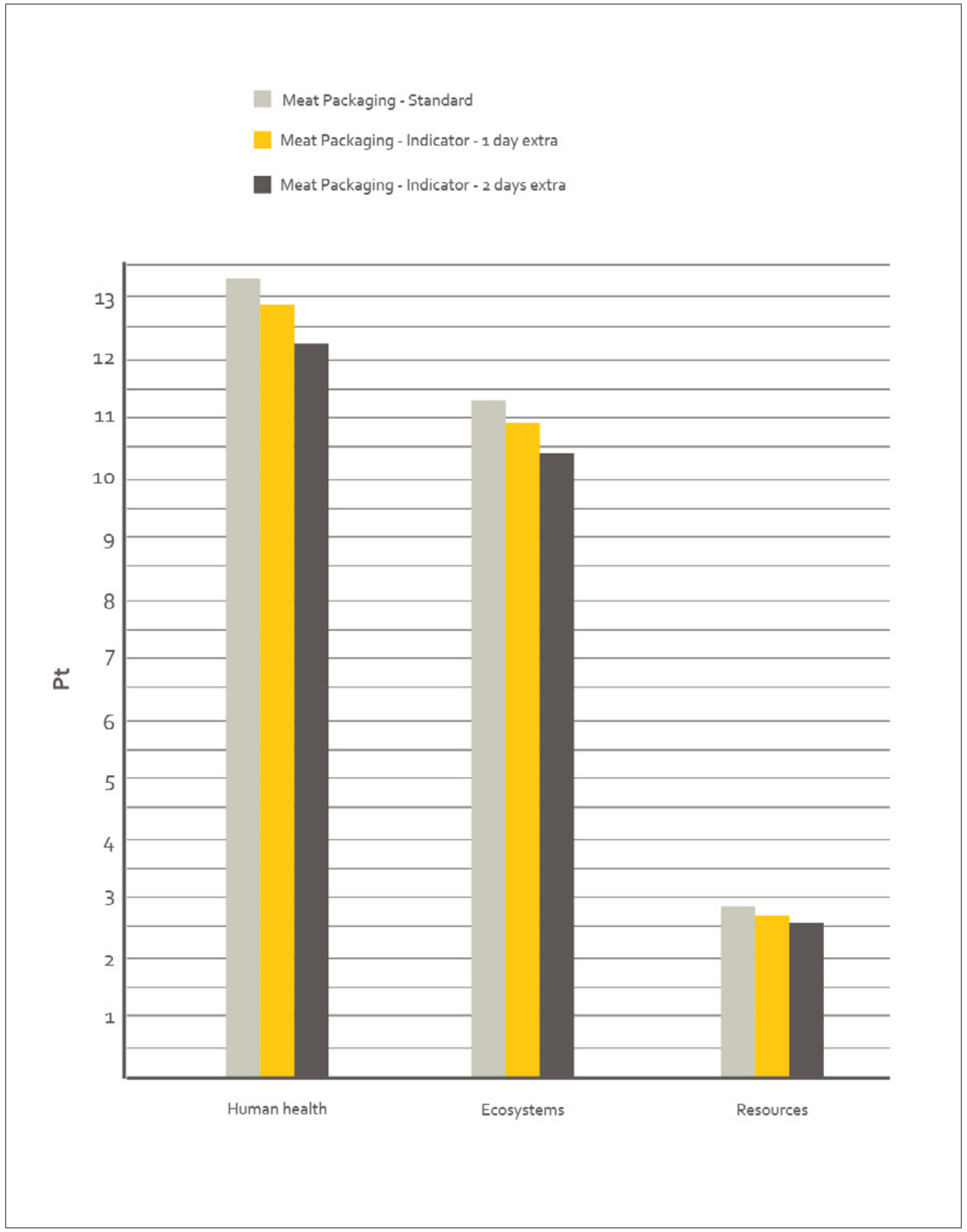


Figure 13. Comparison of beef packaging scenarios – end-point - weighting

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

COMPARISON OF SCENARIOS – SINGLE SCORE

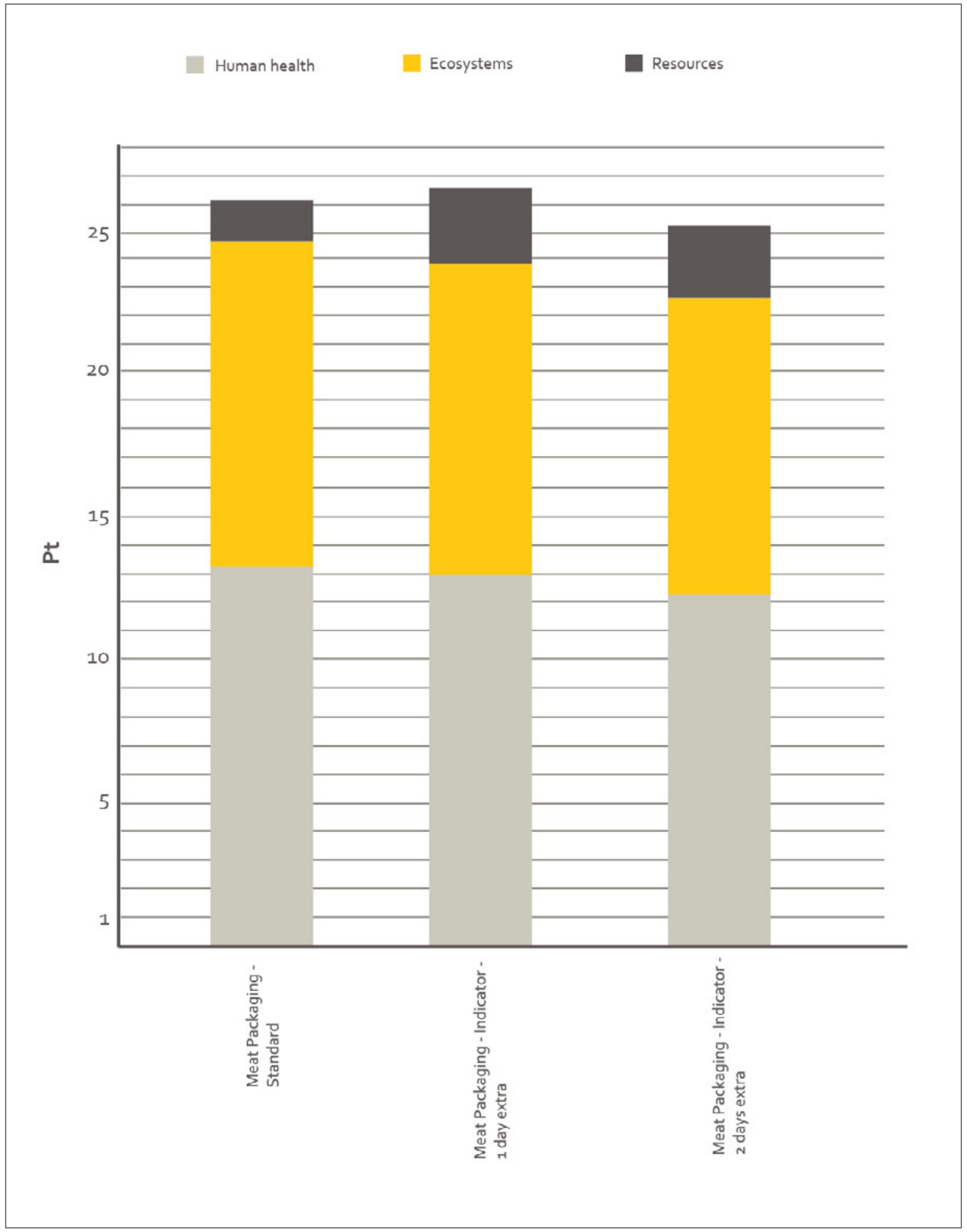


Figure 14. Comparison of beef packaging scenarios – single score

DEMONSTRATOR 1 - INTELLIGENT PACKAGING FOR MEAT

Following observations can be made for demonstrator 1 – intelligent indicator for meat products:

- Meat production processes amount to 91% of all environmental impacts
- Climate change, agricultural land occupation and natural land transformation are the main environmental impacts of beef production
- Fossil depletion is the main environmental impact for beef packaging
- According to assumptions set for the study, intelligent component in meat packaging decreases the environmental impact of beef consumption by about 4% if the meat is eaten 1 day after its best before date, and by 9% if the meat is eaten 2 days after its best before date.

