# Life Cycle Assessment

# Fenty Beauty Setting Powder

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# Part 1: Scope of Study

## 1.1. Aim of the study

The goal of the face powder LCA study would be to evaluate the product's environmental impact throughout its entire life cycle, from raw material extraction to production, distribution, use, and disposal. This would entail calculating the energy and resource consumption, emissions, and waste generated at each stage of the product's life cycle.

The study could also look for ways to reduce the environmental impact of face powder, such as changes in materials, manufacturing processes, or packaging. Finally, the goal would be to provide insights that can help inform more sustainable decisions about the production and use f face powder products.

## 1.2. Functional Unit

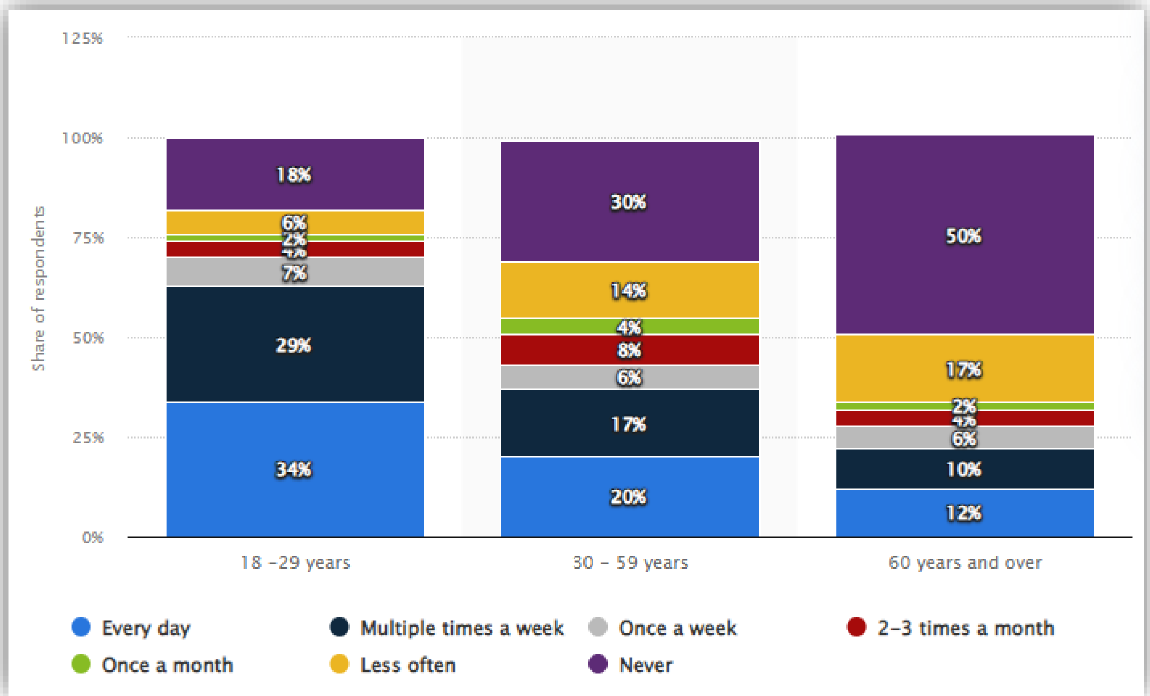


Chart 1: Illustration of the frequency of the Face Powder use by the product user according to age group

It can be seen that the 18–29-year-old age group uses the product more frequently while 60 years and over use it less frequently.

## 1.3. System Boundaries

### 1.3.1. Raw Materials Sourcing

Raw materials for the production of face powder have been sourced from a European company. The table given below provides information about used raw materials.

Table 1. Raw materials quantities

| **Raw Materials** | **Quantity** | **over 1kg** |
| --- | --- | --- |
| Benzyl alcohol {RER}\| production \| Alloc Def, S | 0,000375 | kg |
| Zinc oxide {GLO}\| market for \| Alloc Def, U | 0,02 | kg |
| Kaolin {GLO}\| market for \| Alloc Def, U | 0,82 | kg |
| Glycerine {US}\| esterification of soybean oil \| Alloc Def, U | 0,05 | kg |
| Rape seed oil, wholesale | 0,05 | kg |
| Maize starch {GLO}\| market for \| Alloc Def, U | 0,05625 | kg |

### 1.3.2. Manufacturing process

The manufacturing of face powder involves the following processes:

- Weighing and Mixing:

The raw materials have been accurately weighed down according to the desired formulation and these have been placed into a mixing vessel.

- Esterification of Soybean Oil to produce glycerin:

The esterification process has been performed on soybean oil to modify its properties. It involves reacting the soybean oil with an alcohol, resulting in esters.

- Blending:

It is begun by blending the dry ingredients (Zinc oxide, Kaolin, and maize starch) to ensure uniform distribution of powders. The esterified soybean oil, rape seed oil, and glycerin have been added slowly to the dry mixture while continuing to blend.

- Homogenization:

The mixture has been passed through a homogenizer to achieve a smoother and more uniform texture. This step helps in breaking down particle sizes and ensuring a consistent product.

- Drying:

The homogenized mixture has been spread on trays to remove any remaining moisture.

- Milling:

The dried mixture has been milled to achieve the desired particle size and texture. This step is crucial for the powder's smooth application and feels on the skin.

- Addition of Benzyl Alcohol:

Benzyl alcohol has been incorporated into the milled mixture. This ingredient contributes to the product's fragrance and also has antimicrobial properties.

- Final Blending:

The entire mixture has been blended again to ensure that all components are thoroughly mixed.

- Quality Control:

The quality control tests have been performed to check for colour consistency, particle size, fragrance, and other specifications.

### 1.3.3. Packaging and Distribution

The packaging of the finished face powder was done in suitable containers to ensure proper labeling and adherence to regulatory standards. The packaging for this product was made of PET bottles and 0.2 kg PET for each kg of face powder.

### 1.3.4. Product use and application

Use:

Face powder is a cosmetic product designed for application on the face to set makeup, control shine, and achieve a smooth finish. It is applied after foundation or concealer to mattify the skin, minimize pores, and enhance the overall appearance.

Application:

1-After applying foundation or concealer, use a makeup brush or puff to dust the face powder over the skin lightly.

2-Focus on areas prone to shine, such as the T-zone.

3-Blend evenly for a natural, matte finish.

4-This product can be reapplied throughout the day for oil control and a fresh look.

5-It is suitable for all skin types, enhances makeup longevity and provides a polished appearance.

### 1.3.5. End-of-life considerations

For our product, the following aspects have been taken into account for its end-life considerations:

- Environmental Disposal

Dispose of the face powder packaging responsibly by separating any recyclable components. Follow local recycling guidelines for plastic containers, and consider eco-friendly disposal options for non-recyclable elements.

- Considered cotton as a face powder remover

For each 1 kg of face powder in the end-of-life considerations of the Life Cycle Assessment (LCA), 0.4 kg of cotton will be taken into account. The cotton is used to remove face powder from the skin.

- Container Recycling Reminder

Recycle the face powder container after use. Remove any remaining product, and recycle the container according to local recycling regulations. Help us contribute to a sustainable beauty routine.

### 1.3.6. Regulatory Standards

This face powder complies with EU cosmetic regulations (Regulation (EC) No 1223/2009). It undergoes safety assessments, follows Good Manufacturing Practices (GMP), adheres to ingredient restrictions, and meets labeling and notification requirements through the Cosmetic Products Notification Portal (CPNP). The product is produced consistently, with batch testing and post-market surveillance ensuring its safety and quality.

### 1.3.7. Supply chain

The whole supply chain of the product involves raw materials sourcing, manufacturing, packaging, and then transportation to distribution centers for delivery to different retailers. The retail outlets include beauty stores, department stores, pharmacies, and online platforms. This product would be stocked and displayed for consumers to purchase based on their preferences, and needs. Consumers use the face powder according to the provided instructions. The product is applied to the face as a cosmetic for consumer's regular beauty routine.

### 1.3.8. Consumer health and safety

- Ingredient List:

Our face powder is crafted with care using the following ingredients, Zinc oxide, Kaolin, Glycerine, Esterification of soybean oil, Rape seed oil, Wholesale maize starch, Benzyl alcohol.

- Allergen Information:

This product is free from common allergens such as nuts, gluten, and soy. However, individuals with specific allergies should review the ingredient list before use.

- Usage Instructions:

Apply a small amount of powder using a makeup brush or sponge after your foundation routine. Focus on areas prone to shine, and blend for a flawless matte finish.

- Skin Patch Test:

Before applying the product to your face, we recommend conducting a patch test. Apply a small amount to a discreet area and observe for any adverse reactions over 24 hours.

- Avoid Eye Contact:

Avoid contact with eyes. In case of eye contact, rinse thoroughly with water. If irritation persists, seek medical attention.

- Storage and Shelf Life:

Store in a cool, dry place away from direct sunlight. Close the container tightly after use. This product has a shelf life of 24 months after opening.

- Discontinue Use if Irritation Occurs:

If irritation or redness occurs, discontinue use and consult a dermatologist. Some individuals may be sensitive to certain cosmetic ingredients.

## 1.4. Assumptions

### 1.4.1. Raw materials availability and stability

Raw materials for setting powder have been sourced from reliable suppliers with a stable supply network. The regular quality control checks ensured the stability, purity, and good quality of used raw materials.

Table 3: Ingredients and corresponding percentages

| **Literature Ingredients** | **%** |
|---|---|
| Talc | 77 |
| Zn-stearate | 5 |
| ZnO | 2 |
| Kaolin | 5 |
| Mica | 10 |
| Red Iron Oxide | 0,36 |
| Yellow Iron Oxide | 0,36 |
| Black Iron Oxide | 0,03 |
| Perfume | 0,25 |

Table 4: Actual Ingredients and percentages used for the LCA

| Actual Ingredients used | % |
|---|---|
| Kaolin | 82 |
| ZnO | 2 |
| Glycerin | 0.5 |
| Preservative (benzyl alcohol) | 0.0375 |
| Maize Starch | 5.625 |
| Rape Seed Oil | 5 |

By looking at Table 3 and 4, it is evident that the Talc was replaced by the Kaolin Clay. The Kaolin Clay use was increased from 5% to 77%. The Zn-stearate and Mica were completely disregarded as part of the ingredients. Furthermore, the Red, Yellow and Black Iron Oxide were substituted by the Maize Starch. Glycerin was added partly as the perfume and emollient, and also Rape Seed Oil was added as a perfume. 0.0375% of Benzyl Alcohol was added as a preservative.

In addition, it is assumed that for packaging 0.2kg of PET is used for 1 kg of face powder. In order to remove the face powder, the product user must utilize cotton wool, and it is assumed that 0.4kg of cotton is used for every 1 kg of face powder.

Overall Assurance:

Ethical Sourcing: All raw materials are ethically sourced, promoting fair trade practices and sustainable production methods.

Continuous Monitoring: Ongoing monitoring and collaboration with suppliers ensure timely adjustments to market fluctuations or unforeseen challenges.

Regulatory Compliance: Adherence to regulatory standards for each raw material guarantees safety, quality, and compliance with industry guidelines.

### 1.4.2. Regulatory Compliance

**EU Compliance:** Meets EU Cosmetic Regulation (EC) No 1223/2009 for safety, labelling, and notification.

**Ingredient Safety:** All ingredients, including Zinc oxide and Kaolin, comply with regulatory standards.

**GMP:** Manufactured following Good Manufacturing Practices for consistent quality.

**Allergen Disclosure:** It discloses allergens to ensure consumer safety.

**Environmental Responsibility:** Eco-friendly packaging aligns with sustainability practices.

**Continuous Monitoring:** Adapts to regulatory updates to maintain compliance.

### 1.4.3. Consumer Preferences

Consumer Preferences for Fenty Beauty Setting Powder include a flawless Matte Finish for a flawless look. Lightweight and long-lasting formula for all-day wear. Translucent options for various skin tones. Oil-absorbing properties for shine control and Blemish-blurring effect for a smooth complexion.

### 1.4.4. Health and Safety Concerns

Ethical and safe extraction practices for raw materials have been used, minimizing environmental impact. The manufacturing process adheres to strict safety protocols to protect workers and minimize workplace hazards. Consumers followed the usage instructions for the product, minimizing potential health risks. The product has eco-friendly packaging materials chosen to reduce environmental impact and ensure user safety during handling. Safe transportation practices are adapted to prevent accidents and spills during the product's journey through the supply chain. At the end of life, consumers responsibly dispose of the product and packaging according to provided guidelines, minimizing environmental and health hazards.

### 1.4.5. Packaging Durability

The selected packaging material for this product is durable and transportation has minimal impact on its durability, considering efficient logistics. It is recyclable and good shelf life, supporting eco-friendly disposal methods and remains intact during use.

### 1.4.6. Supply Chain Durability

The sourcing of raw materials follows sustainable practices, minimizing environmental impact. Packaging is designed for durability, reducing the need for frequent replacements. Manufacturing processes are energy-efficient, contributing to a lower carbon footprint and minimization of production waste through efficient manufacturing practices. Efficient transportation methods have been used to reduce greenhouse gas emissions during distribution. Packaging materials are recyclable, promoting responsible end-of-life disposal. The stable formulation and quality control checks contributed to an extended product shelf life. Awareness and guidance to consumers have been provided for responsible disposal or recycling. Adherence to environmental regulations and standards has been ensured throughout the supply chain.

### 1.4.7. Product shelf life

The product's formulation remains stable over its shelf life, preserving its quality and effectiveness. Packaging materials are durable, protecting the product from external factors, maintaining integrity, and preventing premature deterioration. Consumers store the product under recommended conditions, contributing to its stability and shelf life. Efficient transportation methods minimize environmental impact, supporting the overall sustainability of the product's life cycle. Consumers follow recommended usage guidelines, preventing unnecessary waste and ensuring the product is used within its designated period. Responsible disposal practices are adopted by consumers and waste management systems have disposed of the product appropriately.

# Part 2: Life Cycle Inventory

## 2.1. Life Cycle Stages Considered

The Life Cycle Stages Considered diagram (see appendix A1; for all raw data in this report refer to the Appendix) serves as a visual representation of the comprehensive evaluation undertaken in the Life Cycle Assessment (LCA) of Face Powder. This diagram delineates the key stages from cradle to grave, providing a clear and structured overview of the entire product life cycle. The depicted stages typically include raw material extraction, manufacturing, distribution, use, and disposal. By visually organizing these stages, stakeholders and readers can readily comprehend the holistic approach taken in assessing the environmental, social, and economic impacts associated with the production and consumption of face powder.

Each stage in the Life Cycle Stages Considered diagram represents a critical juncture where various inputs, processes, and outputs contribute to the overall sustainability profile of face powder. This visual representation not only aids in communicating the scope of the assessment but also highlights the interconnectedness of different stages.