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

PROCESS TREE WITH SINGLE SCORE RECORDS

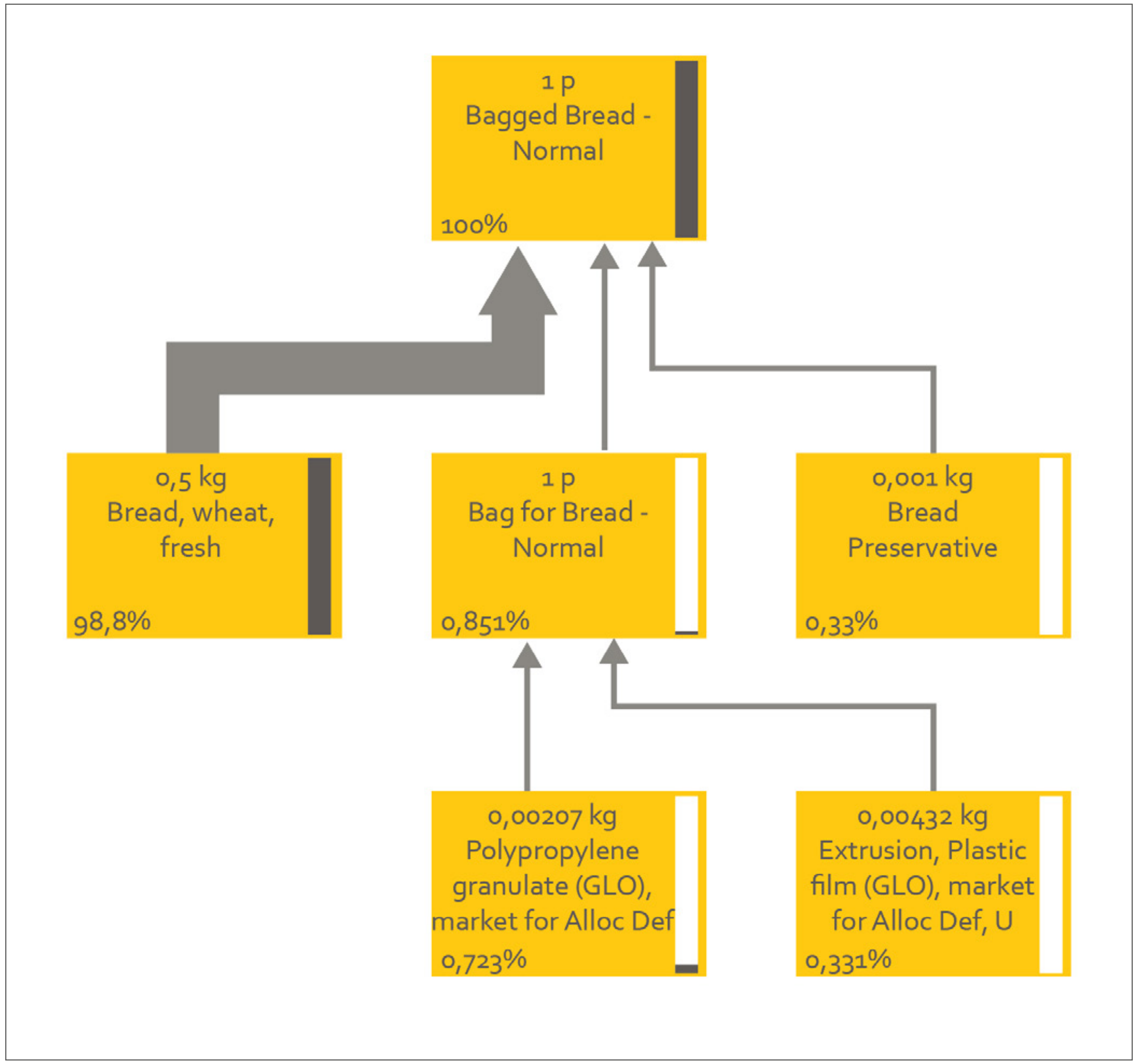


Figure 15. Process tree for bread packaging – no active component

RESULTS

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

DAMAGE ASSESSMENT – PROCESS CONTRIBUTION

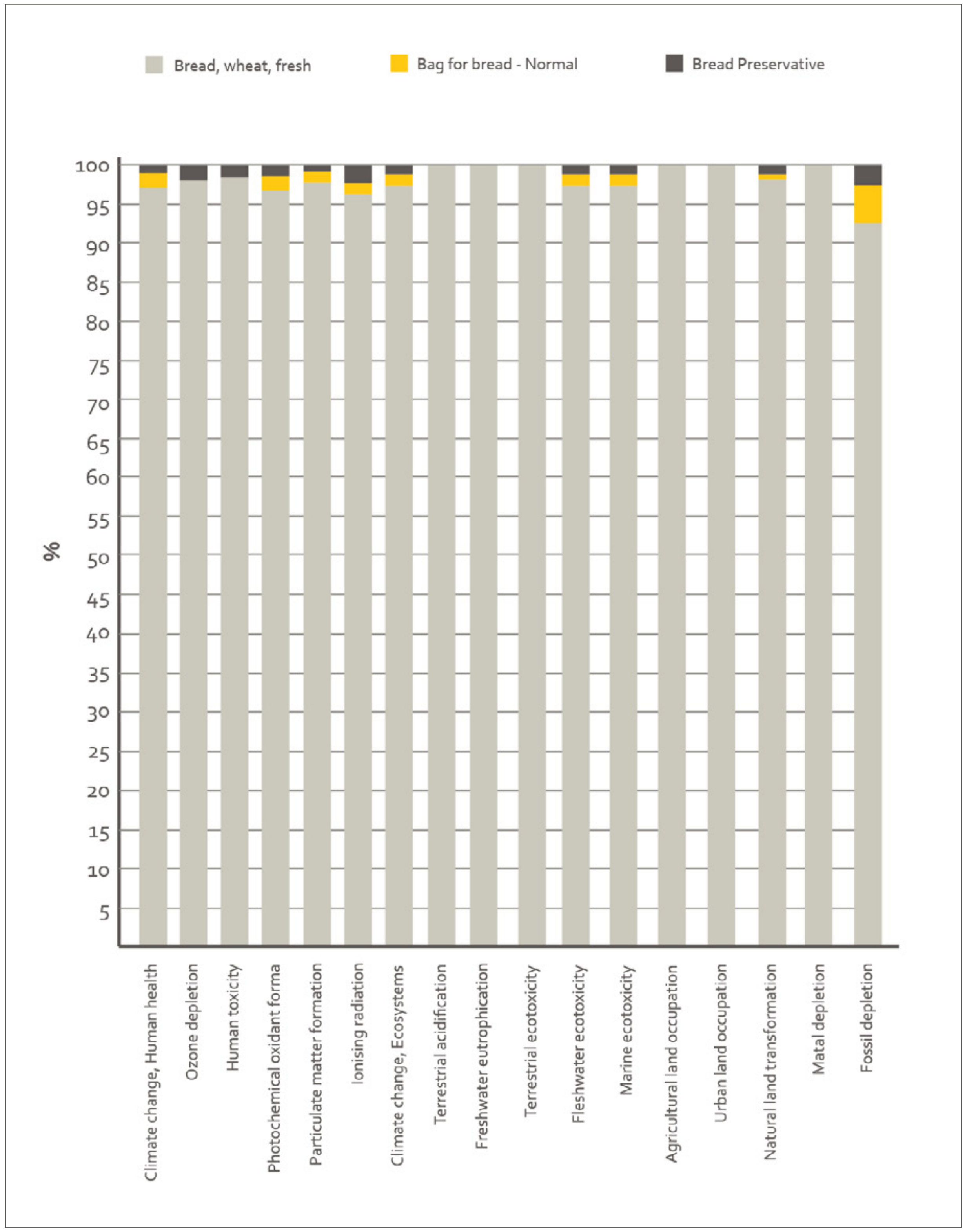


Figure 16. Damage assessment of bread packaging – process contribution – no active component

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

WEIGHTING – PROCESS CONTRIBUTION

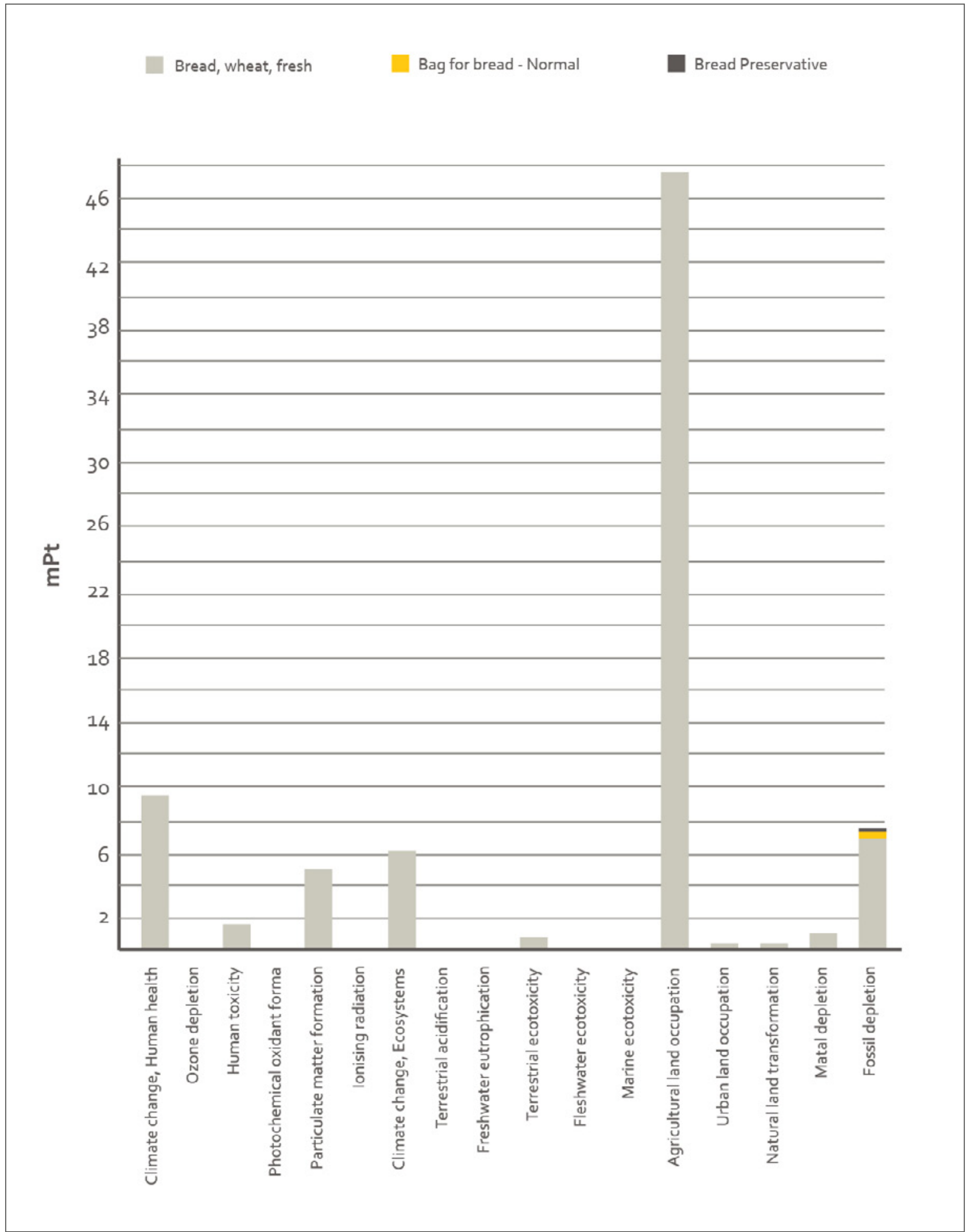


Figure 17. Weighting of bread packaging – process contribution – no active component

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

WEIGTHING – END-POINT – PROCESS CONTRIBUTION

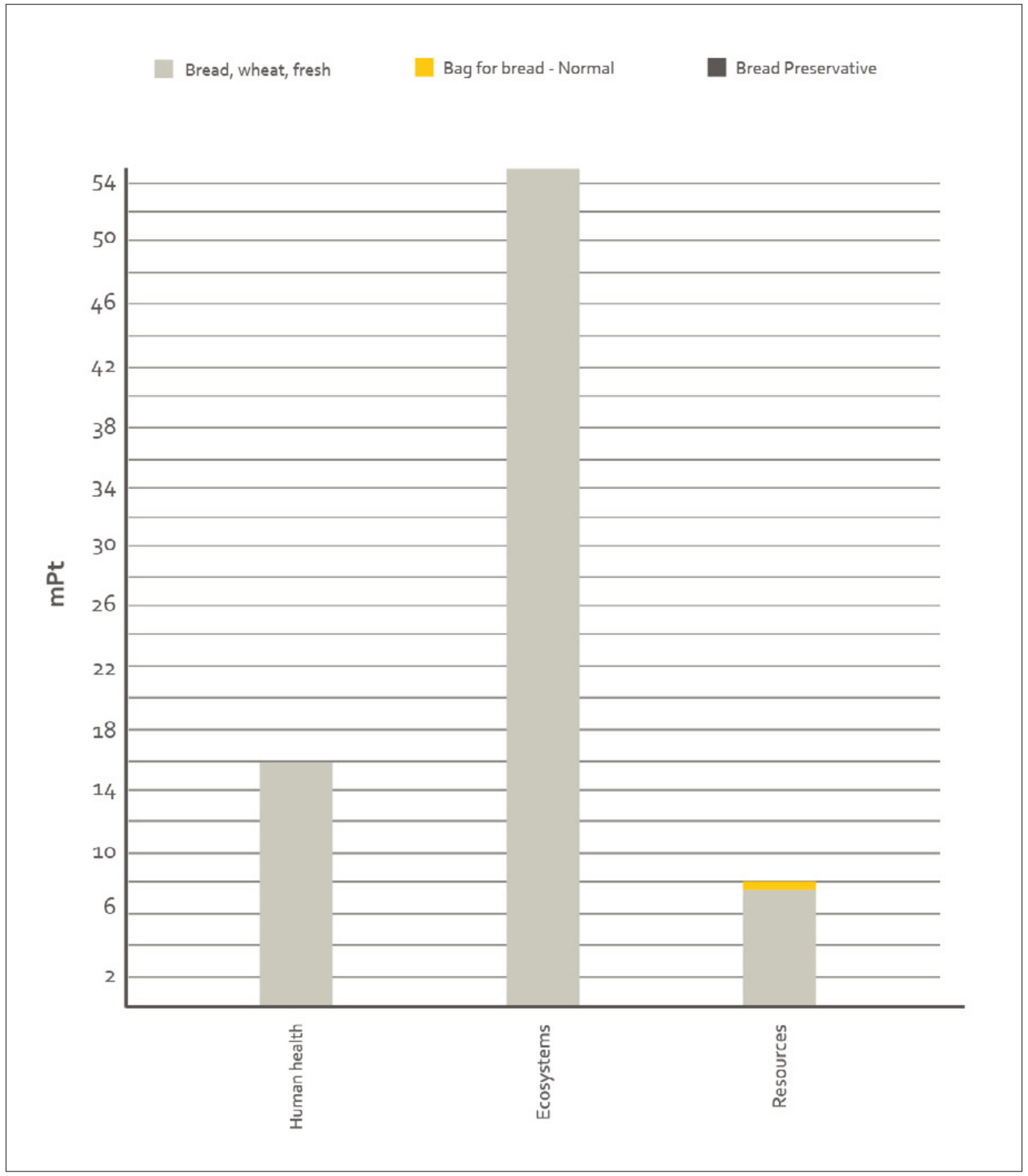


Figure 18. Weighting of bread packaging – end-point - process contribution – no active component