Analyzing the life cycle from a systemic perspective enables a more nuanced understanding of the environmental and social implications at each step, facilitating targeted strategies for improvement. The Life Cycle Stages Considered diagram thus serves as a valuable tool for both experts and non-experts alike, enhancing the accessibility and clarity of the complex assessment process in the context of face powder production.

## 2.2. Diagram of Face Setting Powder Life Cycle

Figure 2 (see Appendix) shows a comparison of the impact between cotton + raw materials + packaging against waste. Notably, waste emerges as a primary contributor to environmental burdens, particularly in terms of Freshwater ecotoxicity, with a value of 191,95565 CTUe. This metric signifies the potential harm to freshwater ecosystems, integrating the impact over time and volume per unit mass of the emitted chemical. Furthermore, the adverse effects extend to Human toxicity, non-cancer effects, with a value of 3.78E-06 CTUh, and Climate Change, with an associated impact of 10,090.531 kg CO2 eq. These findings underscore the importance of waste management strategies and highlight the need for interventions to mitigate the environmental repercussions of face powder product disposal.

In Figure 3, the assessment of the environmental impact of setting face powder reveals a compelling comparison between the contributions of raw materials, specifically focusing on cotton, and the packaging involved in the product life cycle. Notably, the analysis exposes cotton as a significant driver of adverse environmental effects, particularly in the realms of Ozone Depletion, Water Resource, and Climate Change. The highest impact is observed in Ozone Depletion, where cotton registers an alarming 3.91E-05 kg CFC-11 equivalent. This finding underscores the importance of scrutinizing raw material choices, as the production and processing of cotton appear to carry substantial environmental repercussions, implicating the release of ozone-depleting substances.

Furthermore, when examining water resource sustainability, cotton again emerges as a noteworthy contributor, accounting for 0.53178378 m3 water equivalent. This emphasizes the water-intensive nature of cotton cultivation and processing, shedding light on the strain it places on global water resources. Additionally, the evaluation of Climate Change impact reveals that cotton is associated with 8.5323831 kg CO2 equivalent, signifying its substantial carbon footprint. These findings underscore the need for sustainable sourcing practices and alternative materials in the cosmetics industry. While packaging often garners attention for its environmental impact, these results highlight the critical role of raw material selection, urging stakeholders to explore eco-friendly alternatives and adopt practices that mitigate the environmental toll of specific ingredients like cotton in cosmetic products.

In Figure 4, the comparative analysis highlights a notable discrepancy in the environmental impacts between raw materials and packaging in the life cycle of setting face powder. The results indicate that PET packaging emerges as asignificant contributor to Climate Change, Particulate Matter, and Human Toxicity. The elevated values of 8,6397641 kg CO2 eq, 0,0092338056 kg PM2.5 eq, and 4,96E-07 CTUh associated with PET packaging underscore its substantial environmental footprint. This finding is particularly crucial for sustainable product development and lifecycle management, prompting a closer examination of alternative packaging materials or strategies that could mitigate these adverse effects.

The striking impact of PET packaging on Climate Change is a cause for concern, as it suggests a substantial carbon footprint associated with the production and disposal of these materials. Identifying and adopting alternative packaging solutions with lower carbon emissions could play a pivotal role in minimizing the overall environmental impact of setting face powder. Additionally, the observed contributions to Particulate Matter and Human Toxicity underscore the need for a comprehensive evaluation of the entire supply chain to identify hotspots and implement targeted interventions. Strategies such as recycling, using recycled materials, or exploring biodegradable alternatives may offer avenues for reducing the environmental burdens associated with the packaging phase.

Furthermore, these results emphasize the importance of considering the full life cycle of products in sustainability assessments. While it is essential to scrutinize raw materials and their extraction processes, the packaging phase is a critical aspect that should not be overlooked. Decision-makers in the cosmetics industry should use these findings to inform their choices in material selection and packaging design, aiming for solutions that align with environmental sustainability goals. By addressing the environmental hotspots identified in the life cycle assessment, the industry can move towards more eco-friendly practices, contributing to a more sustainable and responsible approach to cosmetic product development and consumption.

From the Life Cycle Assessment diagram of Face Setting Powder (Figure 5), the discernible negative impacts associated with the use of rape seed oil and the transportation of kaolin raise critical considerations for the environmental sustainability of the product. Rape seed oil, a common ingredient in cosmetic formulations for fragrance, is linked to concerns such as land use change, deforestation, and potential biodiversity loss during its cultivation. From the above Tree Diagram, it is evident that even though Rape Seed Oil is only 5% per 1kg of the Face Setting Powder, it has high impact, 59.7%. These impacts underscore the importance of scrutinizing the sourcing practices of raw materials to ensure that the production of face powder aligns with sustainable and ethical principles. Consequently, efforts should be directed towards establishing responsible supply chain practices, potentially exploring alternatives to mitigate the adverse effects associated with the cultivation and extraction of rape seed oil.

Furthermore, the transportation of kaolin, a primary raw material in face powder, contributes to the product's environmental footprint. Kaolin is constitutes about 82% of a kilogram of the Face Setting Powder and it has an impact of about 61.8% which is quite high. The negative impacts of transportation may include greenhouse gas emissions, air pollution, and energy consumption. To address these challenges, optimizing transportation logistics, exploring more sustainable modes of transportation, or sourcing kaolin from closer proximity to manufacturing facilities could be considered. This not only mitigates the carbon footprint associated with transportation but also aligns with broader sustainability goals by promoting regional sourcing strategies. In essence, addressing these negative impacts requires a holistic approach, incorporating sustainable sourcing practices, and reevaluating transportation strategies to enhance the overall environmental performance of face powder throughout its life cycle.

In Figure 6, the Life Cycle Assessment (LCA) results reveal a striking comparison between the environmental impacts of waste and cotton in the setting face powder life cycle. Notably, waste emerges as a major contributor to adverse effects on Freshwater Ecotoxicity, Human Toxicity, and Land Use. The high value of 179,658.75 CTUe for Freshwater Ecotoxicity indicates a substantial potential for harm to aquatic ecosystems. This impact could be attributed to the disposal and management of waste generated throughout the life cycle, pointing to the need for improved waste management practices to mitigate these ecological risks.

Furthermore, the Human Toxicity impact, measured at 3.61E-06 CTUh, emphasizes the importance of understanding the potential harm to human health associated with the production and disposal of waste in the setting face powder life cycle. The relatively low numerical value does not diminish its significance, as even minute quantities of toxic substances can have cumulative effects over time. This result underscores the necessity for strategies that minimize the release of harmful substances into the environment, thereby safeguarding human health throughout the product life cycle.

Moreover, the substantial impact of waste on Land Use, quantified at 55,089.145 kg C deficit, highlights the resource depletion and environmental footprint associated with the space required for waste disposal. This result suggests that the management of waste in the setting face powder life cycle has broader implications for the overall sustainability of land resources. Addressing this issue necessitates a holistic approach, including waste reduction strategies, recycling initiatives, and sustainable disposal practices, to curtail the negative consequences on land use and foster a more environmentally responsible product life cycle. In summary, these findings underscore the imperative for targeted interventions in waste management to minimize the environmental footprint and enhance the overall sustainability of setting face powder production.

In Figure 7, the comparison of raw materials with rape seed oil modifications versus cotton versus packaging reveals noteworthy insights into the environmental impacts associated with these choices. Notably, cotton emerges as a material with substantial repercussions on several environmental indicators, particularly Water Resource Depletion, Ozone Depletion, and Freshwater Eutrophication. The high water intensity in cotton cultivation contributes significantly to Water Resource Depletion, exacerbating concerns related to water scarcity and competing demands for this critical resource.

Additionally, the production and processing of cotton may involve the use of agrochemicals and fertilizers, contributing to Freshwater Eutrophication, where excessive nutrient runoff leads to the proliferation of algae, negatively impacting aquatic ecosystems.

Moreover, the observed impact on Ozone Depletion suggests that the processes associated with cotton cultivation and production may involve substances that have adverse effects on the ozone layer. This is a matter of global concern as the ozone layer plays a crucial role in protecting life on Earth from harmful ultraviolet (UV) radiation. The identification of these environmental hotspots emphasizes the importance of considering alternative materials, such as those with rape seed oil modifications, in the formulation of setting face powder. By opting for more sustainable raw materials, it is possible to mitigate the environmental burdens associated with cosmetic production, aligning with the principles of a life cycle approach to minimize overall environmental impact and promote a more sustainable and responsible product life cycle.

In Figure 8, the comparison between raw materials with rape seed oil modifications against PET packaging material reveals insightful information about the environmental impact of setting face powder. The inclusion of rape seed oil modifications in the raw materials demonstrates a potential alternative that can contribute to a more sustainable production process. Rape seed oil, being a renewable resource, can reduce dependency on non-renewable raw materials, such as certain petrochemical-based ingredients. This substitution aligns with the principles of circular economy and resource efficiency, aiming to minimize the environmental footprint associated with the extraction and processing of finite resources. Furthermore, the cultivation of rape seed for oil production may provide additional environmental benefits, such as carbon sequestration, depending on the agricultural practices employed.

However, it is crucial to address the notable impact of PET packaging on various environmental indicators. The results indicate that PET packaging significantly contributes to land use, ionization radiation, and terrestrial eutrophication. This underscores the importance of reevaluating the packaging choices in the life cycle of setting face powder. Exploration of alternative packaging materials with lower environmental impacts, such as biodegradable or recycled options, could be explored to mitigate the adverse effects associated with PET.

Additionally, considering the end-of-life management of the packaging materials, such as recycling programs, could further enhance the sustainability profile of the overall product life cycle. By carefully scrutinizing the environmental implications of both raw materials and packaging, manufacturers can make informed decisions to minimize their ecological footprint and contribute to a more sustainable beauty industry.

In Figure 9, the notable correlation between waste generation and its impact on freshwater ecotoxicity and human toxicity with non-cancer effects underscores the critical role that waste management plays in shaping the environmental and human health footprint of setting face powder production.

The high waste generation associated with the production process manifests in elevated freshwater ecotoxicity, indicating a potentially detrimental impact on aquatic ecosystems. This finding is particularly concerning given the importance of freshwater resources for biodiversity and human consumption. The presence of harmful substances in the waste stream may lead to adverse effects on aquatic organisms, disrupting ecological balances and potentially compromising the quality of water resources.

Moreover, the observed link between waste generation and human toxicity with non-cancer effects highlights the intricate relationship between industrial processes and public health. The disposal and treatment of waste from setting face powder production can introduce substances with non-cancerous health effects into the environment. This may pose risks to human health through various exposure pathways, such as inhalation, ingestion, or dermal contact. Understanding and mitigating these effects are crucial for designing sustainable practices within the cosmetics industry. Implementing waste reduction strategies, optimizing production processes, and promoting the use of environmentally friendly materials can contribute to minimizing the adverse impacts associated with waste generation, fostering a more sustainable life cycle for setting face powder.

In Figure 10, the comparison between raw materials with modified kaolin transport against packaging against cotton, reveals noteworthy insights into the environmental impact of these components throughout their life cycle. One striking observation is the relatively high impact of cotton on ozone depletion, water resource depletion, and particulate matter. This outcome underscores the importance of understanding the cradle-to-grave environmental footprint of raw materials in cosmetic products.

Cotton cultivation involves the use of pesticides, fertilizers, and significant water resources, contributing to the depletion of water resources. Additionally, the production processes associated with cotton, such as spinning, weaving, and dyeing, may release particulate matter into the environment. Moreover, the energy-intensive nature of cotton processing may contribute to ozone depletion, further highlighting the need for sustainable alternatives or practices in the cosmetics industry to mitigate these environmental impacts.

Conversely, modified kaolin transport and packaging exhibit a different environmental profile. Assessing the life cycle of modified kaolin, which, may reveal lower impacts on ozone depletion, water resource depletion, and particulate matter compared to cotton. This could be attributed to the extraction and processing of kaolin being less resource-intensive and having a lower environmental footprint. Evaluating the transportation and packaging stages separately allows for a comprehensive understanding of the overall impact, shedding light on potential areas for improvement.

In Figure 11, the comparison between raw materials with modified kaolin transport against PET packaging reveals insightful trends in environmental impacts. Notably, the data underscores the prominence of packaging in contributing to adverse effects on various environmental indicators. Specifically, the high impact observed in marine eutrophication, water resource depletion, and land use associated with packaging emphasizes its significant role in environmental strain. The transportation of modified kaolin, a critical raw material in the production process, seems to exhibit a comparatively lower impact on these specific environmental aspects. This information sheds light on the potential areas for improvement within the life cycle of setting face powder, with a targeted focus on reducing the environmental footprint of packaging materials.

The elevated impact of packaging on marine eutrophication, water resource depletion, and land use demands a closer examination of the materials and design choices in this phase of the product's life cycle. Identifying and implementing sustainable packaging solutions, such as biodegradable materials or recycling initiatives, could be instrumental in mitigating these adverse effects. Additionally, exploring alternative transportation methods for raw materials, like modified kaolin, may offer opportunities to further reduce the environmental impact associated with their transport. By addressing these aspects, cosmetic manufacturers can enhance the overall sustainability of setting face powder, aligning their production processes with environmentally responsible practices and minimizing the product's ecological footprint throughout its life cycle.

In Figure 12, the comprehensive life cycle assessment (LCA) reveals a nuanced interplay of environmental impacts associated with setting face powder, particularly when comparing raw materials with modifications on kaolin and rape seed oil against the backdrop of cotton. Notably, cotton emerges as a significant contributor to adverse environmental effects, exhibiting high impacts on freshwater ecotoxicity, climate change, and human toxicity with non-cancer effects. The cultivation and processing of cotton involve intensive water usage, leading to increased freshwater ecotoxicity. Furthermore, the production of cotton contributes substantially to climate change, given the energy-intensive processes and agricultural practices associated with its growth. Additionally, the raw materials and processes involved in cotton production are identified as sources of human toxicity with non-cancer effects, underscoring the importance of considering the broader ecological and health implications of the chosen materials in the formulation of setting face powder.

The comparison between raw materials modifications, such as kaolin transport and rape seed oil, offers insights into potential alternatives with more favorable environmental profiles. While acknowledging the impacts associated with transportation, the LCA sheds light on the potential benefits of opting for alternatives to cotton in setting face powder formulations. The use of kaolin and rape seed oil, despite their own set of environmental considerations, appears to mitigate certain negative impacts when contrasted with cotton. This emphasizes the importance of making informed choices in material selection, taking into account the entire life cycle, and underscores the need for a holistic approach in product development.

In Figure 13, there is vivid illustration of the comparative environmental impacts of setting face powder, emphasizing the role of raw materials, transportation, and packaging. Kaolin, a key component in face powder, is contrasted with modifications in its transport and the inclusion of rape seed oil. The analysis underscores the nuanced environmental implications associated with these modifications. Kaolin transport, typically energy-intensive, demonstrates a notable influence on the overall environmental footprint. Meanwhile, the integration of rape seed oil, often considered a more sustainable alternative, introduces complexities in the life cycle, demanding a careful evaluation of its sourcing, processing, and transportation. The juxtaposition of these modifications against a baseline of Cotton further delineates the intricate interplay of raw materials, transportation, and packaging in shaping the environmental profile of setting face powder.