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

WEIGTHING – END-POINT – PROCESS CONTRIBUTION – SINGLE SCORE RESULTS

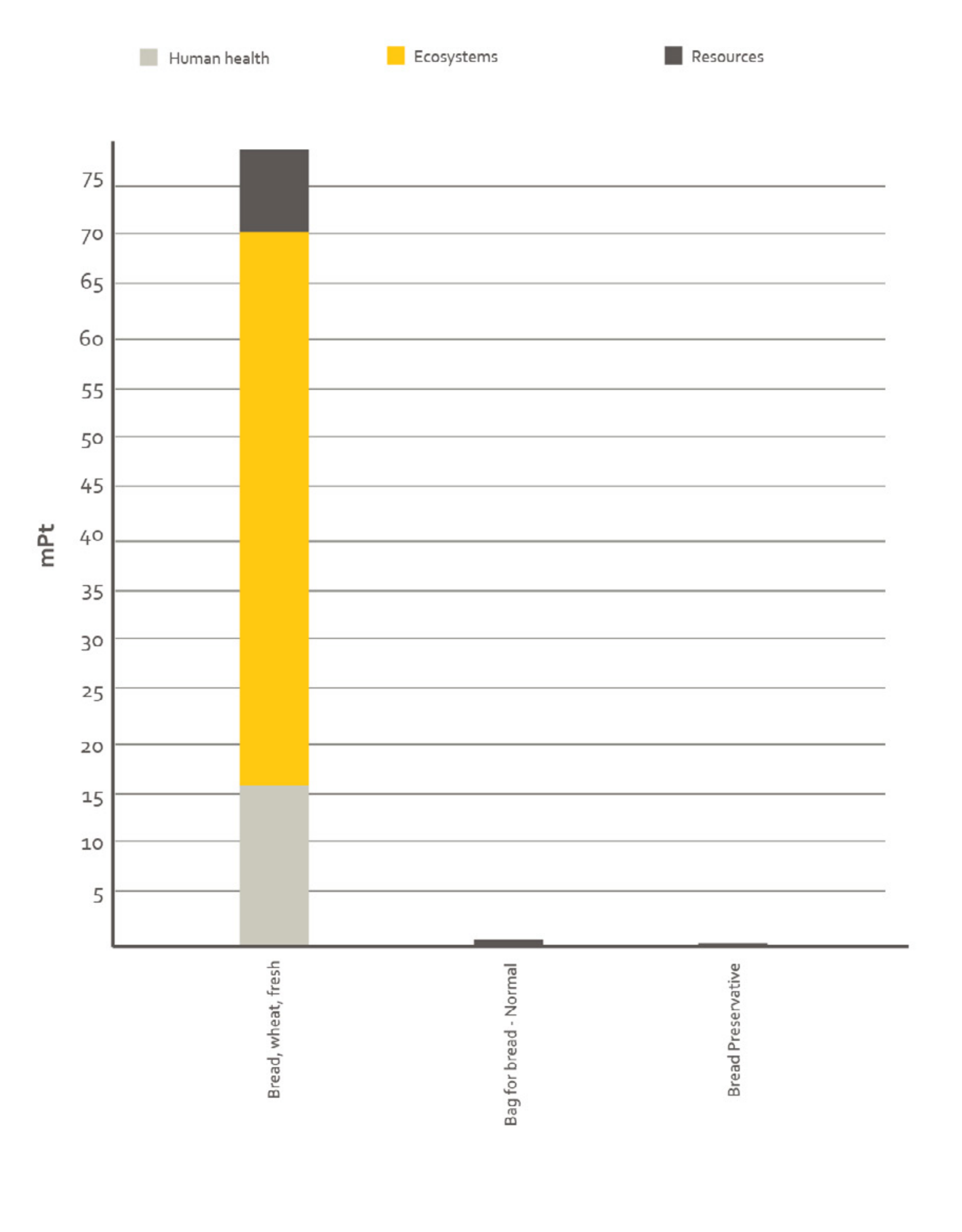


Figure 19. Single score of bread packaging – no active component

RESULTS

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

PROCESS TREE WITH SINGLE SCORE RECORDS

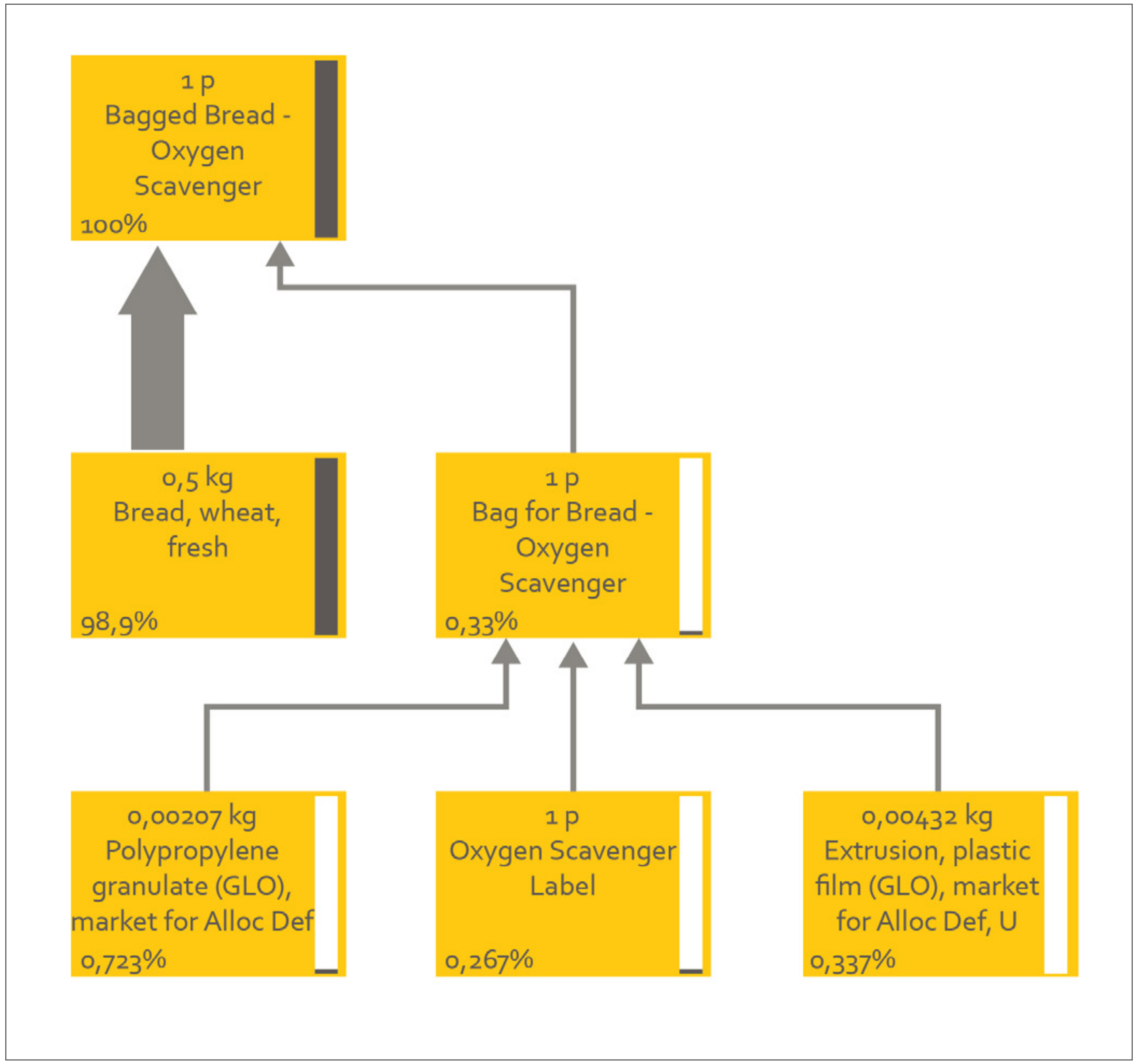


Figure 20. Process tree for bread packaging – active component

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

DAMAGE ASSESSMENT – PROCESS CONTRIBUTION

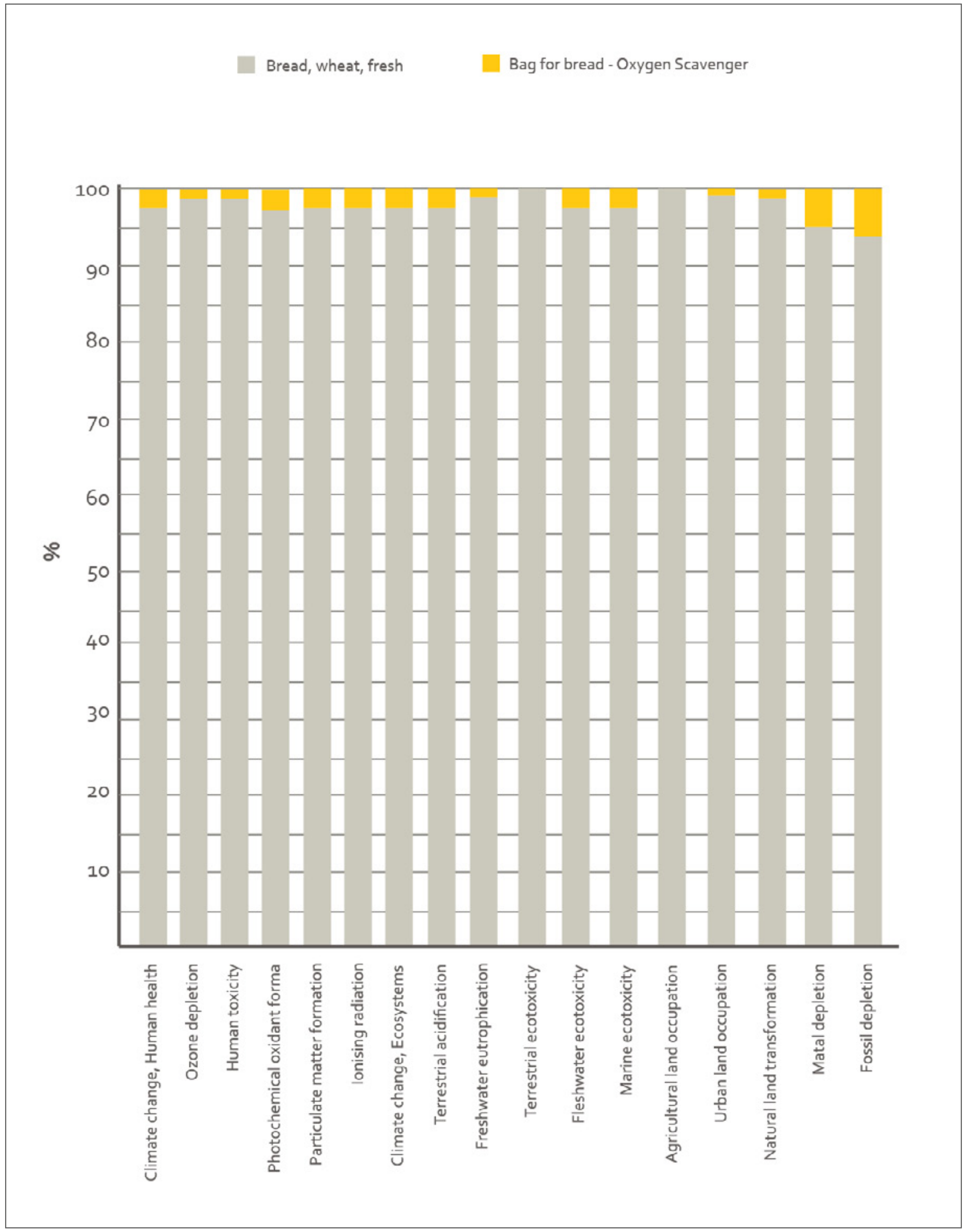


Figure 21. Damage assessment of bread packaging – process contribution – active component

RESULTS

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

WEIGHTING – PROCESS CONTRIBUTION

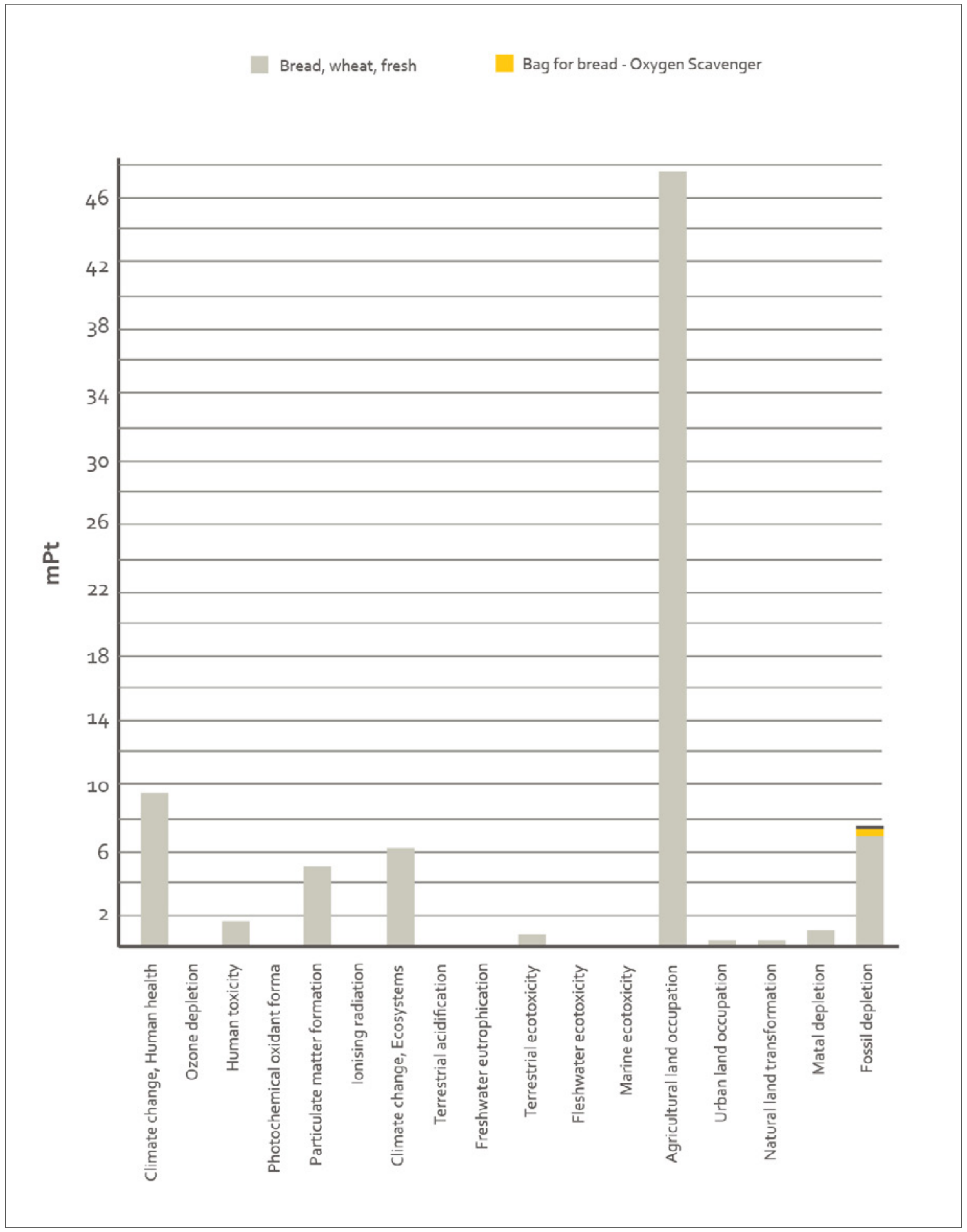


Figure 22. Weighting of bread packaging – process contribution – active component

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

WEIGTHING – END-POINT – PROCESS CONTRIBUTION

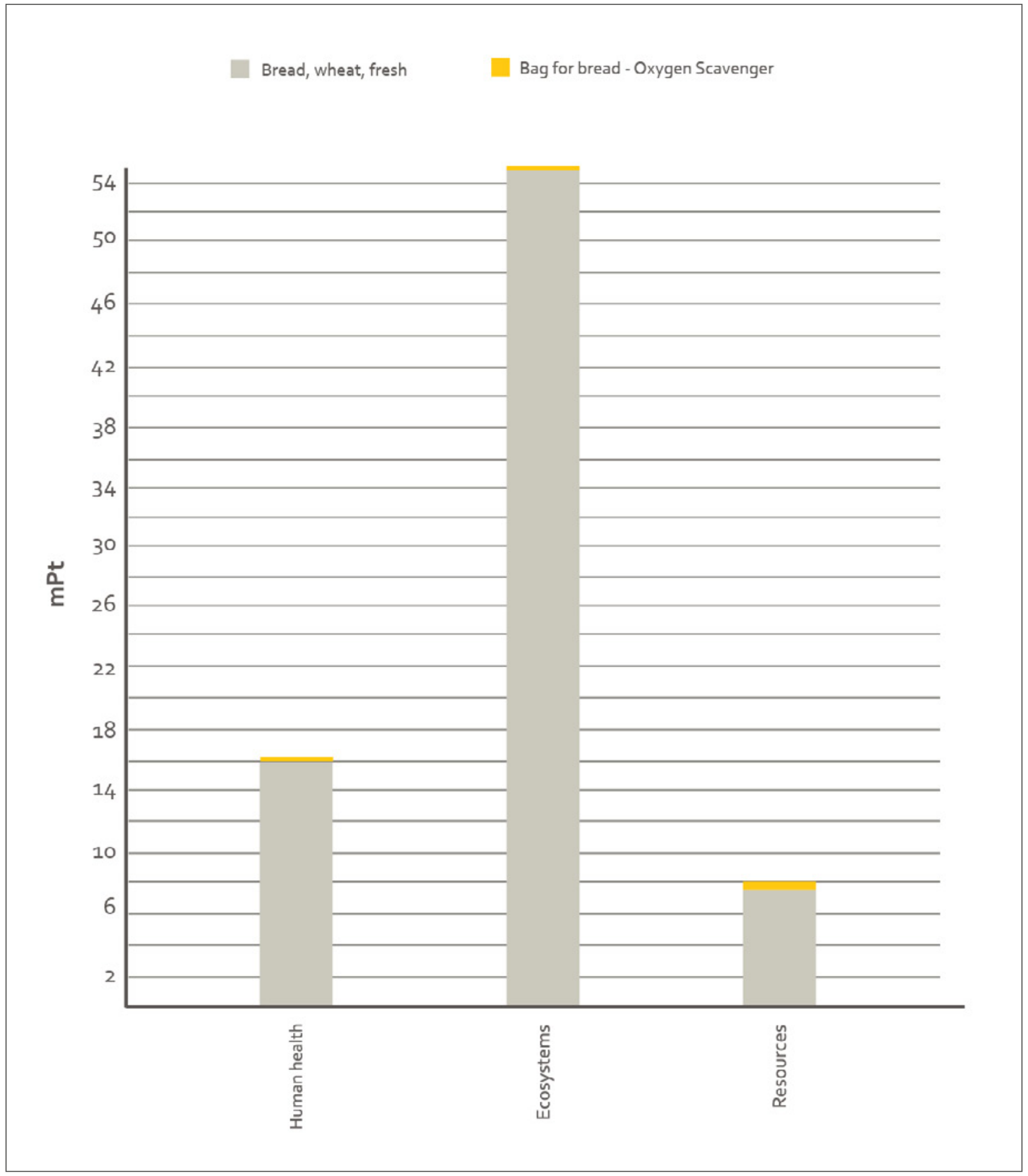


Figure 23. Weighting of bread packaging – end-point - process contribution – active component