The salient finding in Figure 13 is the pronounced impact of Cotton on key environmental indicators, particularly freshwater eutrophication, water resource depletion, and ozone depletion. Cotton, a common ingredient in cosmetics packaging, emerges as a significant contributor to these environmental stressors. The heightened freshwater eutrophication potential suggests a substantial risk to aquatic ecosystems due to nutrient imbalances, potentially leading to algal blooms and oxygen depletion. Simultaneously, the observed increase in water resource depletion underscores the strain on local and global water supplies associated with cotton cultivation and processing. Furthermore, the elevated ozone depletion potential points to the role of certain chemicals or processes in cotton production that contribute to the thinning of the ozone layer. These findings illuminate the need for targeted interventions and sustainable sourcing practices in the cosmetic industry to mitigate the environmental impact of setting face powder, especially in the context of raw material choices and packaging materials.

In Figure 14, the results highlight the significant environmental impacts associated with the raw materials used in setting face powder, particularly when considering modifications such as kaolin transport and the use of rape seed oil. The data indicates that these modifications contribute to varying degrees of environmental burdens, with a particular focus on the packaging stage. Kaolin transport, as a key component in the formulation, is associated with specific environmental implications, and its impact is evident in areas such as energy consumption and emissions during transportation.

Additionally, the use of rape seed oil introduces another layer of complexity, emphasizing the need for careful consideration of the entire supply chain to comprehend the holistic environmental profile of the product.

Furthermore, it is noteworthy that cotton, a common raw material in the setting face powder, emerges as a key driver of environmental impact across multiple categories, including marine eutrophication, land use, and water resource depletion. The high impact on marine eutrophication suggests a potential contribution to nutrient imbalances in aquatic ecosystems, possibly leading to algal blooms and oxygen depletion.

The extensive land use associated with cotton cultivation raises concerns about habitat disruption and biodiversity loss. Moreover, the significant water resource depletion indicates a strain on local water supplies, especially in regions where water scarcity is already a critical concern. This comprehensive understanding of the environmental hotspots within the life cycle of setting face powder can guide targeted improvements in the product's sustainability, helping to minimize its overall ecological footprint.

## 2.3. Data Representativeness:

The data obtained came from sources mostly from Europe and America. The list of most of the ingredients were obtained from the Fenty Beauty Official Website, and some from the National Library of Medicine (NCBI). The rest of most of the data came from Cosmetics Articles and Published Papers from *SpecialChem*, Washington State Department of Ecology Olympia and Washington State Department of Ecology Olympia.

The chosen sources align with the specific scope and system boundaries defined for the assessment of the Face Setting Powder. The data accurately reflects the processes, materials, and energy inputs associated with the life cycle stages under consideration. By prioritizing data relevance, this Face Setting Powder assessment aims to enhance the reliability of its findings and facilitate meaningful comparisons between different environmental impact categories.

Additionally, the inclusion of up-to-date and industry-specific data sources contributes to the applicability and precision of the LCA results, offering a more nuanced understanding of the environmental performance of the assessed product or system.The selected sources are drawn from reputable databases, scientific literature, and industry reports recognized for their reliability and accuracy.

Peer-reviewed studies and data provided by authoritative organizations contribute to the robustness of the assessment, ensuring that the information used is subjected to critical scrutiny and validation by experts in the field.

## Part 3. Impact Assessment and Interpretation

### 3.1. First Scenario Data

After looking at the Tree diagram (Figure 16) it is shown that the most contaminant in terms of kg of $CO2$ are rape seed oil (59.7%) and Kaolin (61.8%). Figure 17 depicts the amount of C02 in kg, with Rape seed oil with 0.172 kg CO2 and Kaolin with 0.178 kg CO2. Rape seed oil is only 5% of 1kg of face powder, however it has great proportional impact. The second modification will be related to the Kaolin because is the main feedstock of the face powder.

Figure 18 shows the raw materials without any modifications. Generally, Kaolin and Rape Seed Oil have great impacts on the aspects. Their impacts are mostly dominant in Freshwater eutrophication, Mineral, fossil and Renewable resources depletion and in Marine Eutrophication.

Figure 19 shows the impact of the raw materials on the Climate Change. It is evident that Kaolin, Rape Seed Oil and Glycerin have high impact on the Climate Change, respectively. For Glycerin, the reason might be because it is extracted by esterification of Soybean Oil.

### 3.2. Second Scenario Data: Rape Seed Oil Organic Modification

The first modification has been changing rape seed oil conventional into organic rape seed oil and this is illustrated in Figure 20. The amount of CO2 emitted has reduced from 0.172 kg CO2 to 0.107kg CO2. The percentage of CO2 obtained in Figure 20 correlates to the kg CO2 in Figure 21, that is the CO2 emission reduced to 48% for Rape Seed Oil from 59.7%.

Figure 22 shows a graph of the global impact of the raw materials and apparently Kaolin has notable impact on Mineral, fossil and Renewable Resource Depletion. Electricity has impact on the Ionizing radiation HH and Ionizing radiation (E) probably because the data was obtained from France, which is a country that produces electricity from nuclear energy.

The percentage of kaolin has increased, because the percentage of rape seed oil has gone down. However, the mass of CO2 on kaolin is the same as before the improvement therefore it can be concluded that there was improvement because the percentage of $CO_2$ reduced.

## 3.3. Third Scenario Data: Modification of Kaolin transportation

The second modification performed on the original scenario was on changing the transportation of Kaolin from global to Europe, which is illustrated in Figure 24 and 25 which show Tree diagrams of the modification in kg $CO_2$ and % $CO_2$. From the figures, it is evident that the amount in kg of $CO_2$ and % $CO_2$ reduced to 0.135 kg of $CO_2$ and 55% for Kaolin.

In Figure 26 and 27 of third modification, it can be found that $CO_2$ emissions by face powder are majorly by rape seed oil and then by kaolin. While Zinc oxide and electricity are also adding some of part to $CO_2$ emissions.

## 3.4. Fourth Scenario Data: Both modifications

Fourth scenario is the third modification which includes organic rape seed oil and transportation in Europe.

In the figure 28 of fourth modification, it can be found that greater $CO_2$ emissions are from rape seed organic oil and kaolin. In this, kaolin is causing 74.8% and rape seed organic oil is emitting 59.6% of $CO_2$ emissions.

In figure 29 of fourth modification, it can be observed that kaolin (0.135 kg $CO_2$) and rape seed organic oil (0.107 kg $CO_2$) are the main cause for the increased $CO_2$ emissions.

In the fourth modification of figure 30, it has been found that percentages of ionizing radiations (HH & E) are high which are coming from electricity consumptions. On the other hand, Kaolin is contributing majorly to freshwater toxicity and eutrophication which is not good for the environment. The rape seed organic oil is causing the marine water eutrophication and also requires a greater land use as compared to others.

In the figure 31 of fourth modification, it can be found that $CO_2$ emissions by face powder are majorly by kaolin and then by rape seed oil. While Zinc oxide and electricity are also adding some of part to $CO_2$ emissions.

## 3.5. Comparison of the 4 Scenarios combined

Figure 32 shows a graph illustrating the comparisons of the 4 scenarios against the environmental aspects. In general, scenario 1 and 3 have greater negative impacts on the environmental aspects especially on the climate change, an particulate matter.

In figure 33, all four scenarios have been compared, it has been found that climate change is less in fourth scenario in which changes was being made in transport and organic oil. The transport changes in third scenario individually doesn't have much effect in decreasing climate change. While changes in rape seed oil have some decreased climate change as compared to third scenario but not less than fourth scenario.

In Figure 34, it can be found that land use was less in third scenario in which changes in transport was made. While in second and fourth scenarios, more land use has been observed.

In the figure 35, water resources depletion can be observed in all four scenarios by doing comparison between them. The water resource depletion was observed more in third and fourth scenarios.

In figure 36, the ionizing radiation HH effect has been compared for all the scenarios. These radiations are more in third scenario with transport changes and in fourth scenario with transport and rape seed oil change as compared to other scenarios.

# 4. CONCLUSION

To conclude, decreased $CO_2$ emissions can be observed in scenario 2, 3 and 4. On the other hand, there are other parameters that wouldn't improve with the modifications (land use, water resource depletion and HH irradiation). The HH irradiation that increases in scenario 3 and 4 is related to the use of nuclear energy in France, so if instead of using nuclear energy, renewable energy was used, this could also be improved.

In the global LCA comparison, it is shown that some of the impact comes from the waste treatment, but the bigger one comes from the cotton used to remove the face powder. Cotton to remove face powder doesn't depend on the manufacturing of the product as it depends on the user preference.

In the global LCA comparison it can also be observed that packaging has also a big impact compared to the raw materials extraction and manufacturing of the product. Some improvements to avoid this impact could be: using recycled PET bottles from some company which recycle PET bottles. Another improvement can also be using PLA instead of PET. In this case, product should have labeling "avoid solar or hot exposure" because it might degrade the packaging. Another option could be using PHB instead of PET but this case has a drawback, the product would be more expensive as PHB is more expensive than PET.

Another conclusion after this analysis is that there is no perfect scenario for the LCA, because each modification can come with its own drawbacks. The most ideal situation would be a deeper real study on the demographic zone and optimizing the scenarios in which the drawbacks are less. In this case, even $4^{th}$ scenario is not an optimal one, it is just best of the 4 scenarios that we have studied.

It also has to be commented, that the assumption is made on the Kaolin instead of Talc, because of its similar properties, taking into account that talc was the main material to produce face powder, it might have some change on the LCA analysis.

# 5. References

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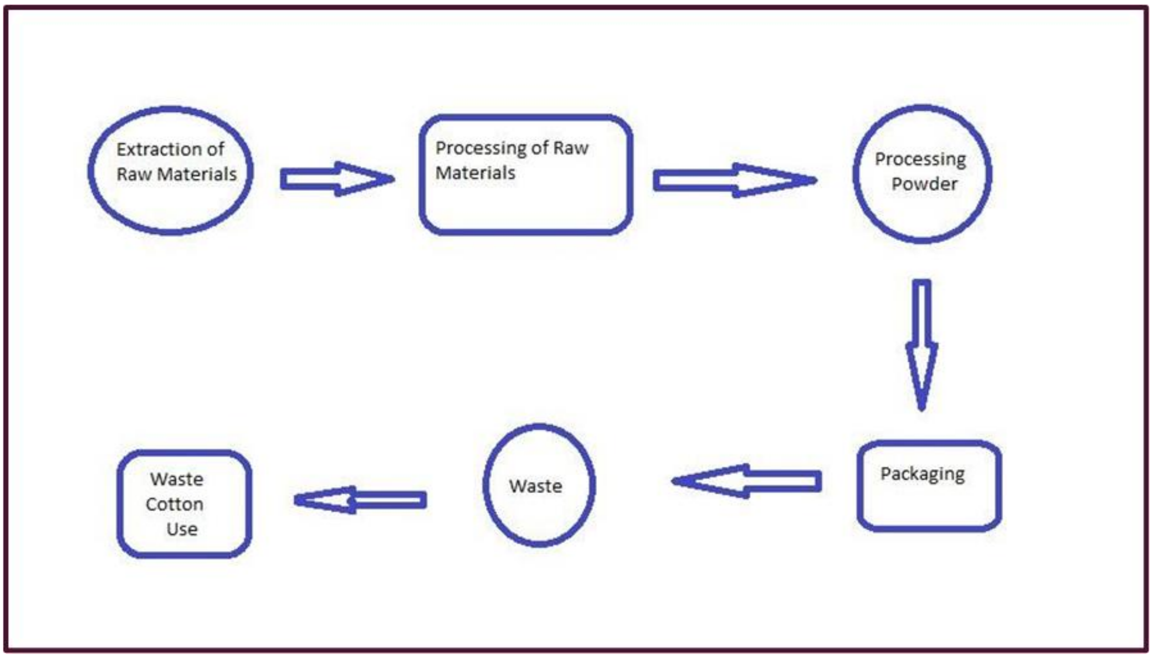
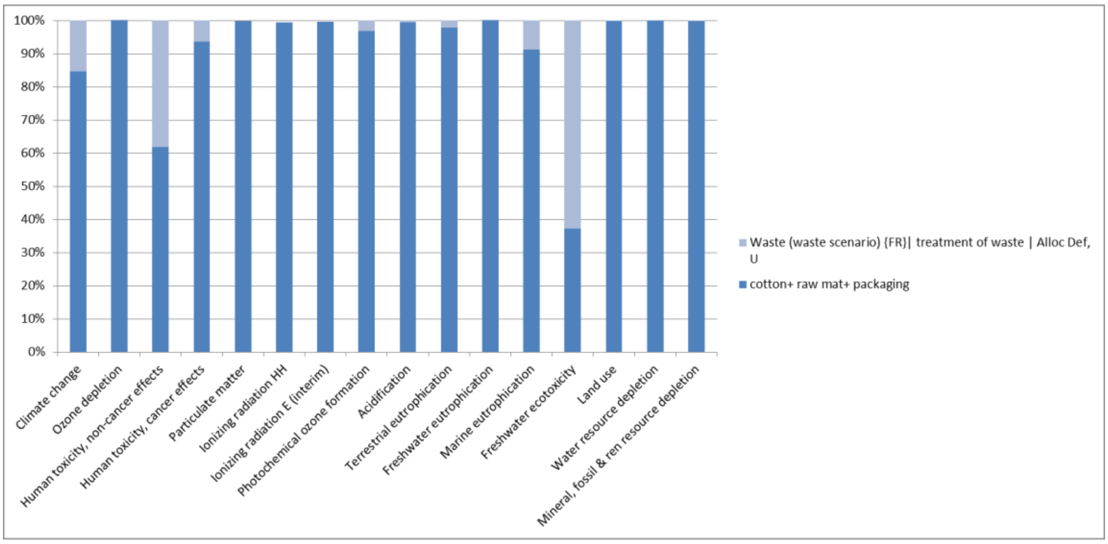
# 6. Appendix