RESULTS

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

WEIGTHING – END-POINT – PROCESS CONTRIBUTION – SINGLE SCORE RESULTS

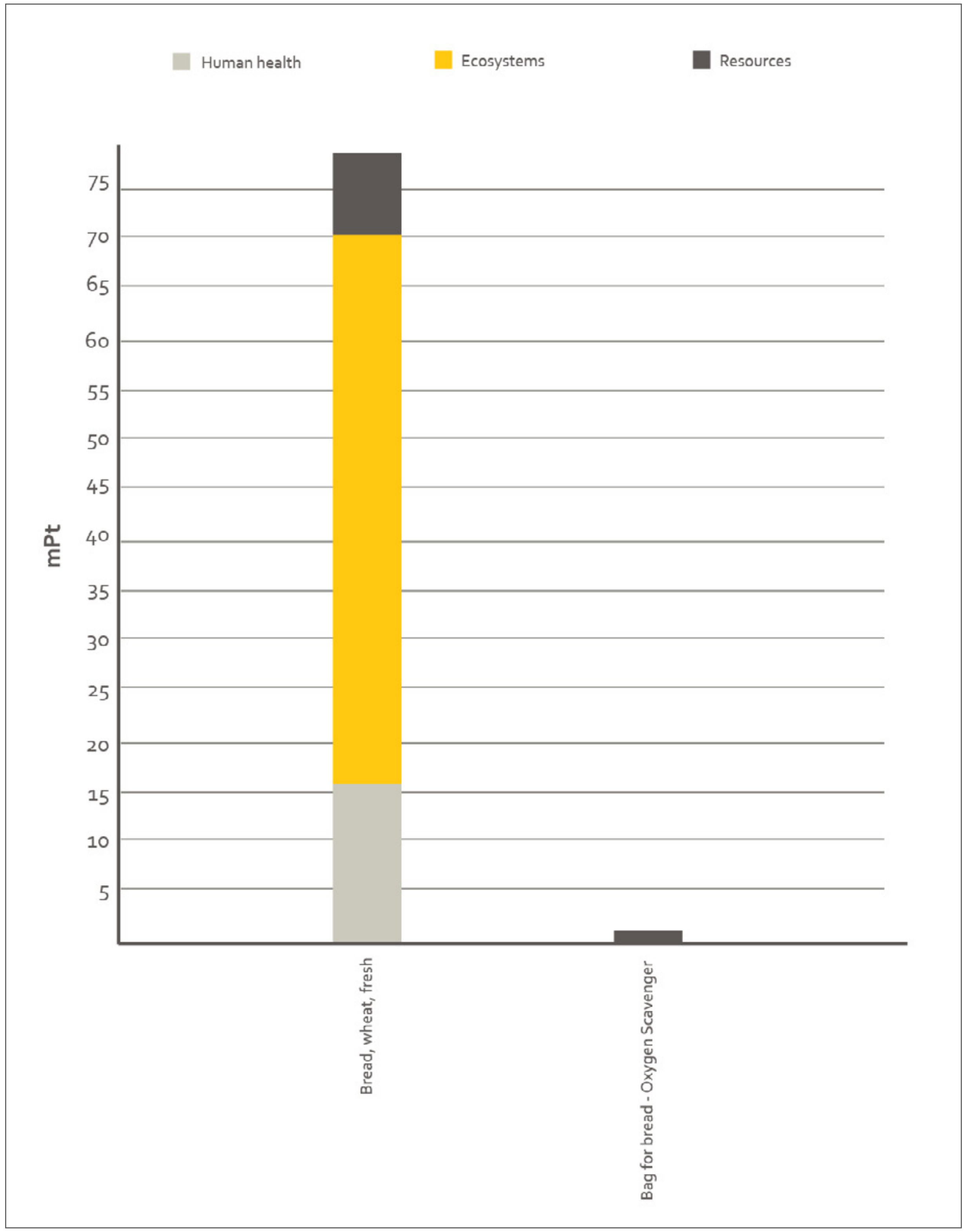


Figure 24. Single score of bread packaging – active component

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

COMPARISON OF SCENARIOS – DAMAGE ASSESSMENT

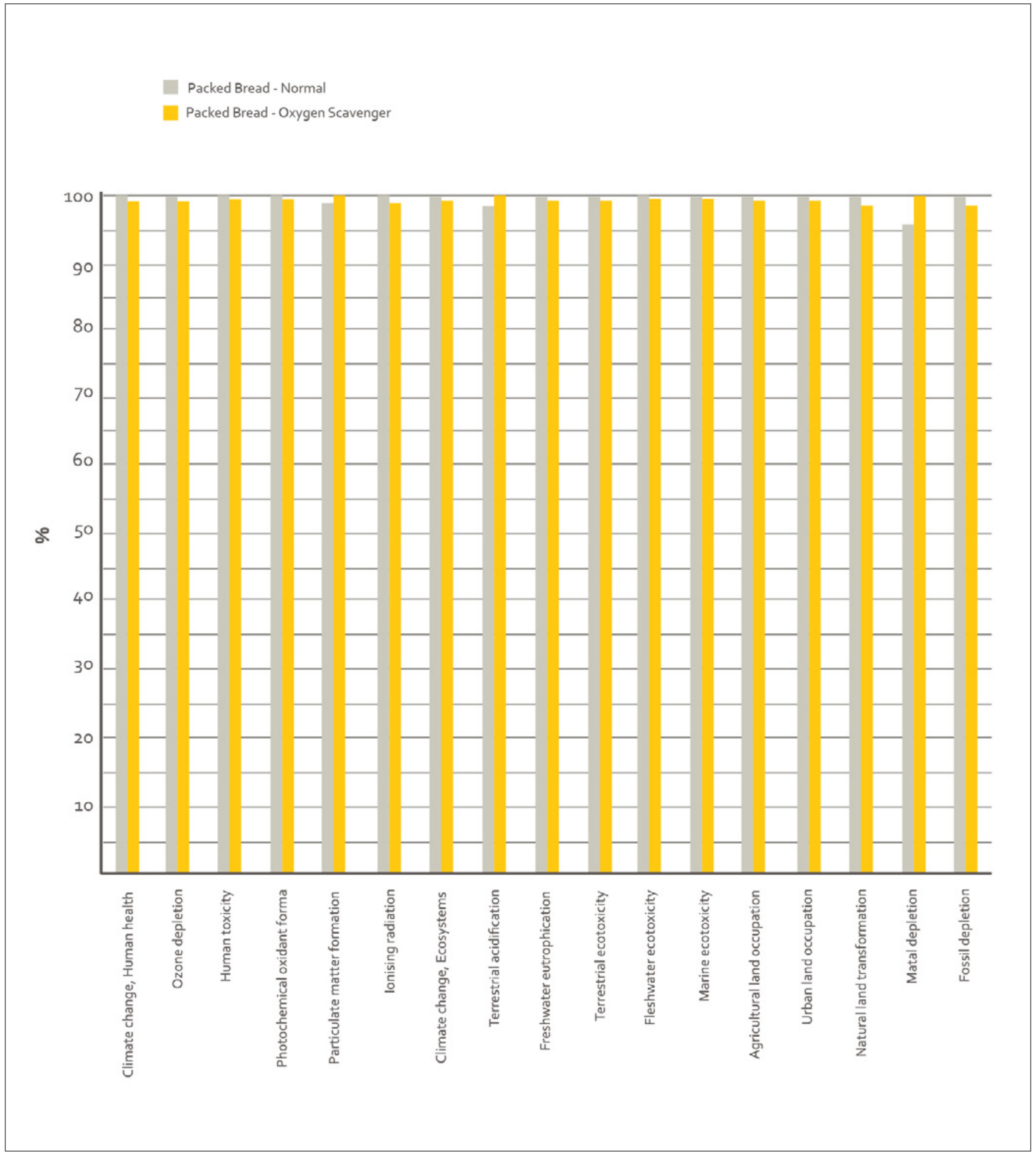


Figure 25. Comparison of bread packaging scenarios – damage assessment

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

COMPARISON OF SCENARIOS – DAMAGE ASSESSMENT – END-POINT

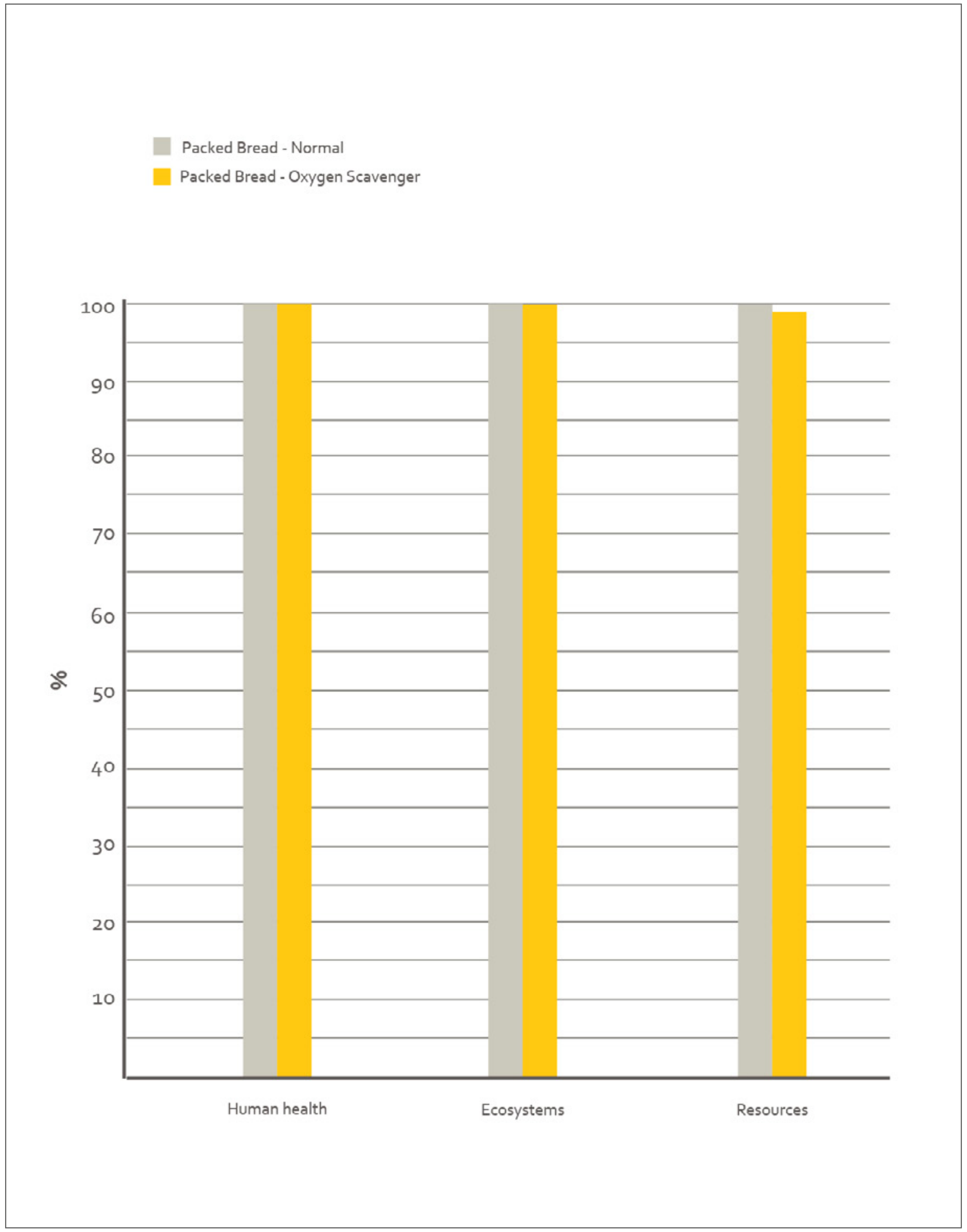


Figure 26. Comparison of bread packaging scenarios – end-point – damage assessment

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

COMPARISON OF SCENARIOS – WEIGTHING

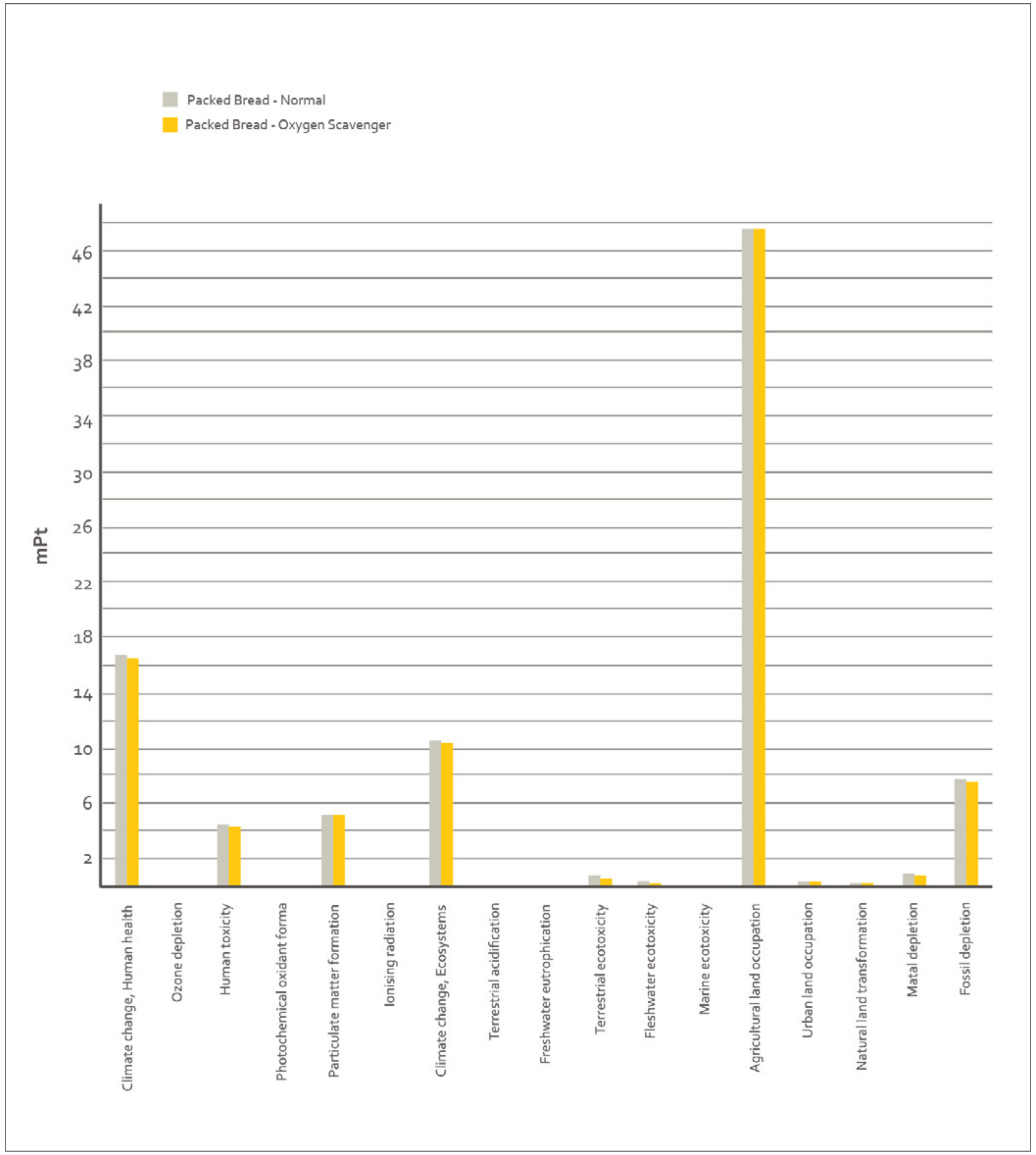


Figure 27. Comparison of bread packaging scenarios – weighting

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

COMPARISON OF SCENARIOS – WEIGTHING – END-POINT

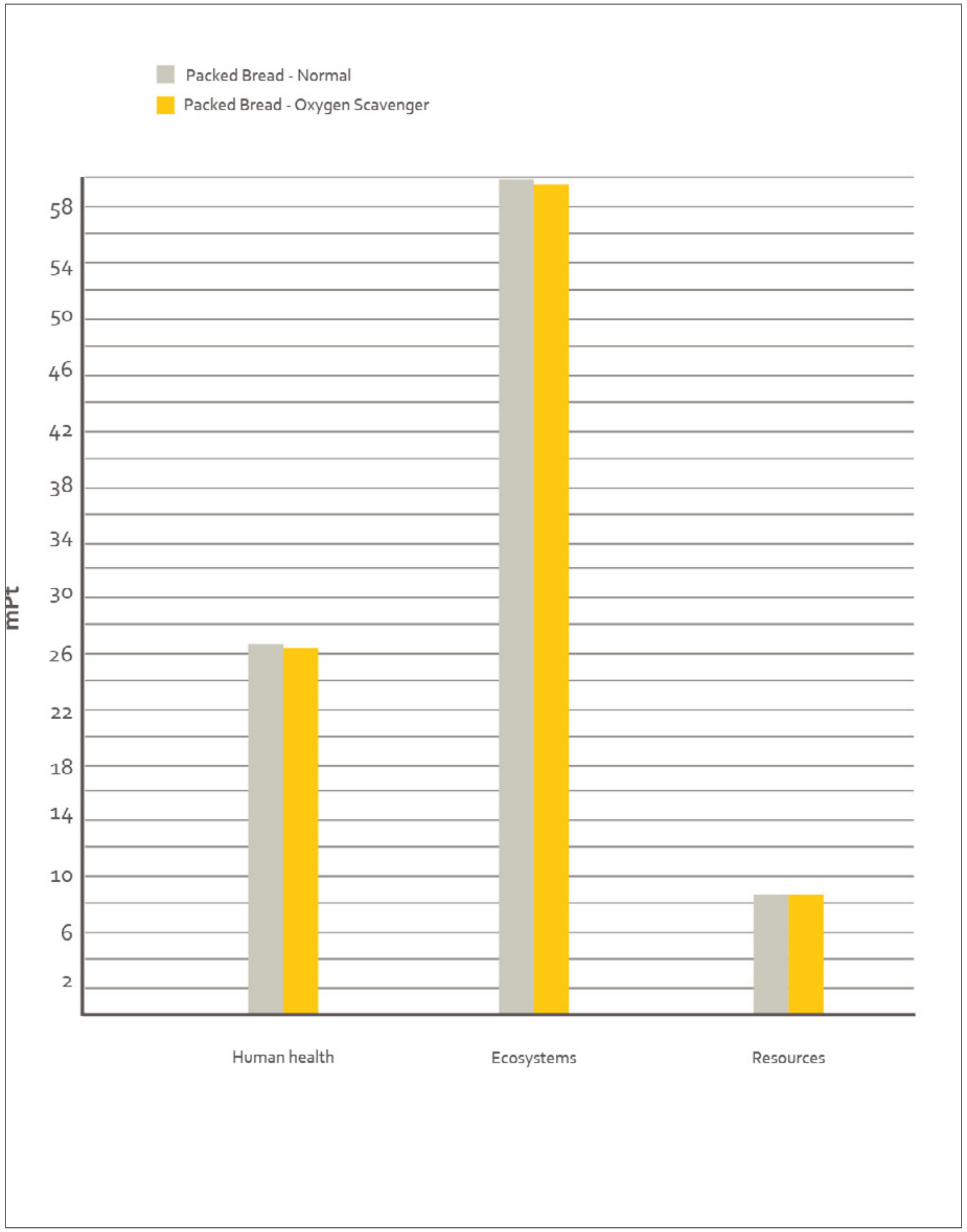


Figure 28. Comparison of bread packaging scenarios – end-point - weighting

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

COMPARISON OF SCENARIOS – SINGLE SCORE

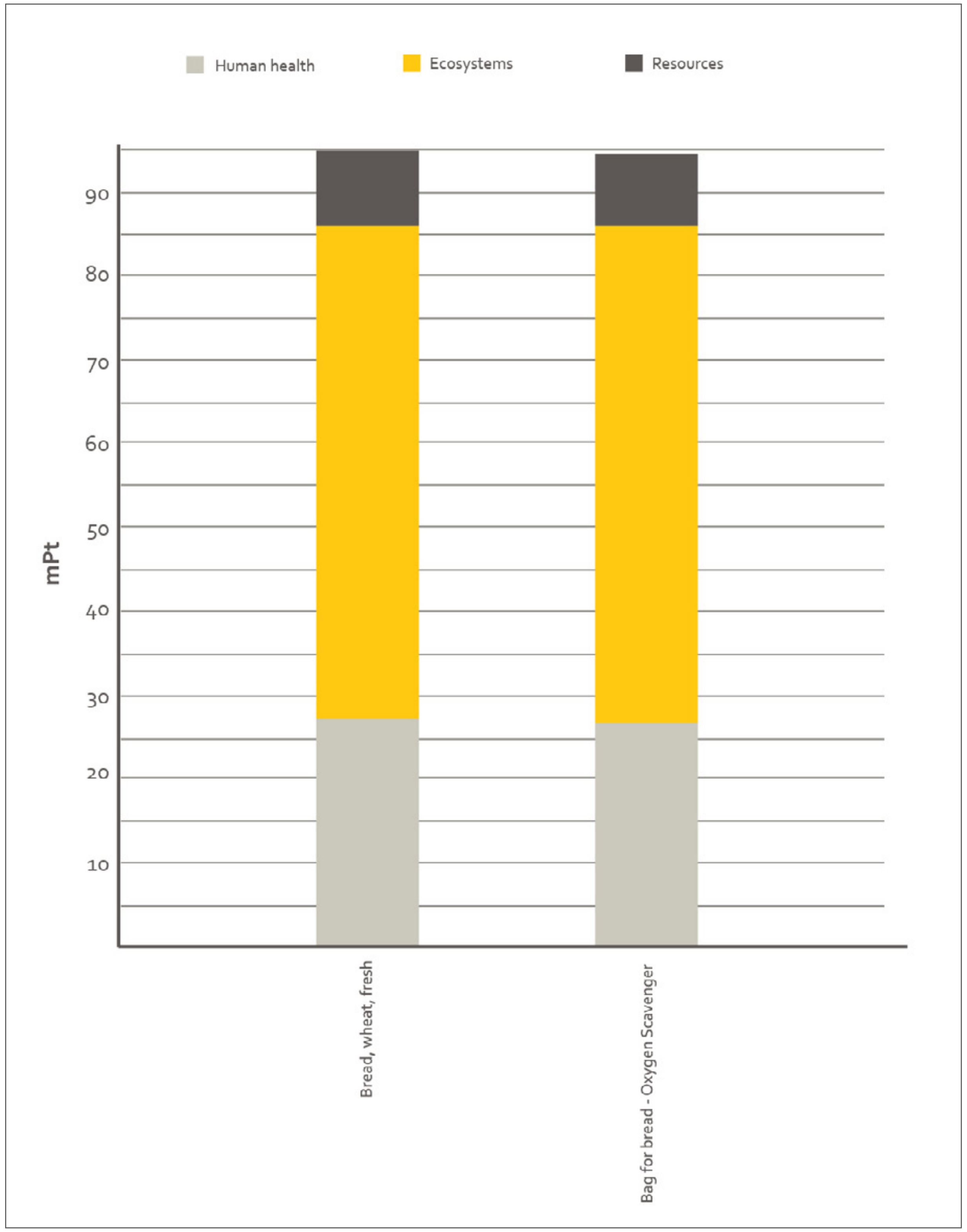


Figure 29. Comparison of bread packaging scenarios – single score results

DEMONSTRATOR 2 - ACTIVE PACKAGING FOR BREAD

Following observations can be made for demonstrator 2 – packed bread active packaging:

- Bread production processes amount to 99% of all environmental impacts. This is due to the mass share of very light plastic bag to 500g of bread.
- Bread preservatives only amounts to 0,33% of all bread environmental impact. However, certain processes of adding bread preservatives were missing from the study
- Major environmental impacts for bread production are climate change, particulate matter formation, agricultural land occupation and fossil depletion
- Impact of bread packaging is negligible
- Oxygen scavenger (active component) amounts to 0,267% of all bread environmental impacts and therefore offsets the impact of preservatives.
- Due to these assumptions, the results of both bread types are identical
- A future study of shelf life extension of oxygen scavenger for bread is recommended

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

PROCESS TREE WITH SINGLE SCORE RECORDS

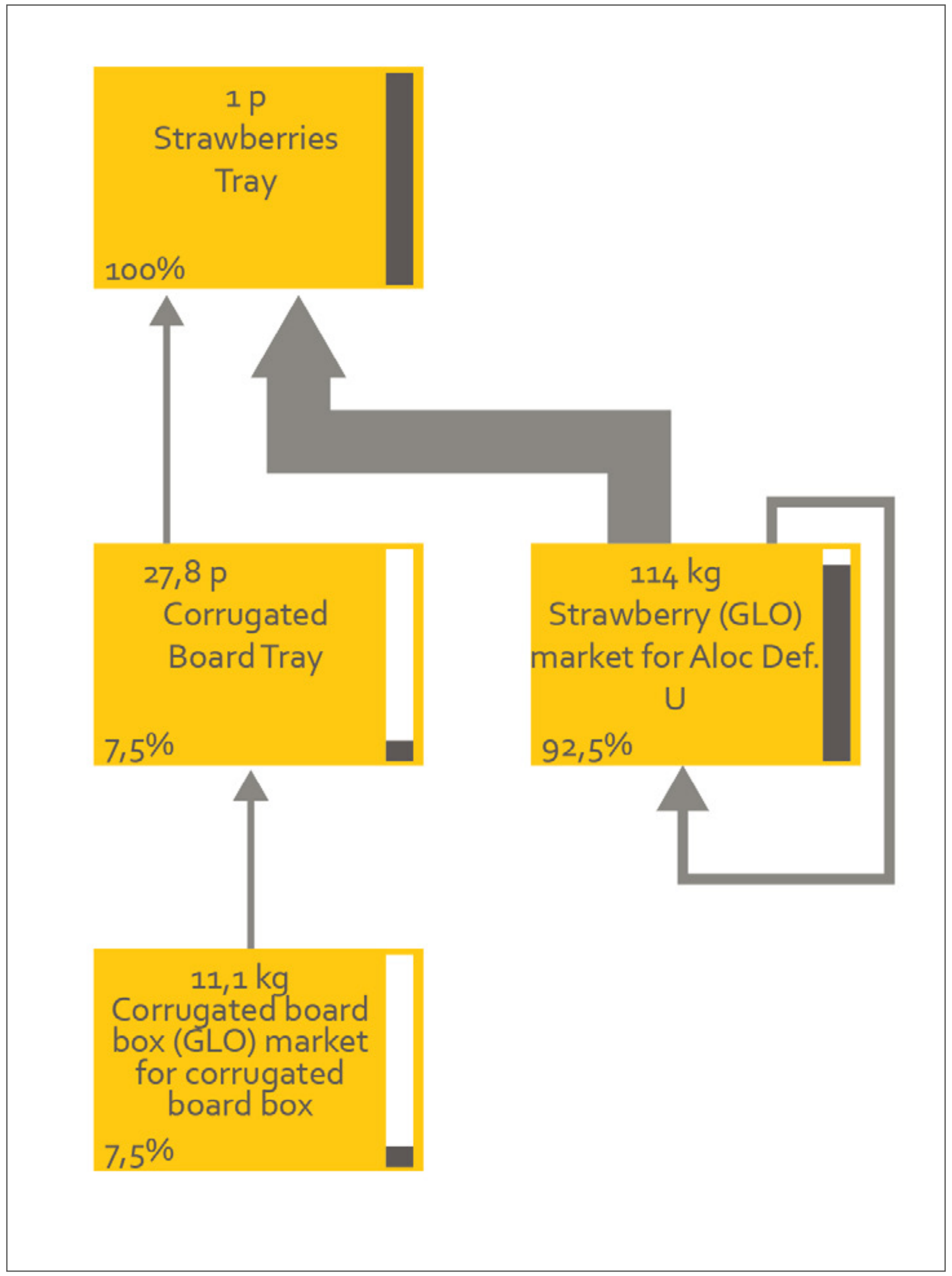


Figure 30. Process tree for strawberry packaging

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

DAMAGE ASSESSMENT – PROCESS CONTRIBUTION

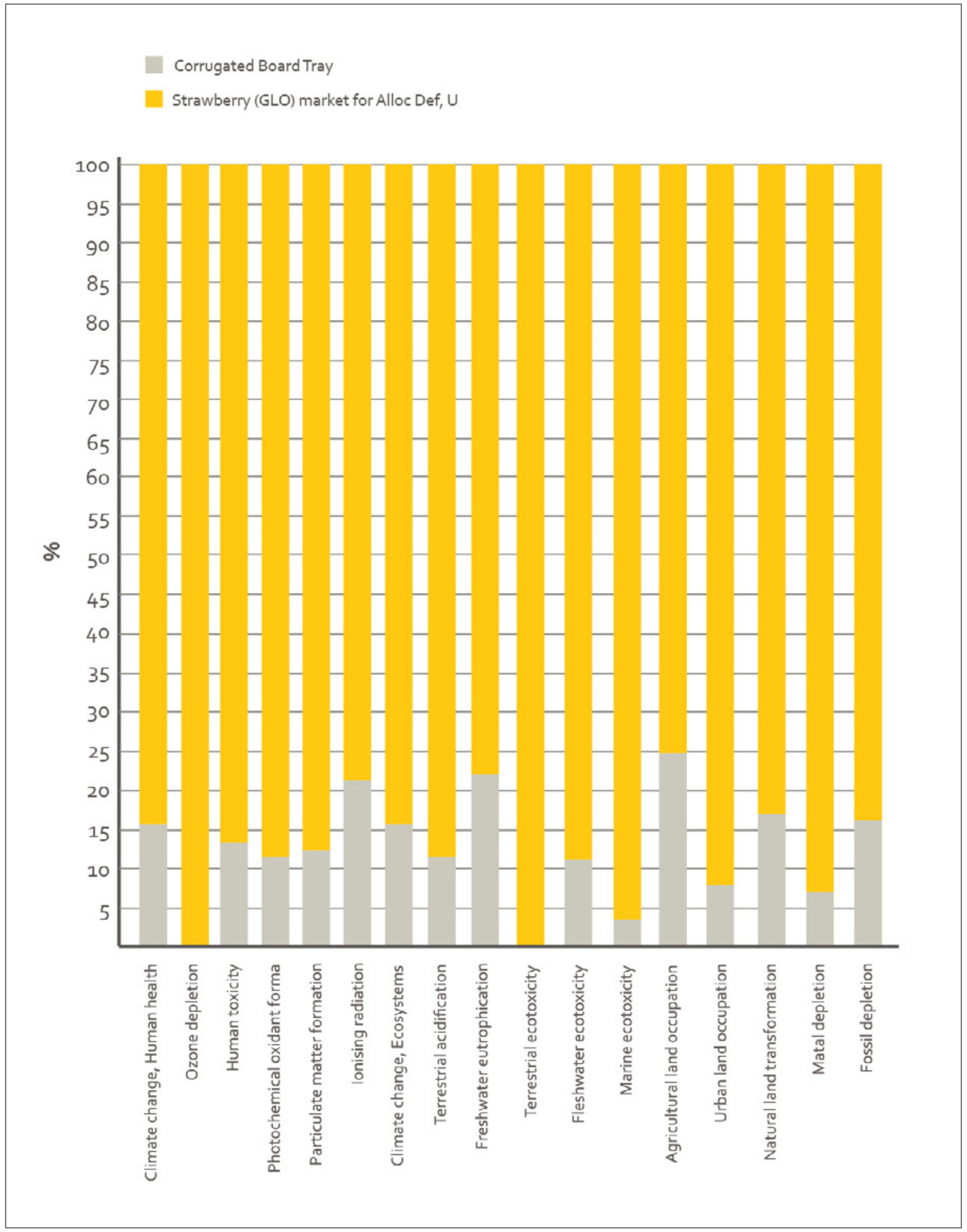


Figure 31. Damage assessment of strawberry packaging – process contribution

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

WEIGHTING – PROCESS CONTRIBUTION

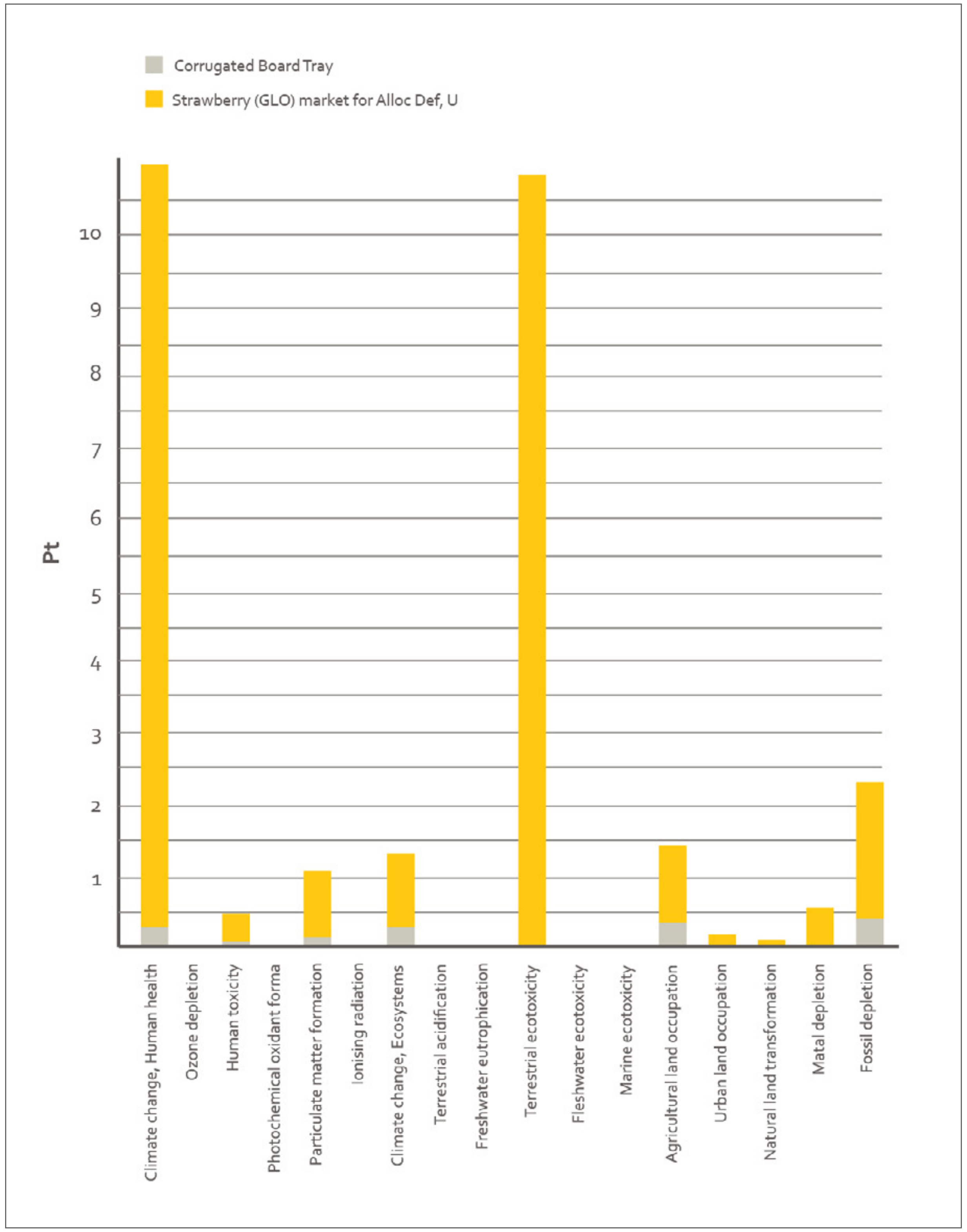


Figure 32. Weighting of strawberry packaging – process contribution

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

WEIGTHING – END-POINT – PROCESS CONTRIBUTION

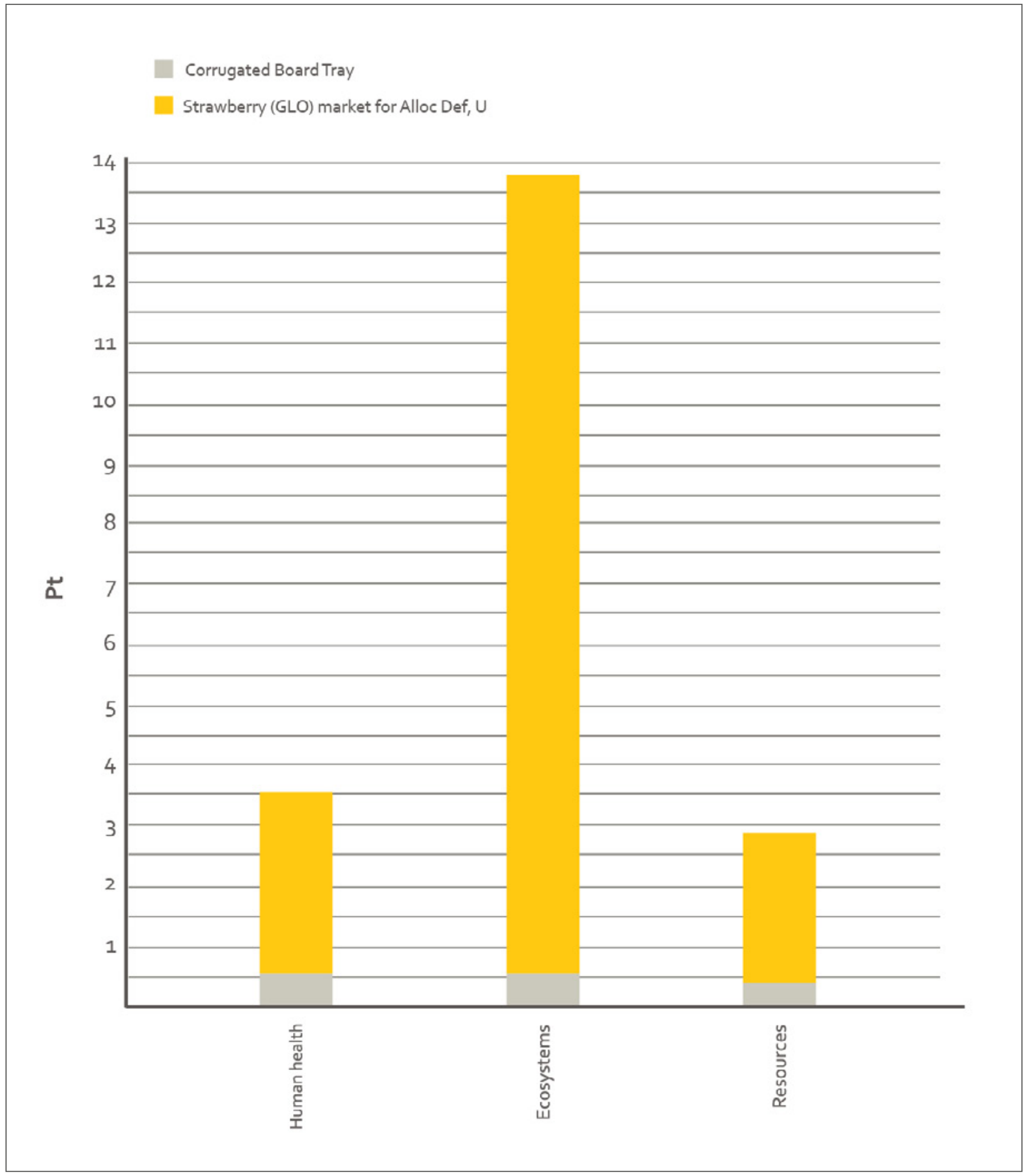


Figure 33. Weighting of strawberry packaging – end-point results