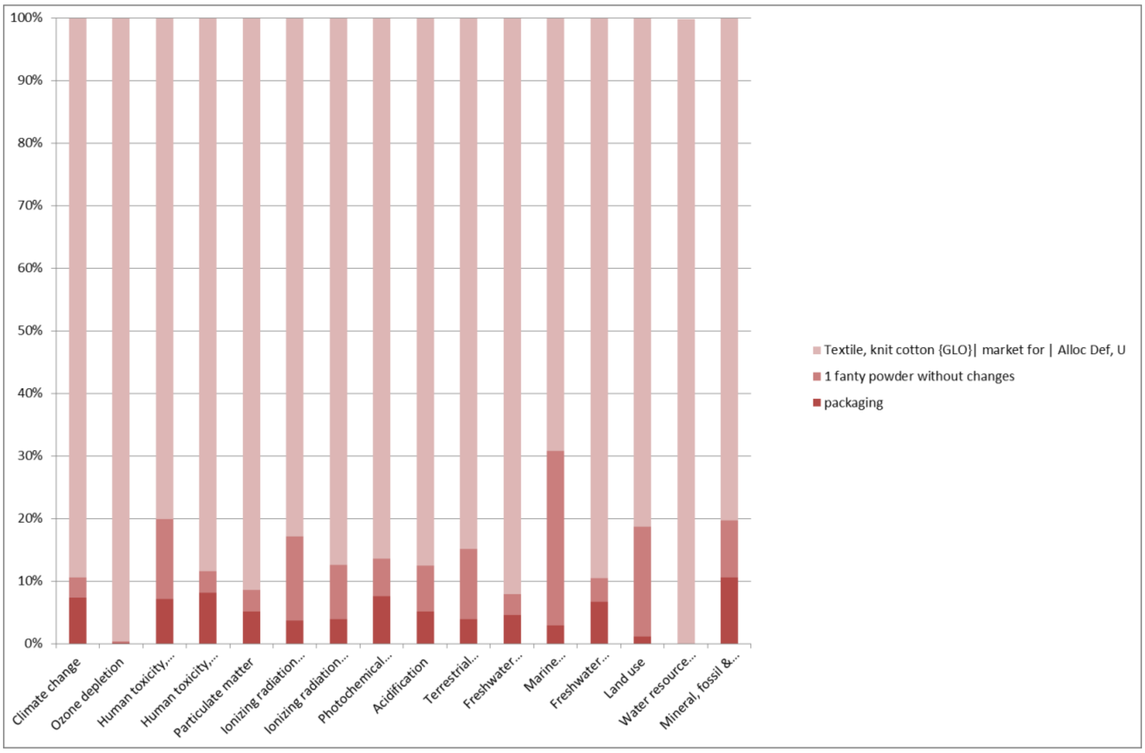
Appendix A1: Figure 1- Life Cycle Stages



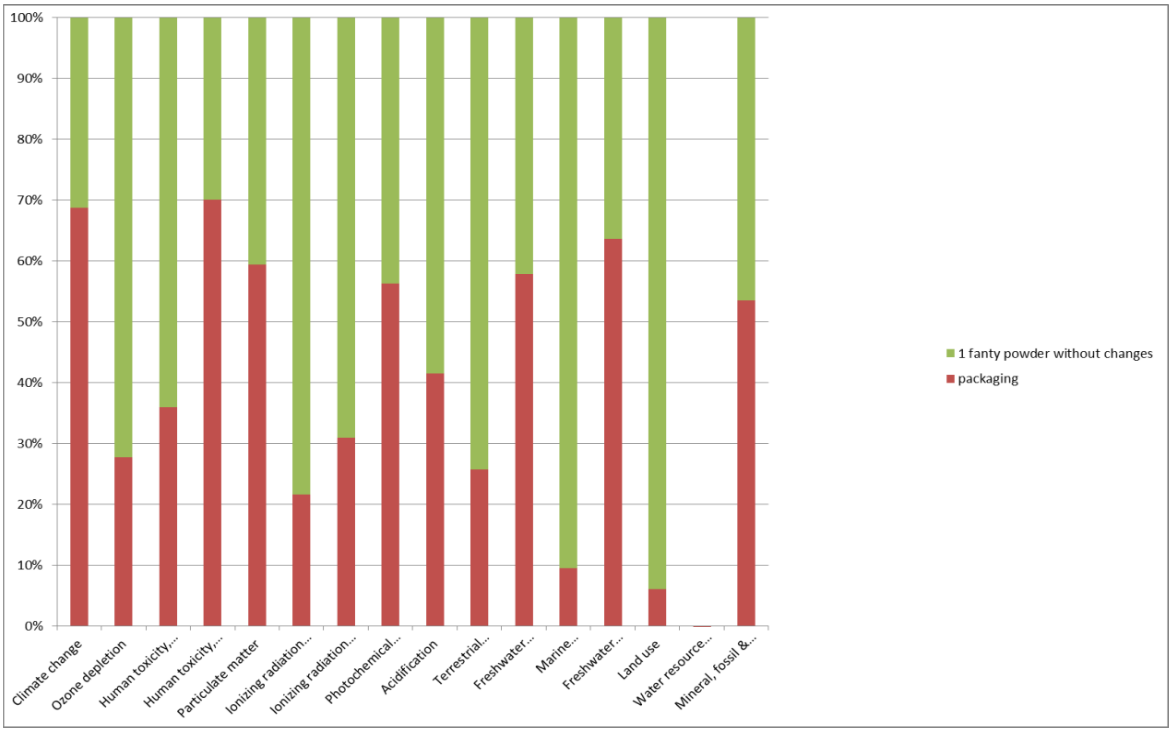

Appendix A2: Figure 2-Comparison between impact of cotton + raw materials + packaging against waste impact.



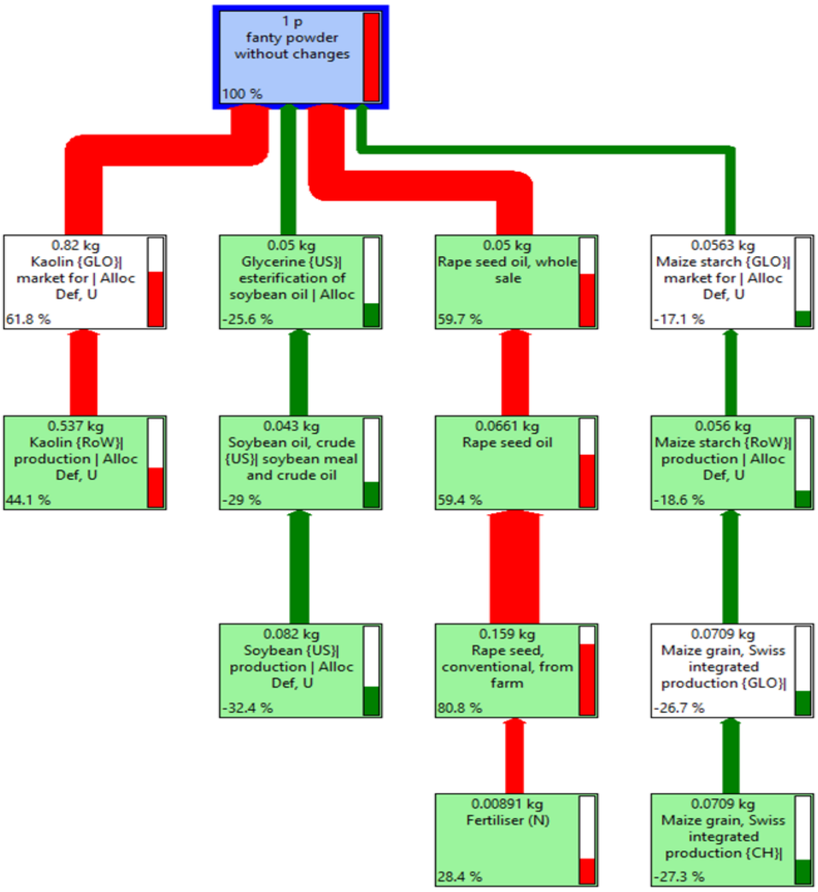
Appendix A3: Figure 3 - Comparison between impact of raw materials + cotton + packaging.



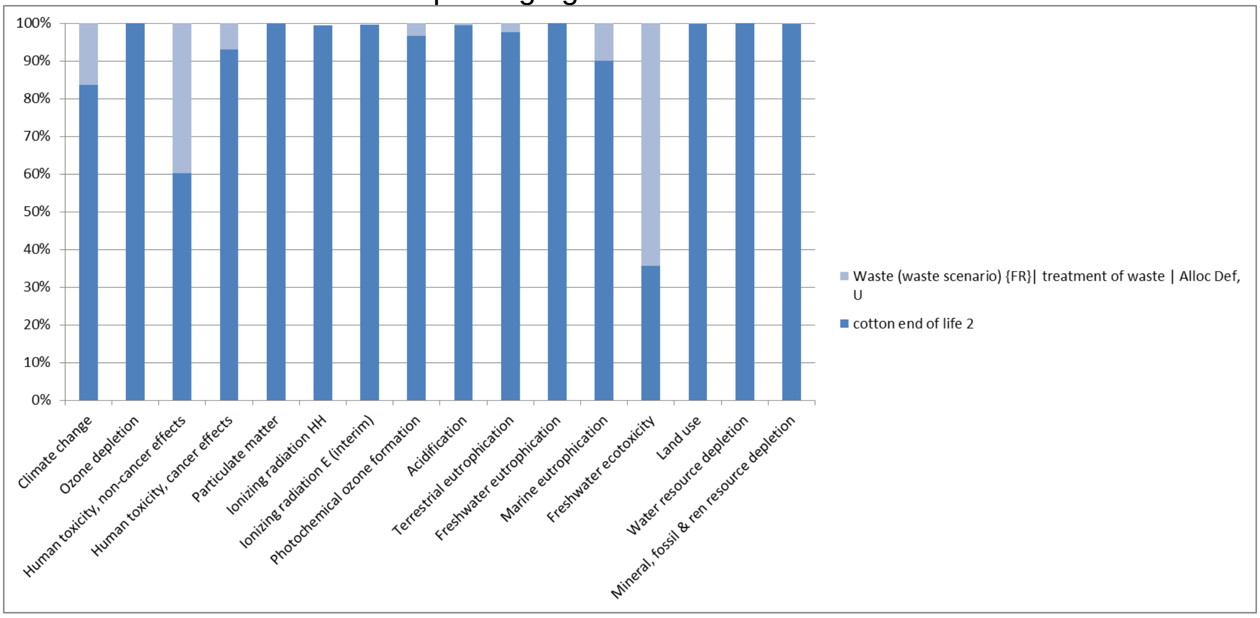

Appendix A4: Figure 4 - Comparison between impact of raw materials + packaging.



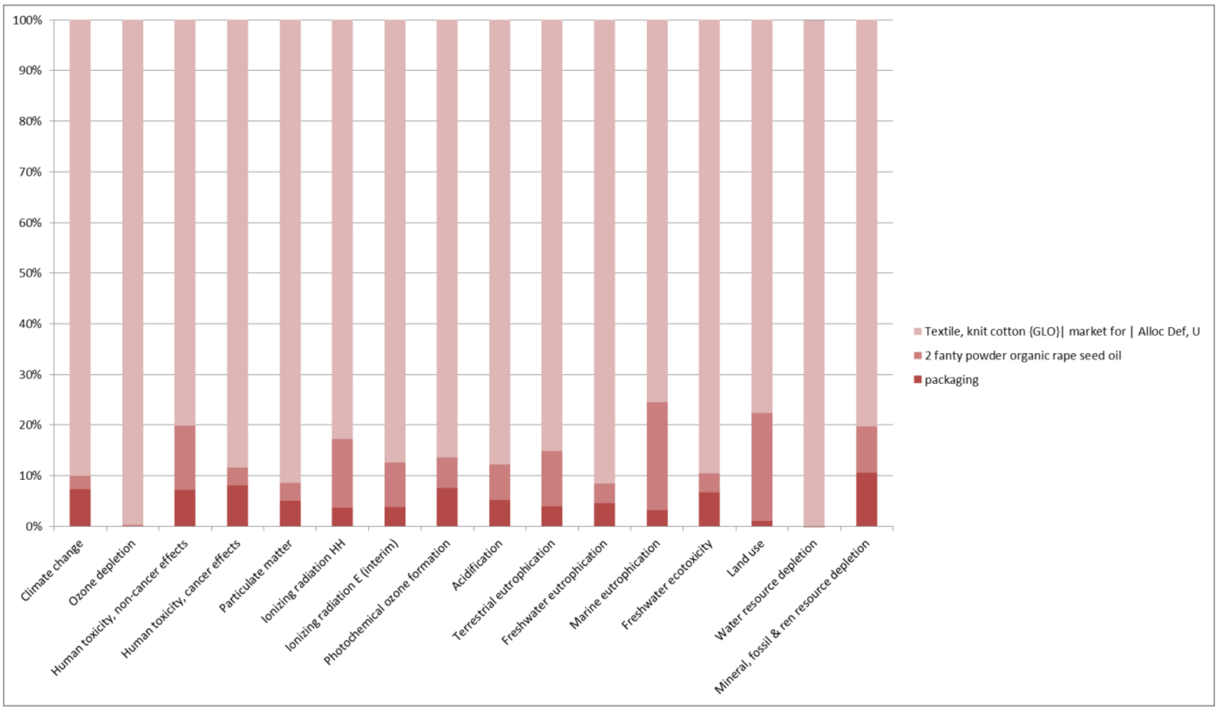
Appendix A5: Figure 5 - Tree Diagram Unmodified Raw Materials



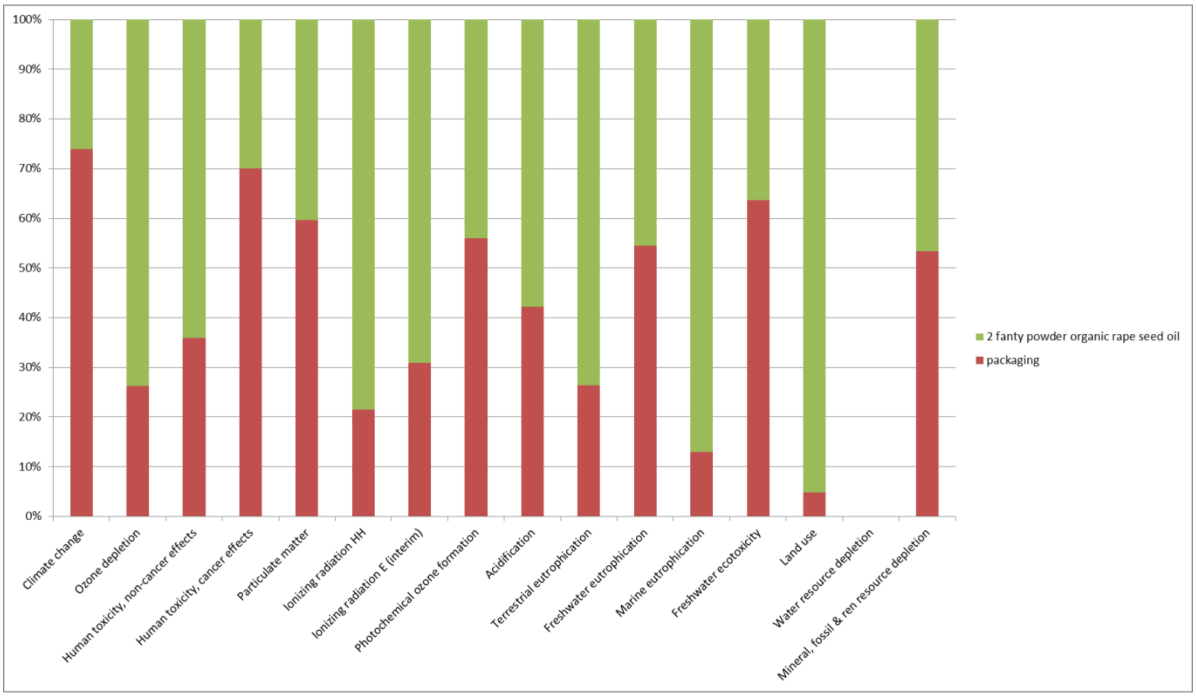

Appendix A6: Figure 6: Life Cycle Stage -Modified (Rape Seed Oil) + cotton + packaging + waste.



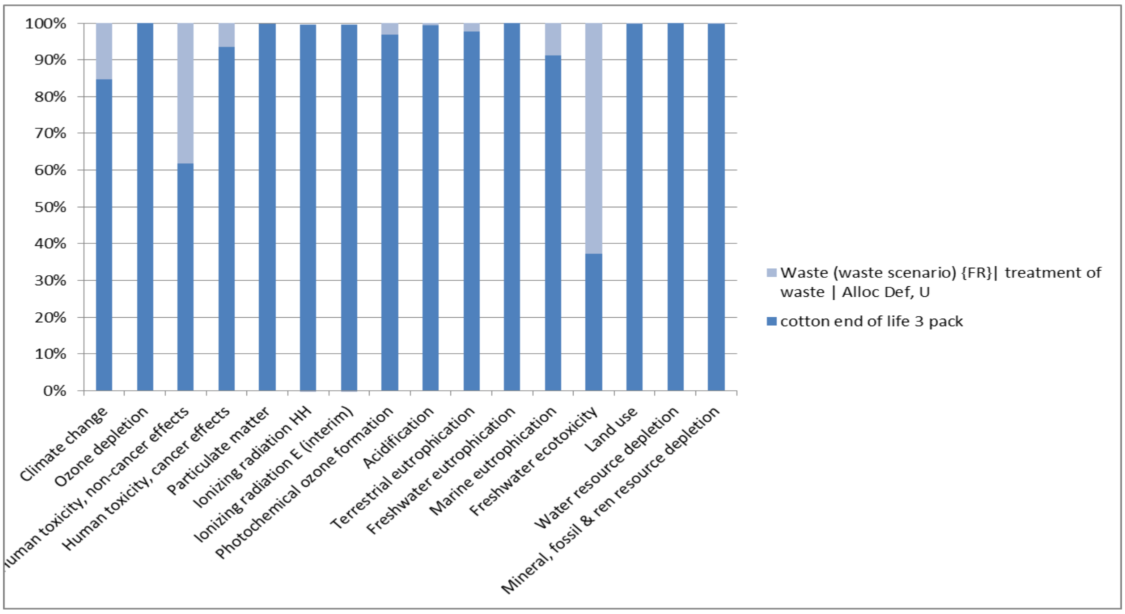
Appendix A7: Figure 7- Life Cycle Stage -Modified (Rape Seed Oil) + cotton + packaging



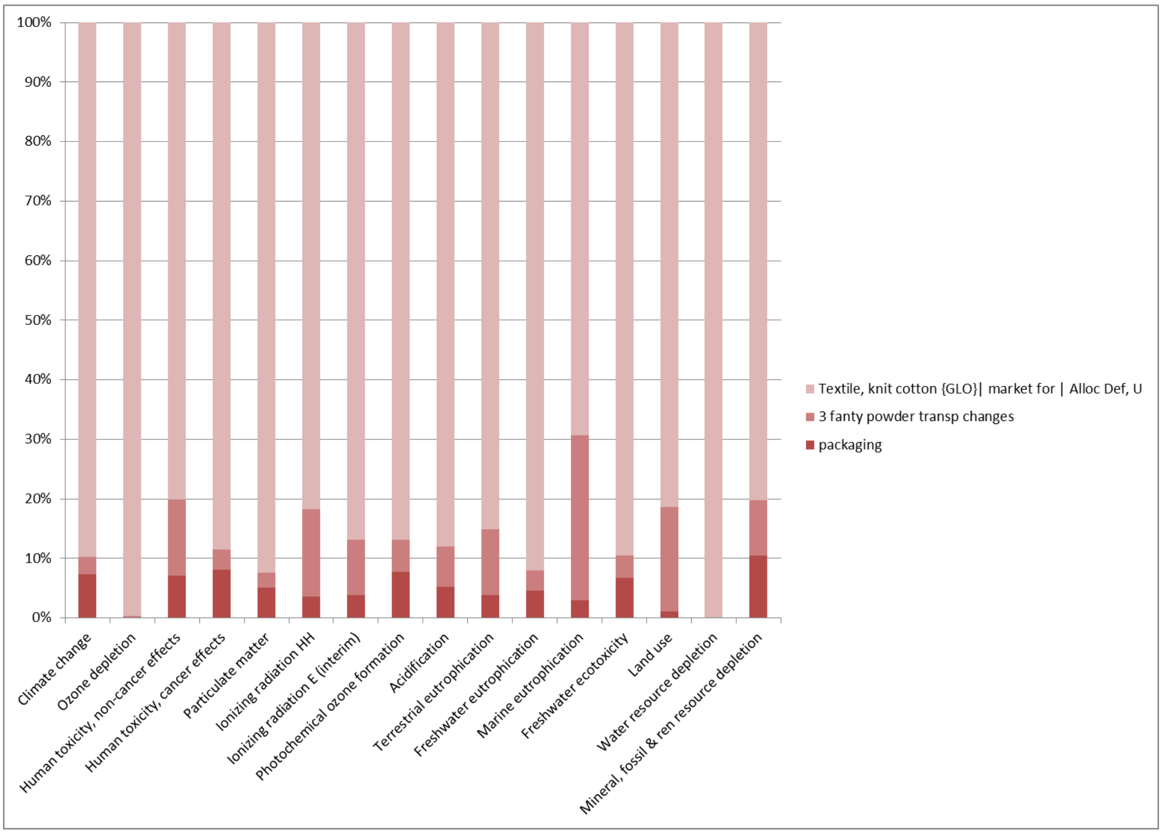

Appendix A8: Figure 8 - Life Cycle Stage -Modified (Rape Seed Oil) + packaging



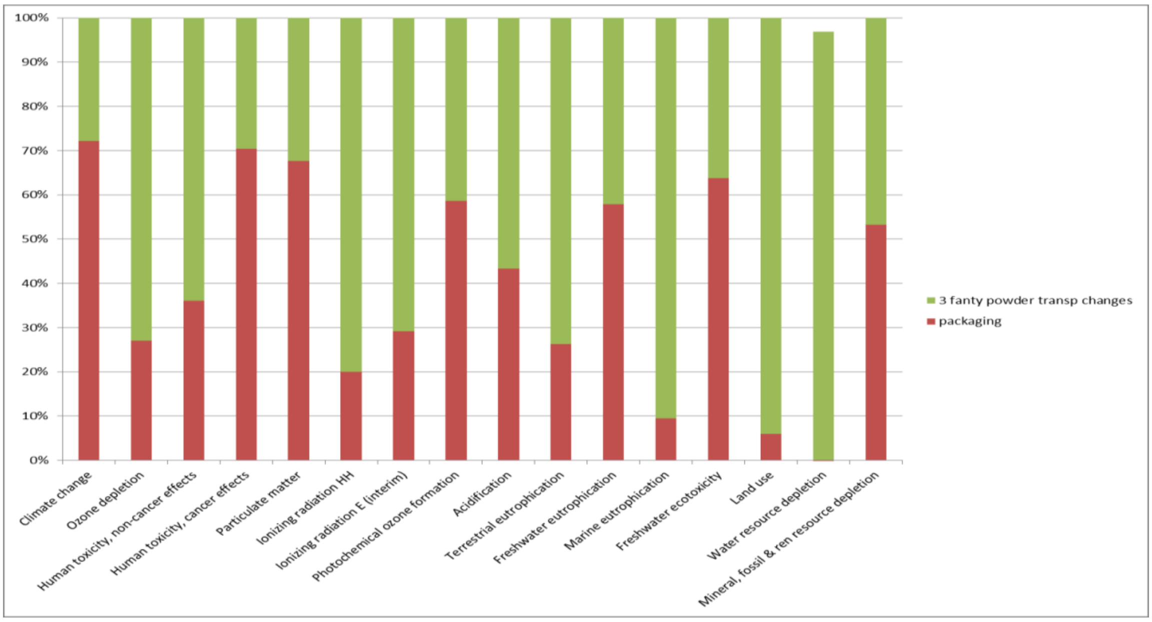
Appendix 9A: Figure 9 - Life Cycle Stage of Modified (Kaolin transportation) + cotton + packaging + waste



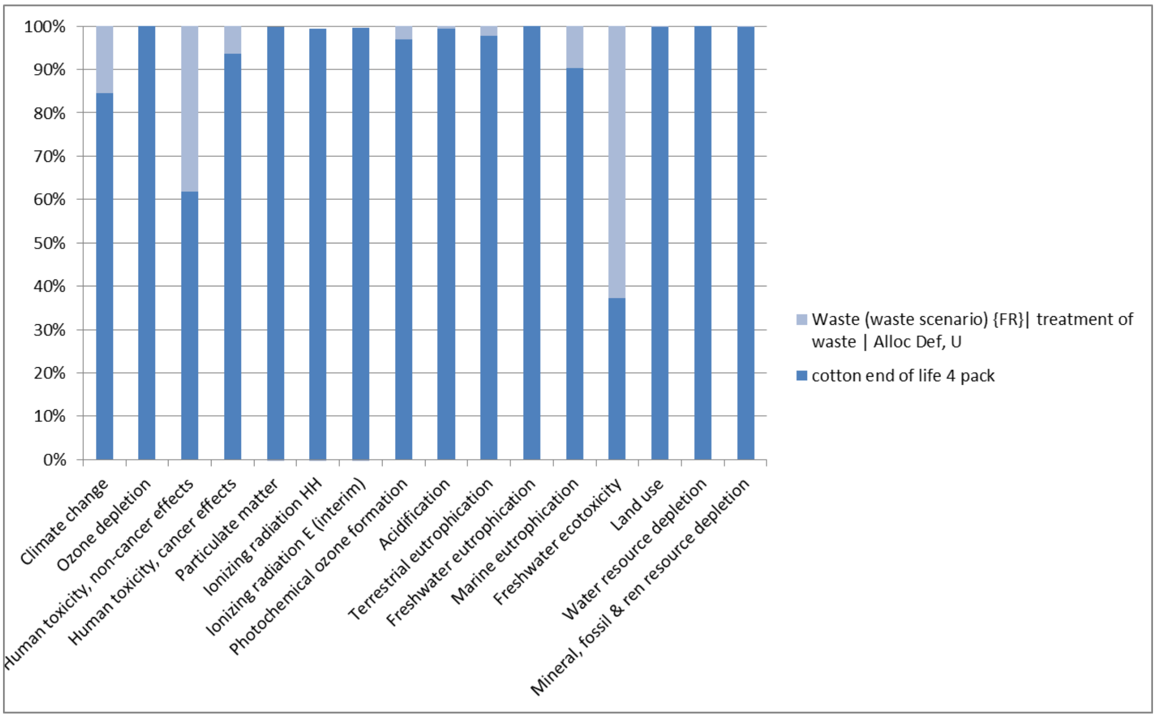

Appendix A10: Figure 10 - Life Cycle Stage -Modified (Kaolin transportation) + cotton + packaging



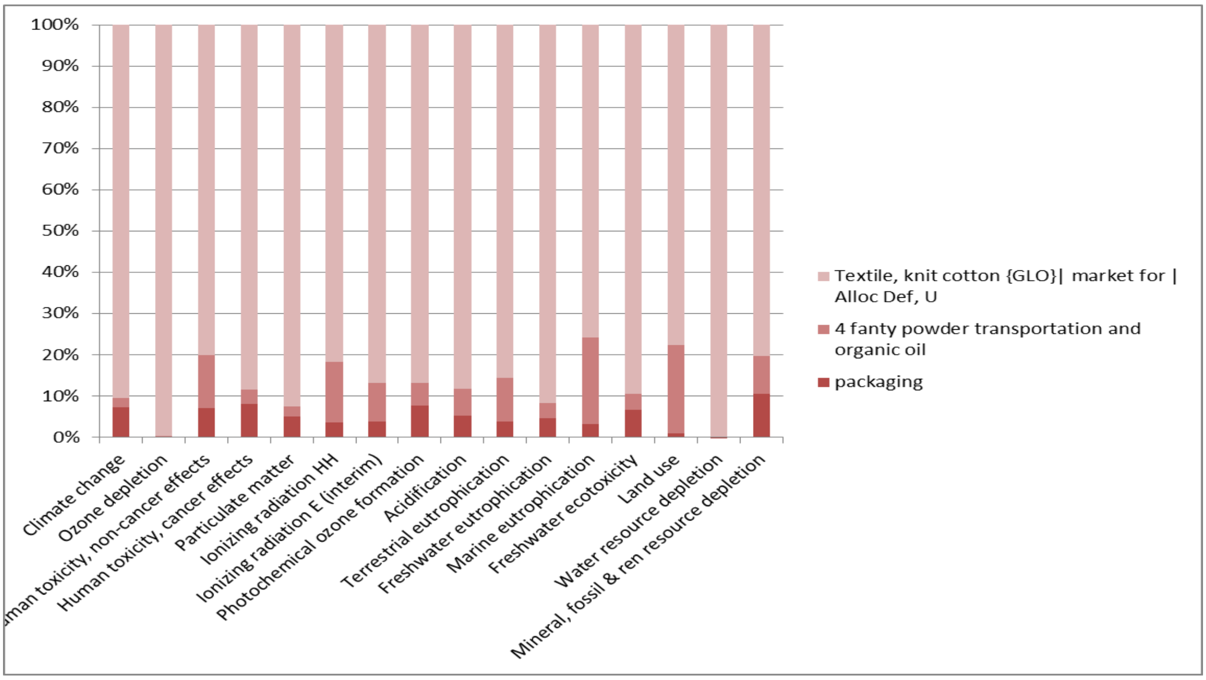
Appendix A11: Figure 11 -Life Cycle Stage -Modified (Kaolin transportation) + packaging