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

WEIGTHING – END-POINT – PROCESS CONTRIBUTION – SINGLE SCORE RESULTS

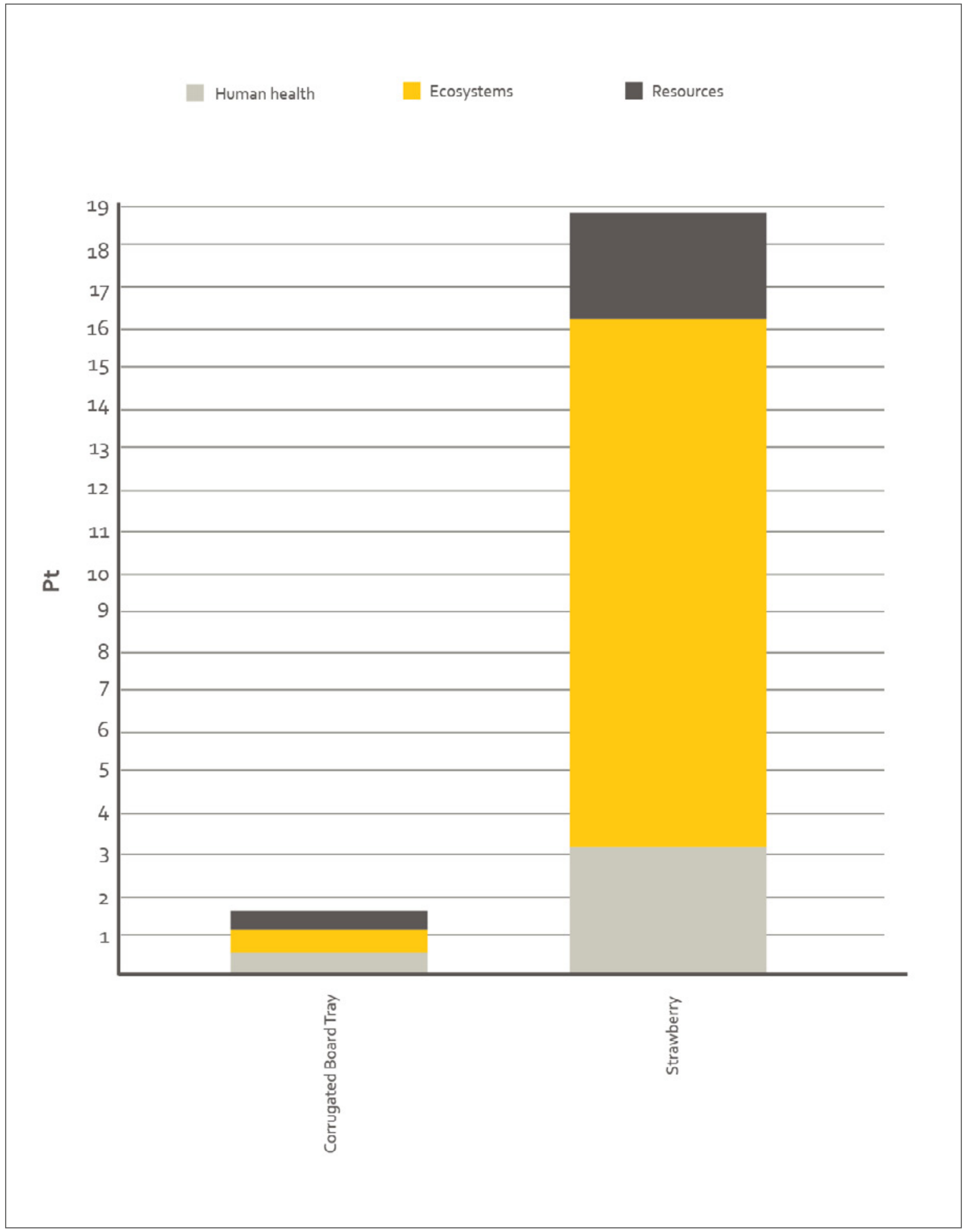


Figure 34. Single score results of strawberry packaging

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

COMPARISON OF SCENARIOS – WEIGTHING

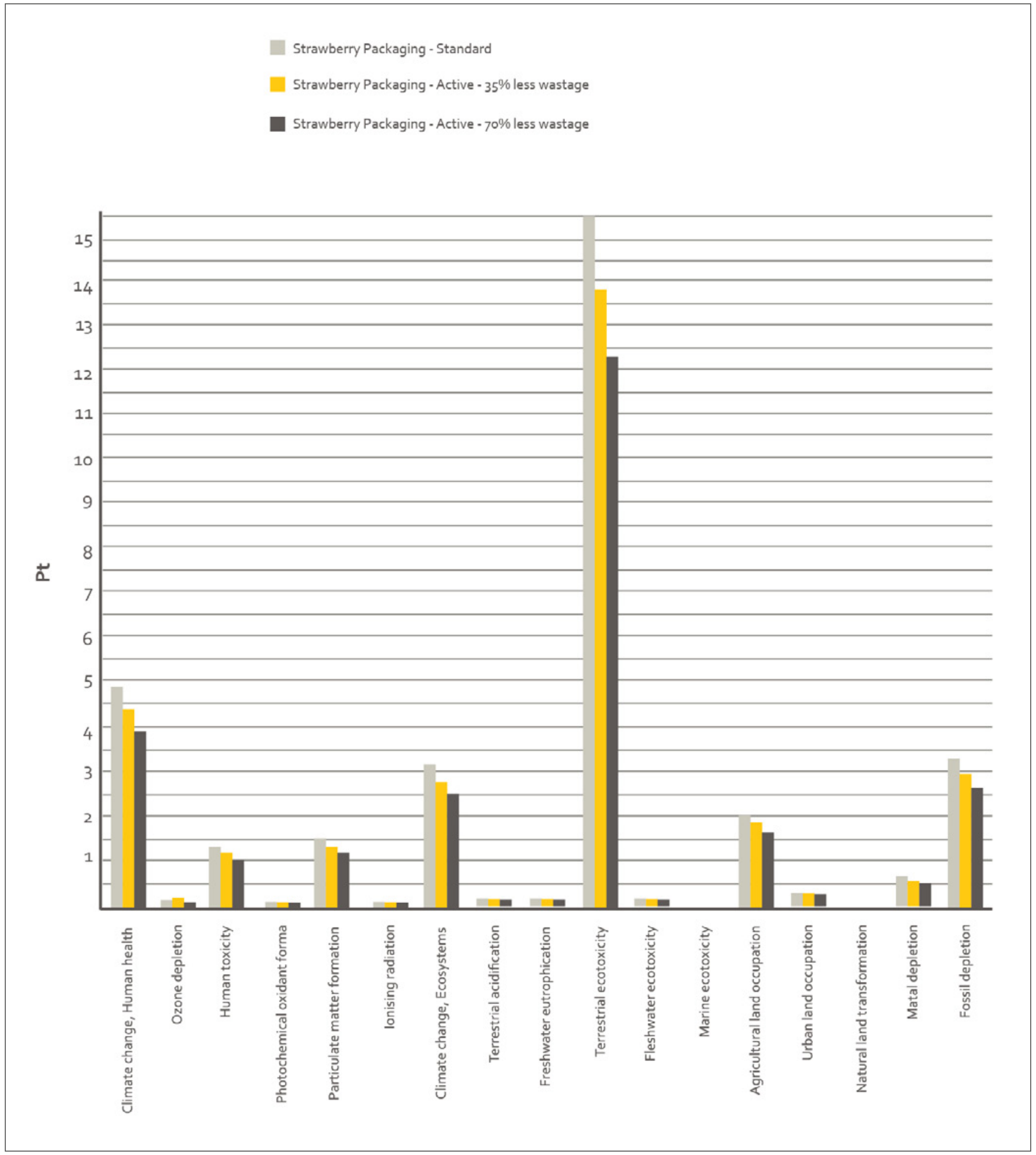


Figure 35. Comparison of strawberry packaging scenarios – weighting

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

COMPARISON OF SCENARIOS – DAMAGE ASSESSMENT – END-POINT

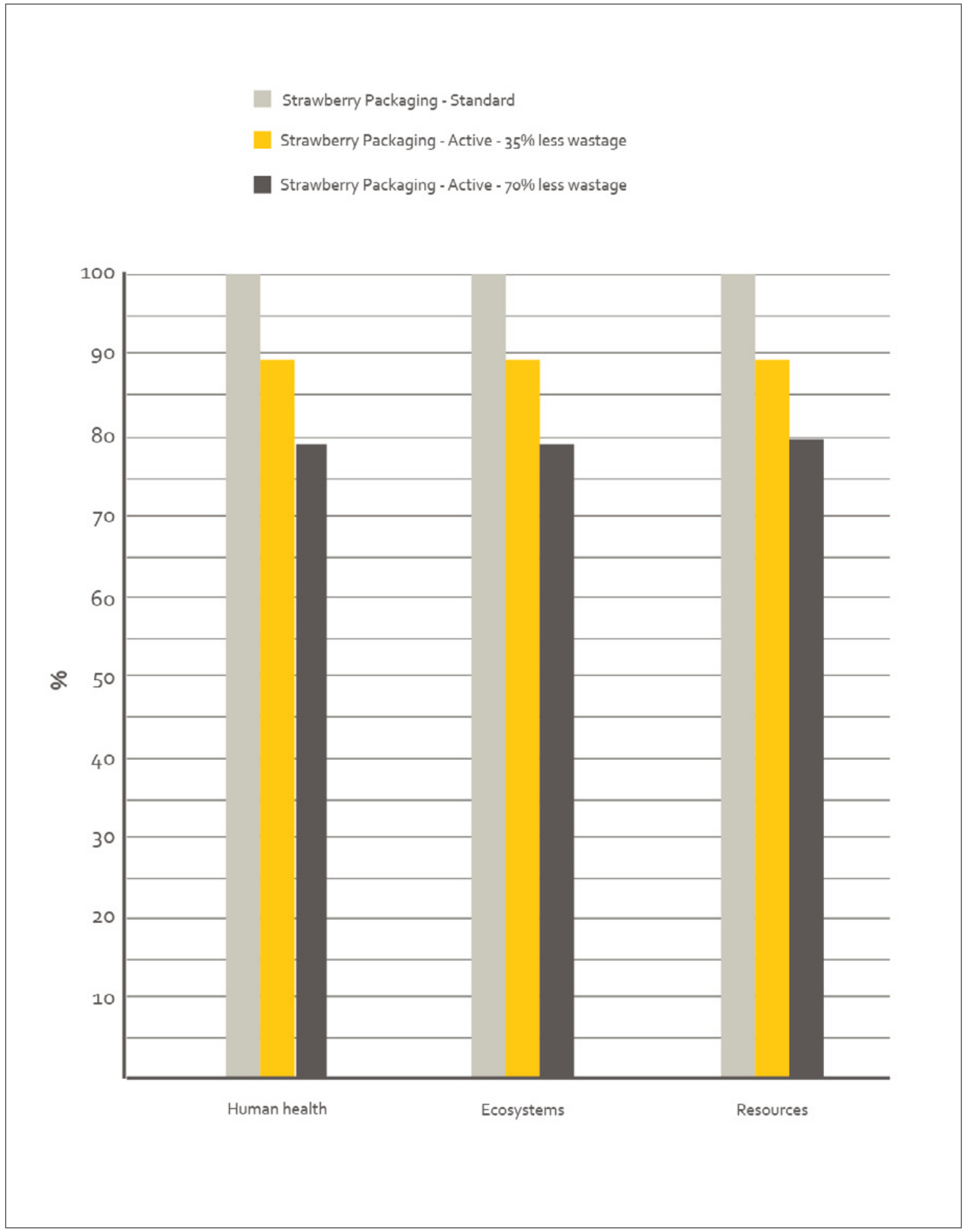


Figure 36. Comparison of strawberry packaging scenarios – end-point – damage assessment

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

COMPARISON OF SCENARIOS – WEIGHTING – END-POINT

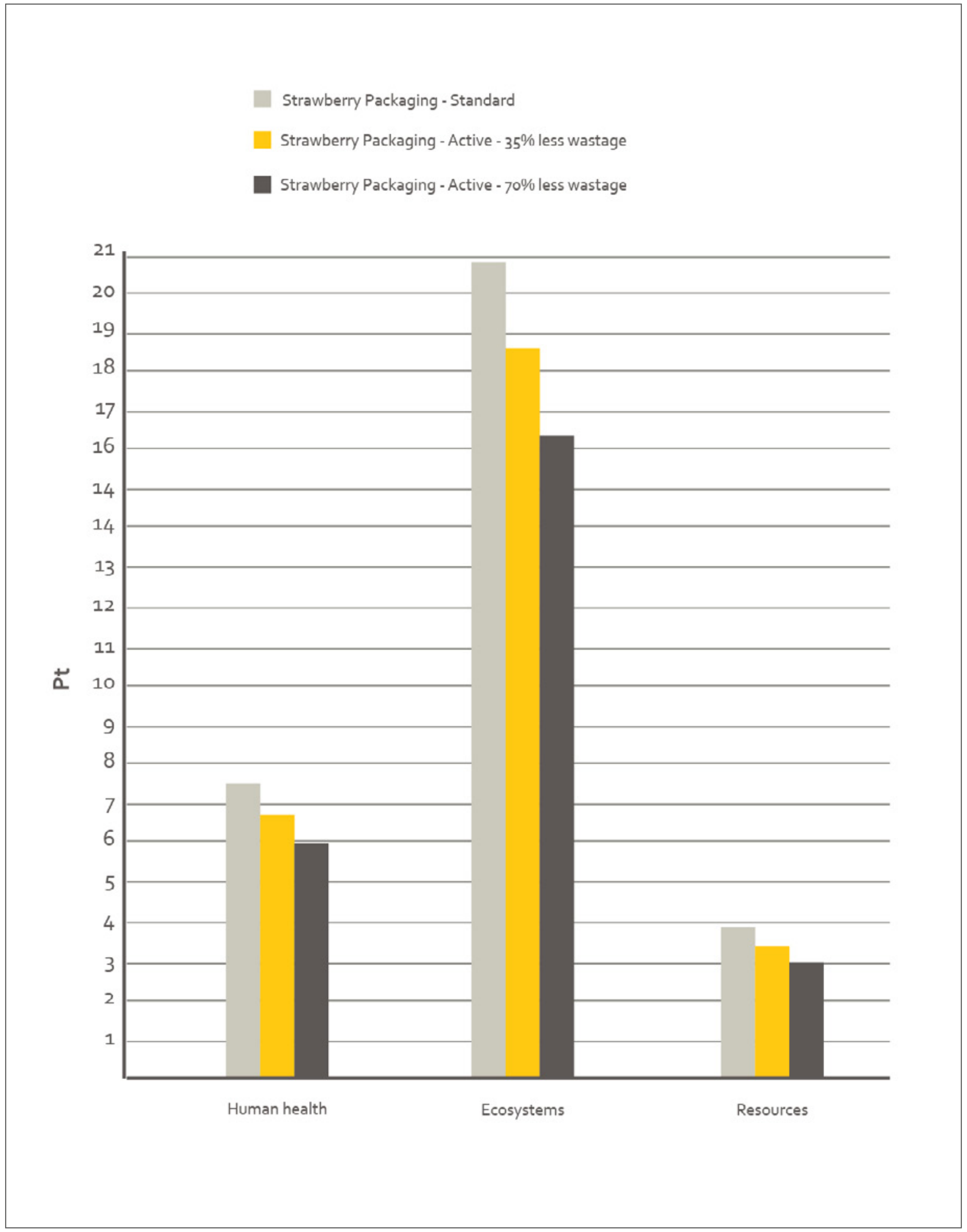


Figure 37. Comparison of strawberry packaging scenarios – end-point – weighting

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

COMPARISON OF SCENARIOS – SINGLE SCORE

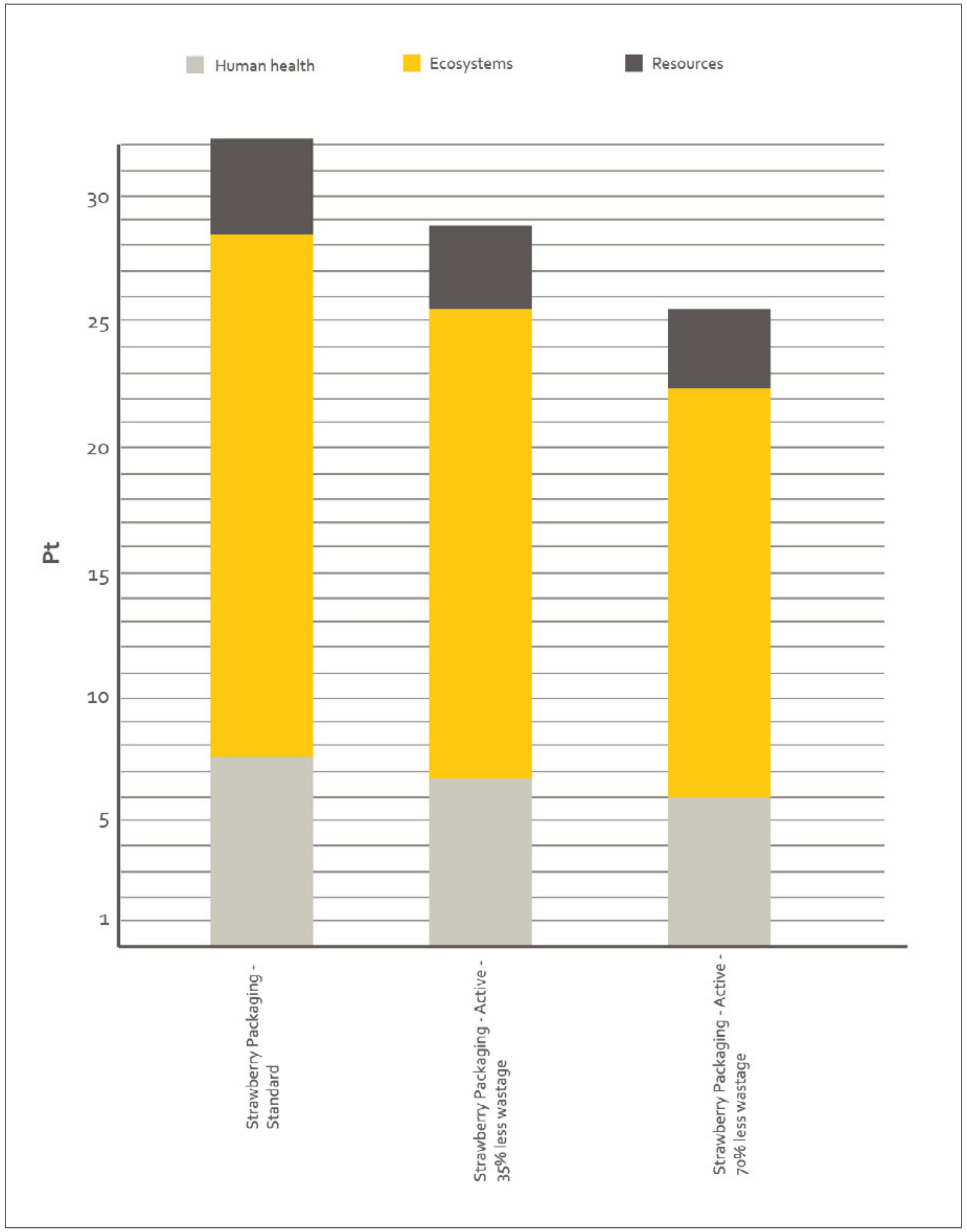


Figure 38. Comparison of strawberry packaging scenarios – single score

DEMONSTRATOR 3 - ACTIVE PACKAGING FOR FRUIT

Following observations can be made for demonstrator 3 – fruits/vegetables active packaging:

- Strawberry production amounts to 92,5% of all environmental loads
- Corrugated board production amounts to 7,5% of environmental impacts.
- Main environmental impact categories for strawberries are – climate change, terrestrial ecotoxicity, agricultural land occupation and fossil depletion.
- Usage of active component in strawberries tray has an environmental benefit for all impact categories.
- Having 35% lower wastage of strawberries equals to about 10% lower environmental loads in all impact and damage categories
- Having 70% less wastage amounts to more than 20% lower environmental impacts in all categories

REFERENCES

[1] Żakowska H., Ganczewski G., Environmental trends in packaging. LCA and „carbon footprint" for selected types of consumer bags [w:] „CURRENT TRENDS IN COMMODITY SCIENCE. Environmenal and Market Research, Zeszyty Naukowe" nr 216/2011, red. Foltynowicz Z., Witczak J., Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, Poznań 2011, s. 79–88.

[2] Żakowska H., Systemy recyklingu odpadów opakowaniowych w aspekcie wymagań ochrony środowiska, Wydawnictwo Akademii Ekonomicznej w Poznaniu, Poznań 2008.

[3] Żakowska H., Wytyczne do wykonywania analizy cyklu życia (LCA) opakowań i ograniczenia tej metody, „Opakowanie" nr 11/2004, s. 20–23.

[4] Żakowska H., Ganczewski G., Nowakowski K., Kilanowski M., Przeprowadzenie ekologicznej oceny cyklu życia (LCA) toreb wielokrotnego użytku, Raport końcowy na zlecenie Ministerstwa Środowiska, COBRO, 2010.

[5] Goedkoop, M.J.; Heijungs, R.; Huijbregts, M.A.J.; De Schryver, A.M.; Struijs, J.; Van Zelm, R. 2009. ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation. 6 January 2009, http://www.lcia-recipe.net.

[6] Sleeswijk, A.W.; van Oers, L.F.; Guinée, J.B.; Huijbregts, M.A.J. 2007. Normalization in product life cycle assessment: An LCA of the global and European economic systems in the year 2000. Sci Total Environ 390 (1):227-240.

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