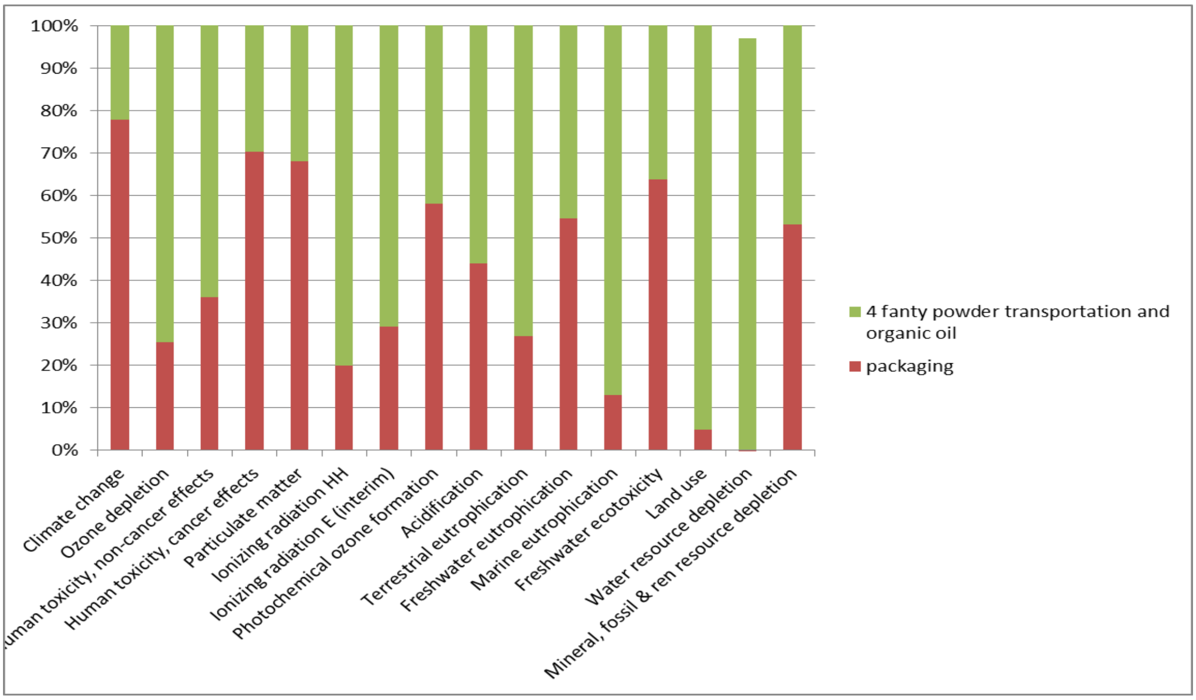

Appendix A12: Figure 12: Life Cycle Stage Both modifications + cotton + packaging + waste



Appendix A13: Figure 13 - Life Cycle Stage Both modifications + cotton + packaging

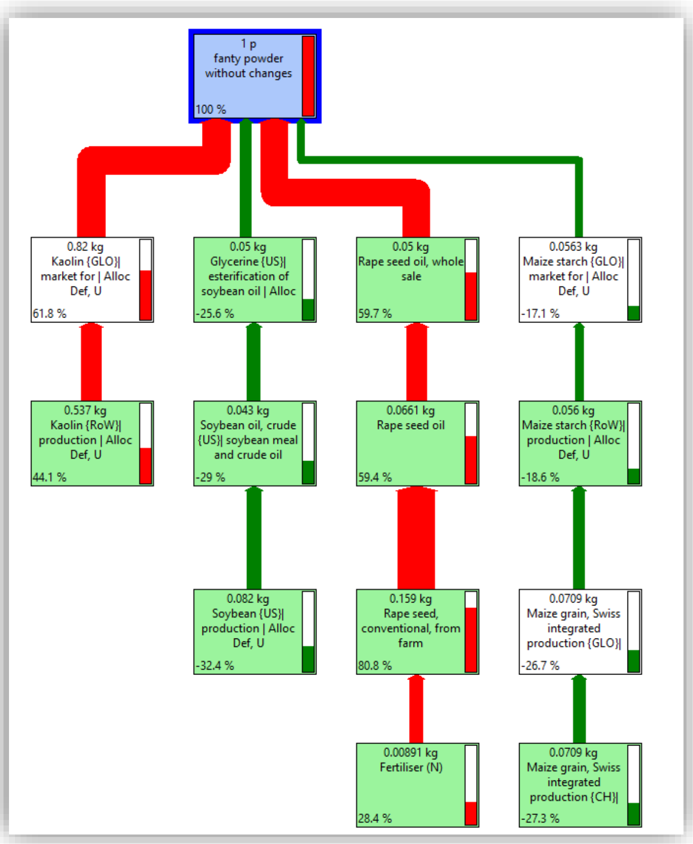



Appendix A14: Figure 14 - Life Cycle Stage Both modifications + packaging

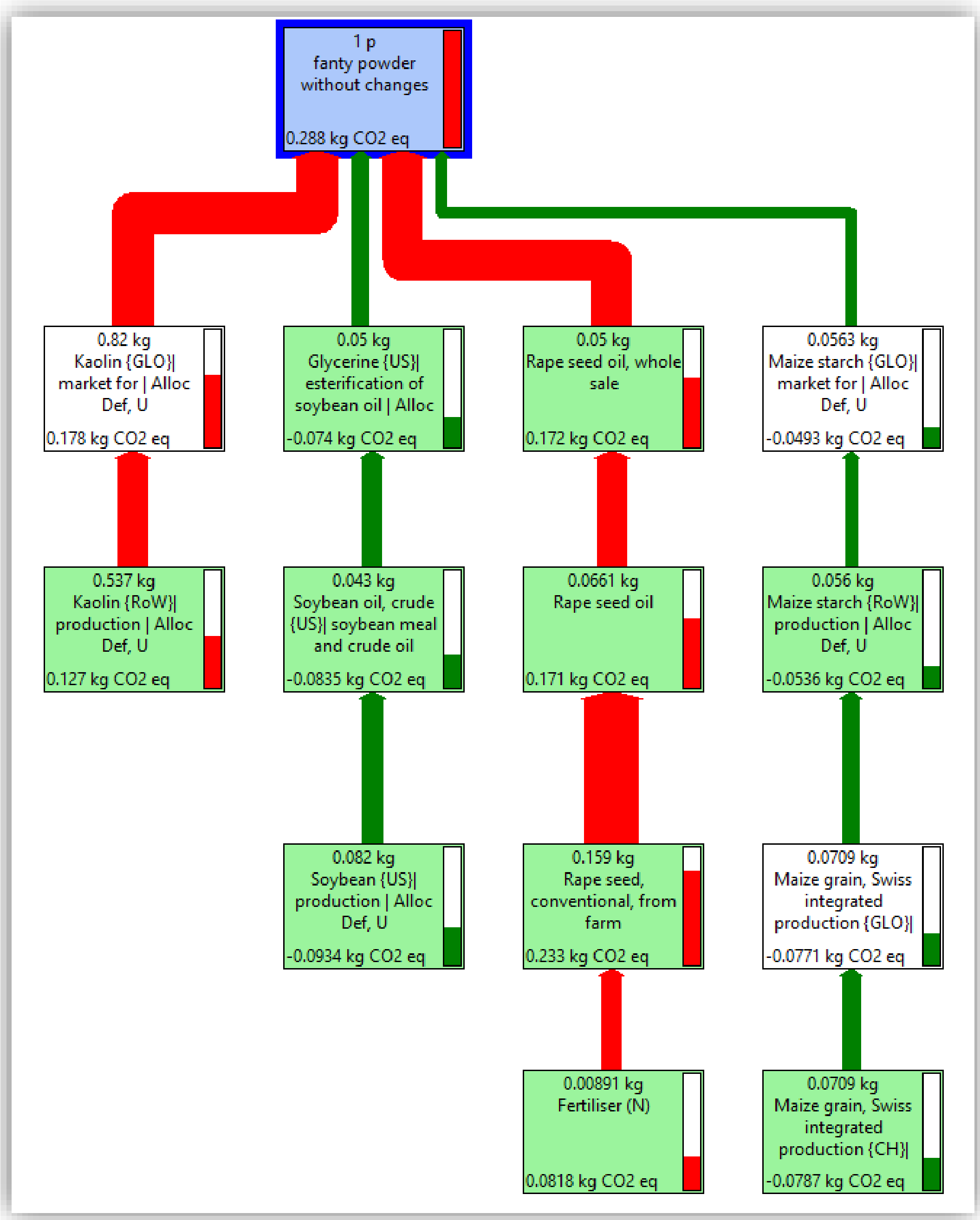


Appendix A15: Figure 15 - Unmodified Tree Diagram 1

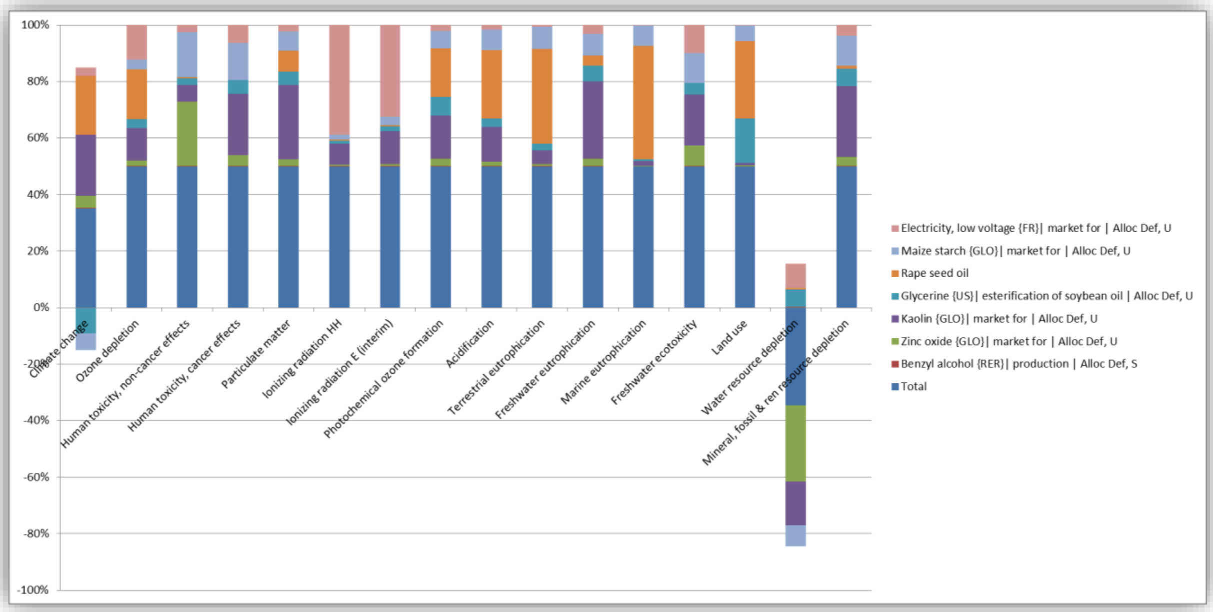

Appendix A16: Figure 16 - Unmodified Tree Diagram 2



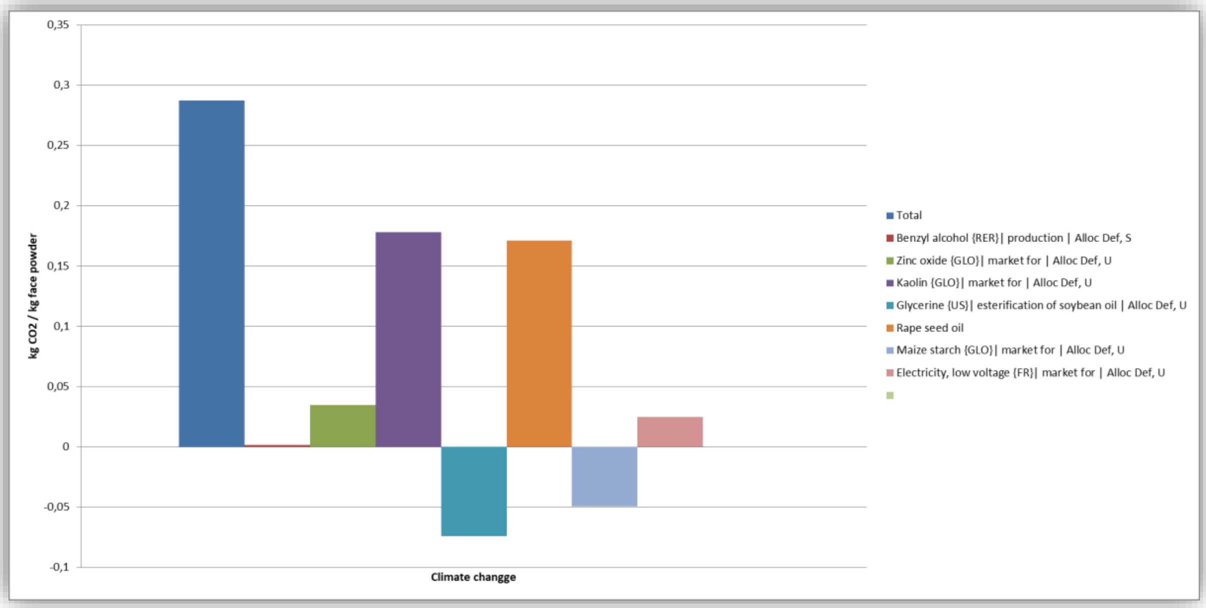
Appendix A17: Figure 17 - Unmodified Tree Diagram 3



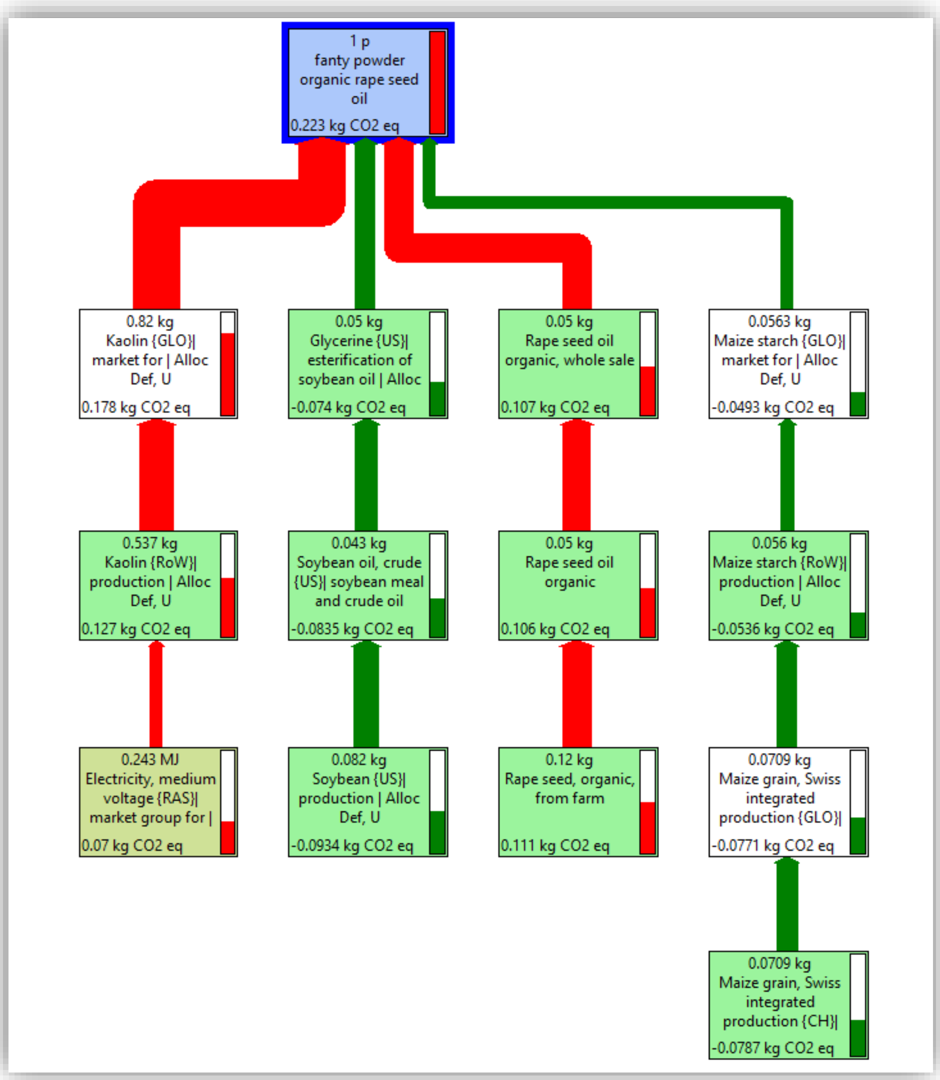
Appendix A18: Figure 18 - Scenario without modifications, raw material impact



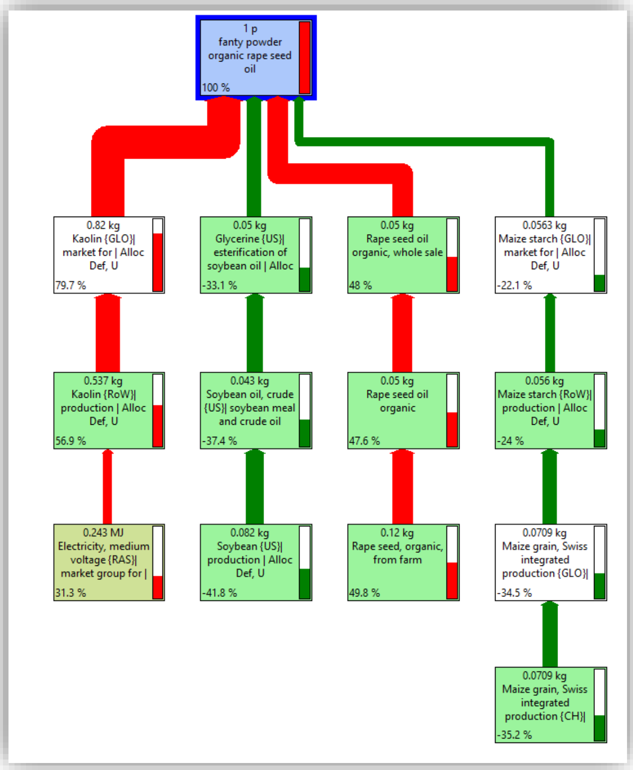

Appendix A19: Figure 19 - Raw materials impact effect on climate change



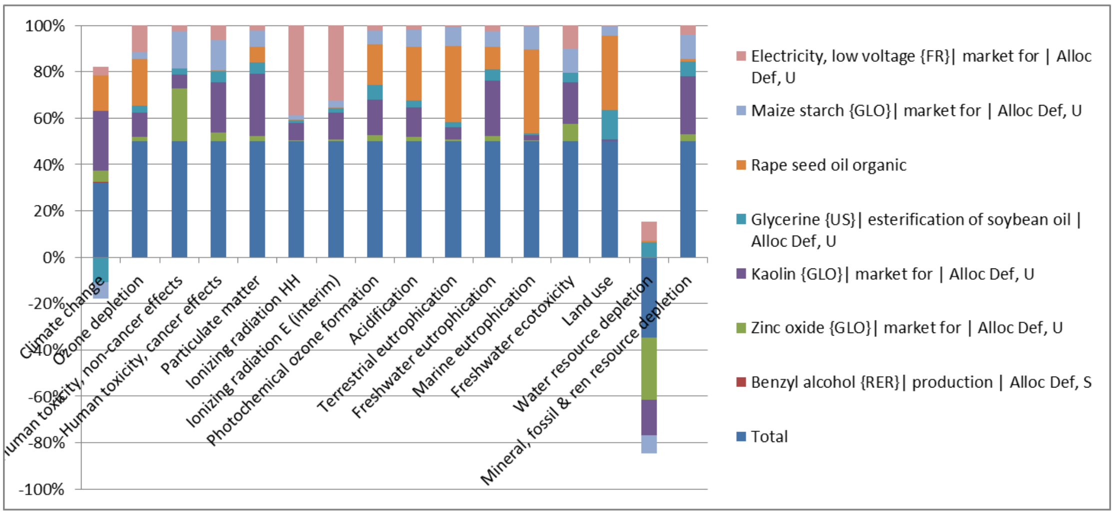
Appendix A20: Figure 20 – Tree Diagram 1 (Rape Seed Modification)



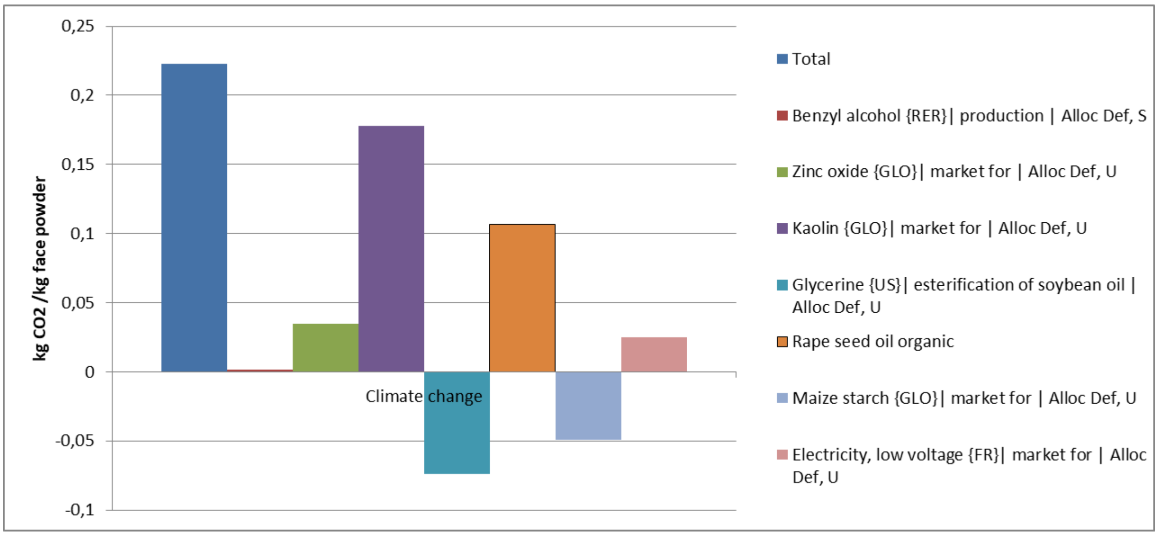
## Appendix A21: Figure 21 – Tree Diagram 2 (Rape Seed Modification)



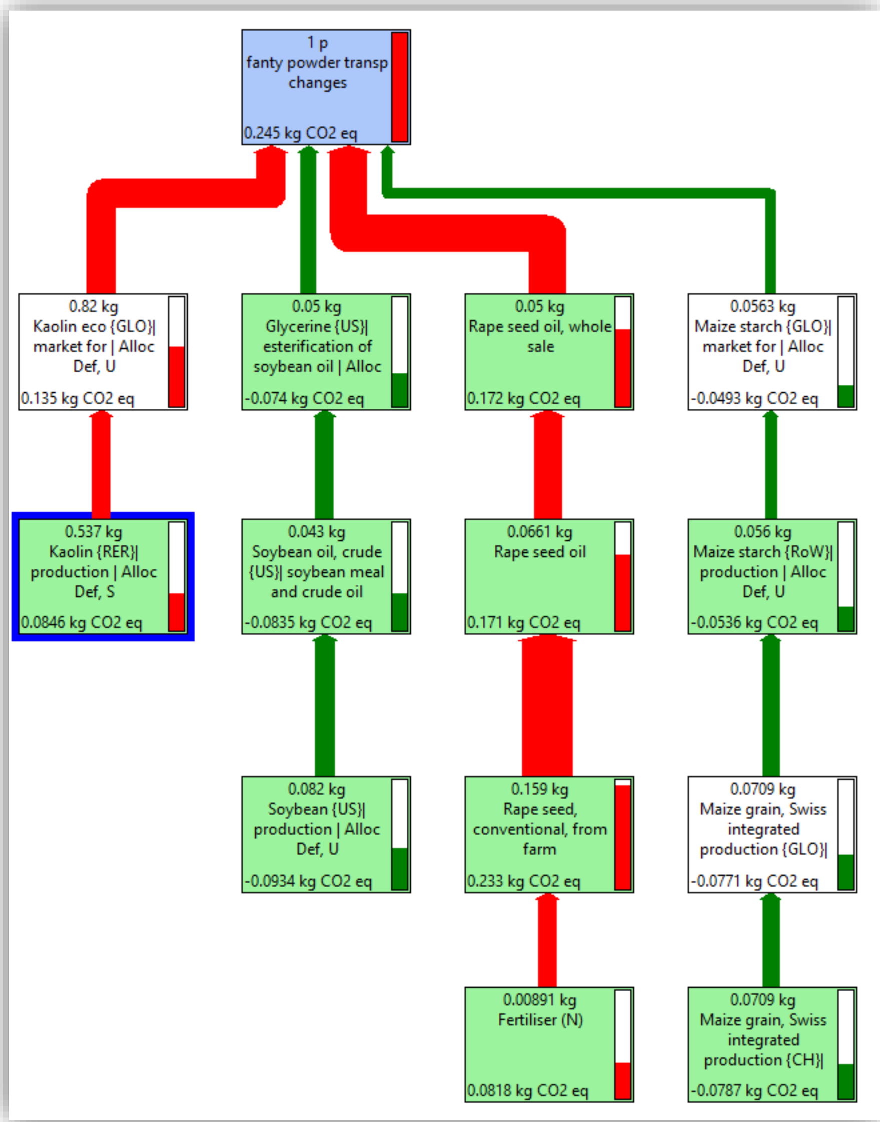

## Appendix A22: Figure 22 – Global Impact of Raw Materials



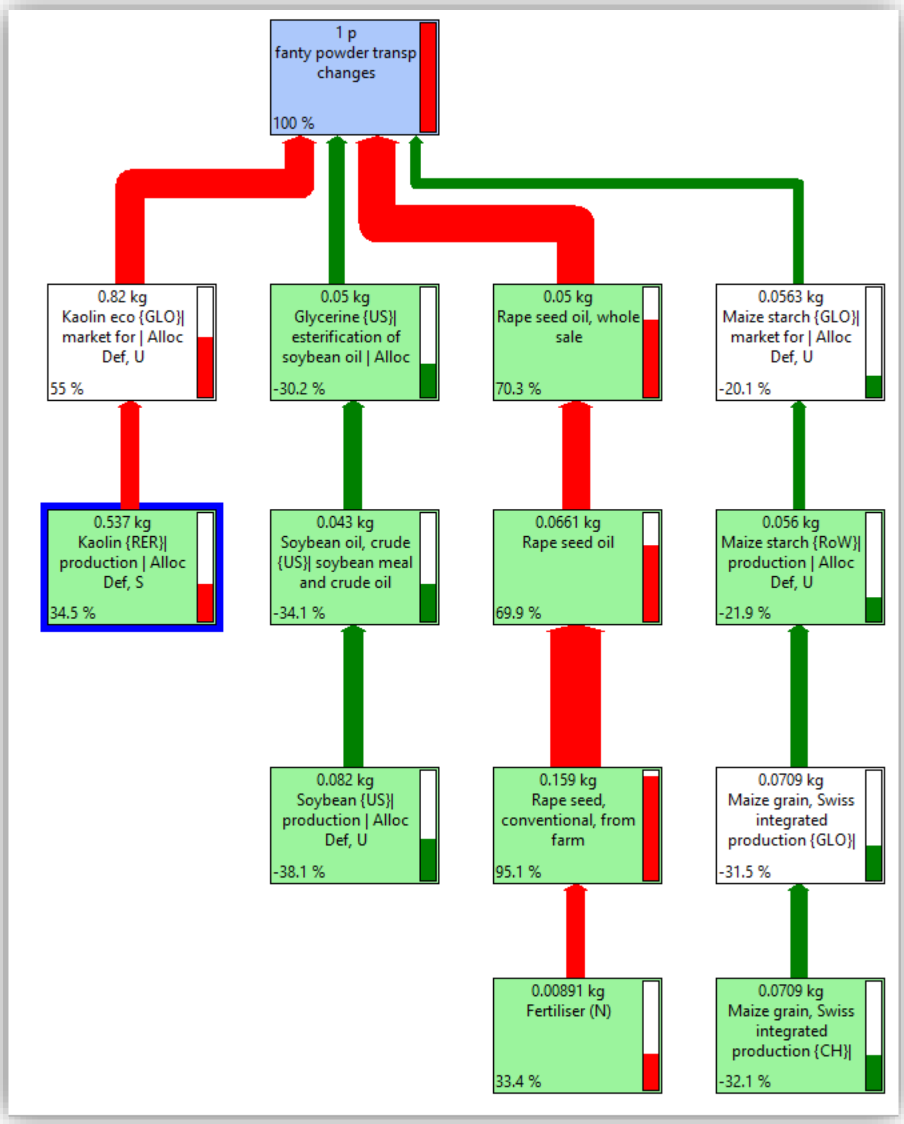
Appendix A23: Figure 23–Global Impact of Raw Materials Vs Climate Change



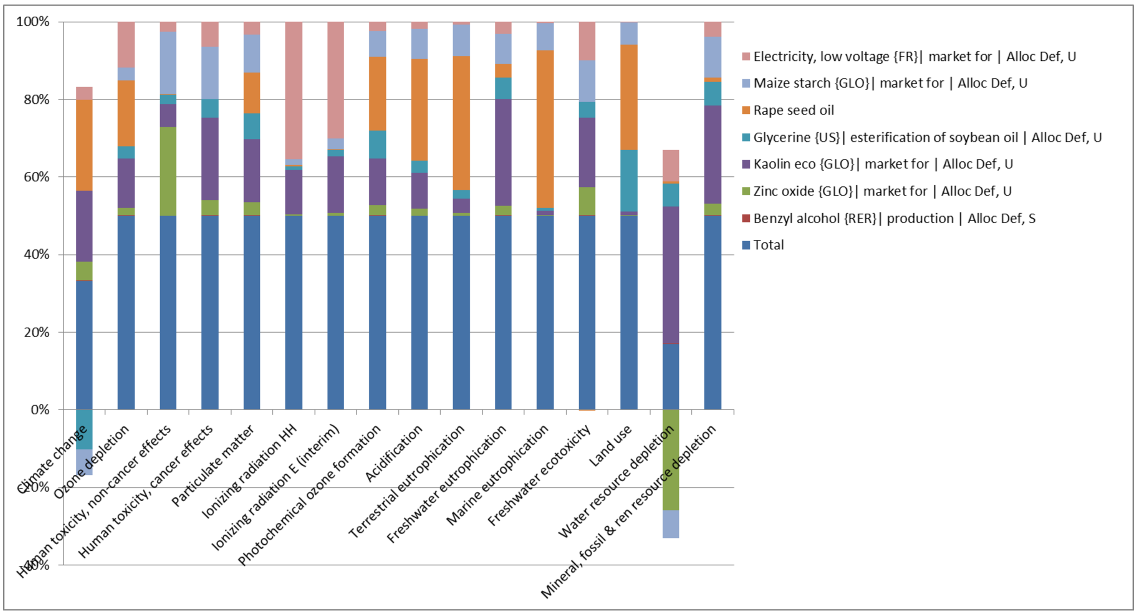
Appendix A24: Figure 24 – Tree Diagram 1 (Kaolin Modification)



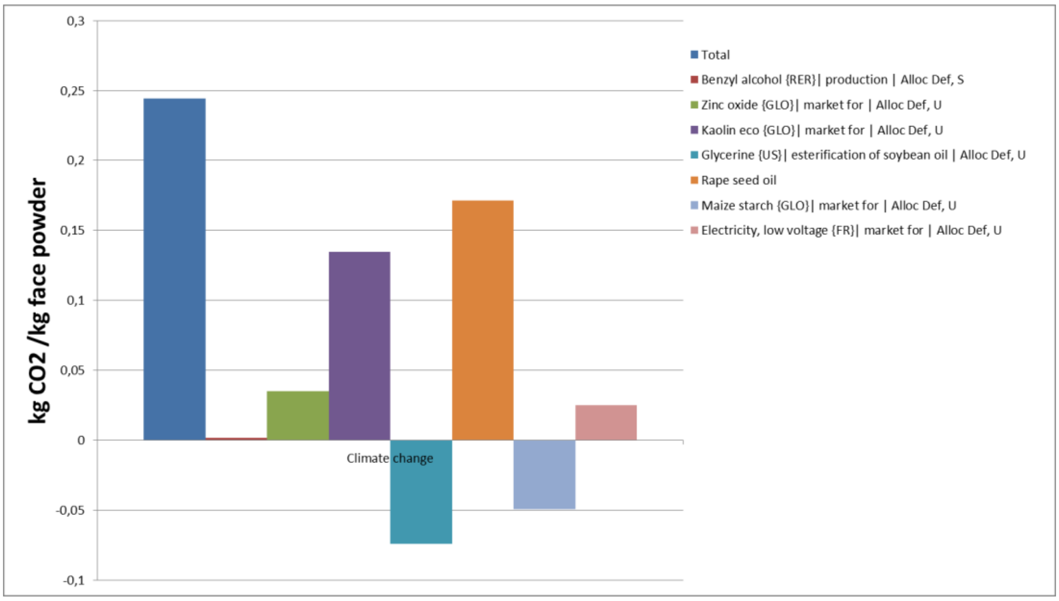
Appendix A25: Figure 25 – Tree Diagram 2 (Kaolin Modification)



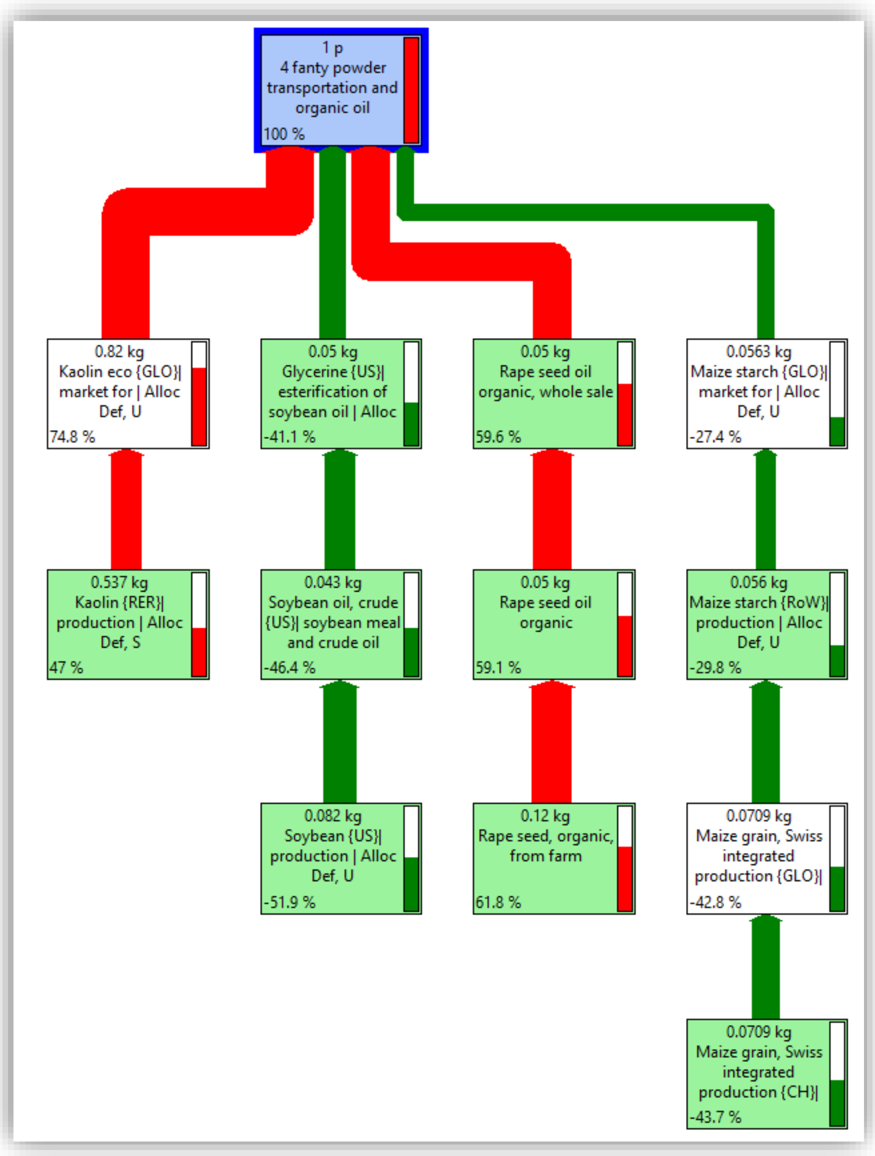
## Appendix A26: Figure 26 – Raw Materials Impact (Kaolin Modification)



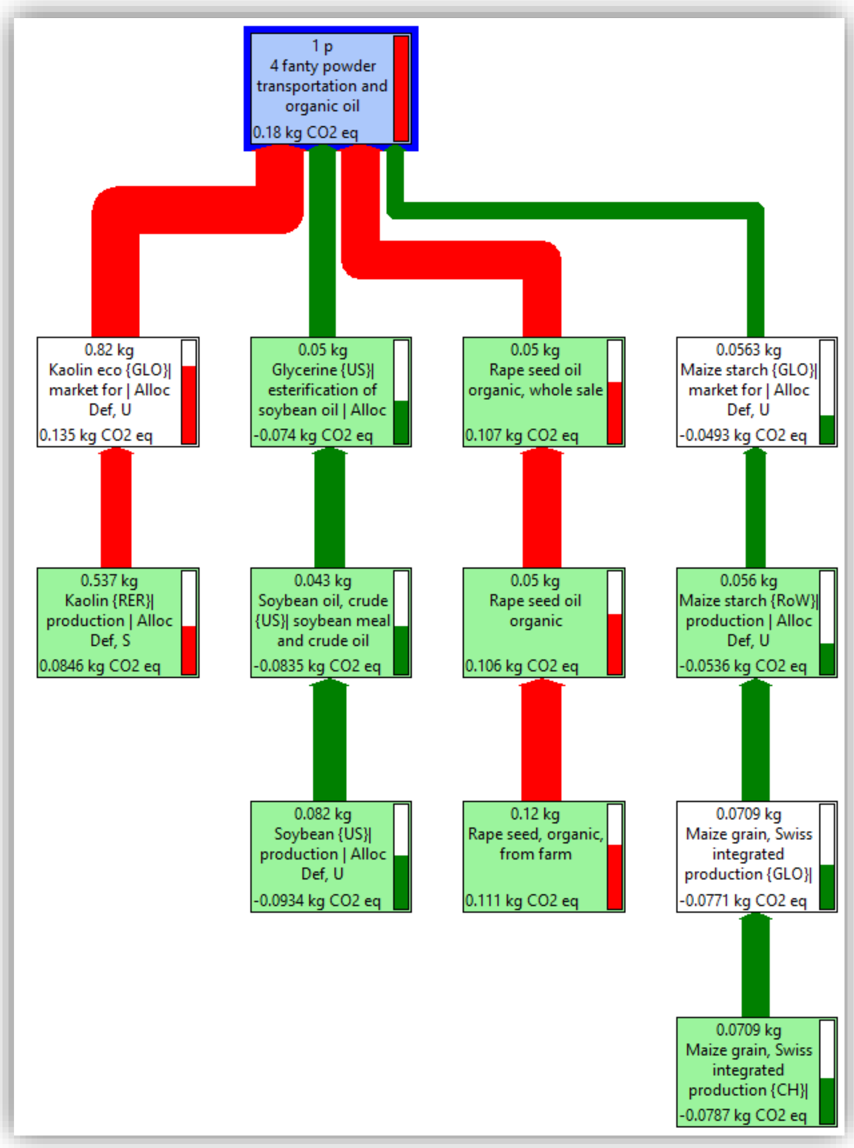

## Appendix A27: Figure 27 –Raw Materials Vs Climate Change (Kaolin Modification)



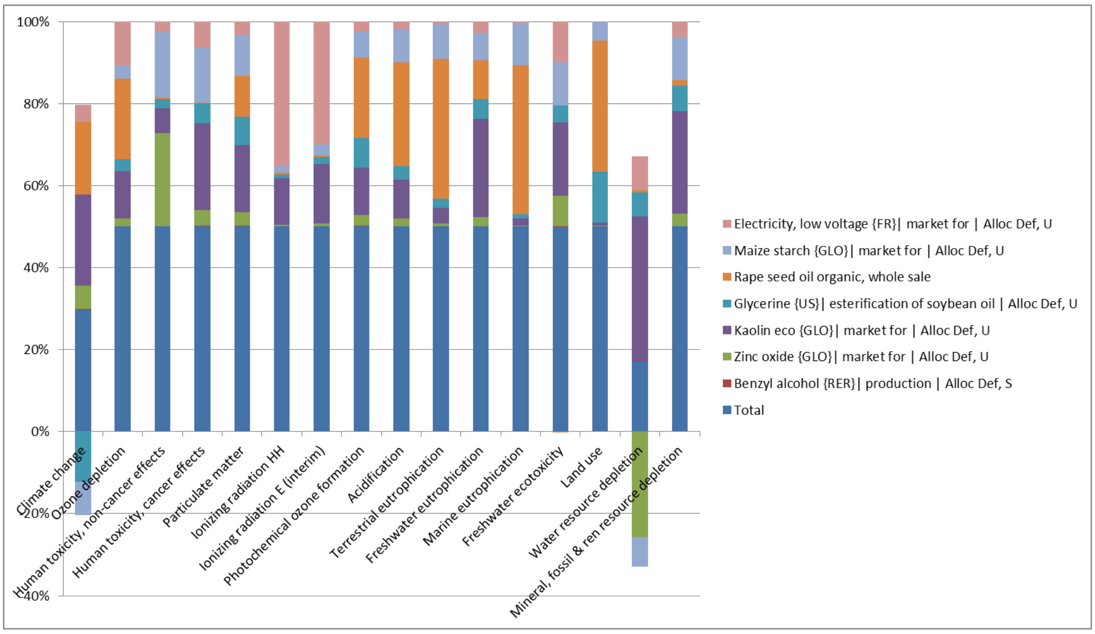
Appendix A28: Figure 28 – Tree Diagram 1 (Rape Seed + Kaolin Modification)



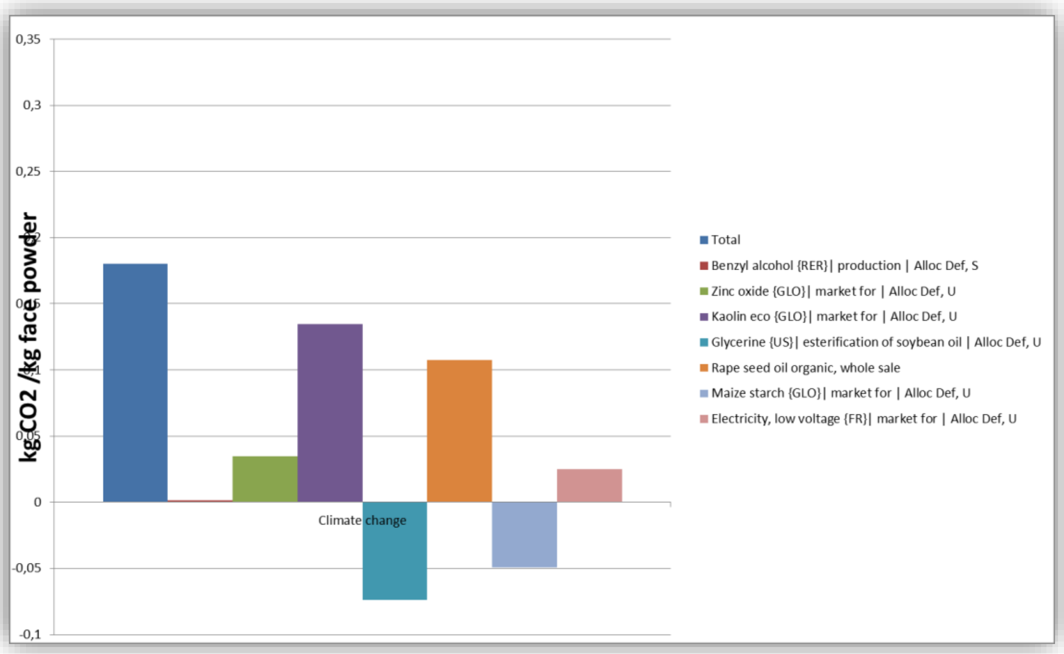
Appendix A29: Figure 29 – Tree Diagram 2 (Rape Seed + Kaolin Modification)



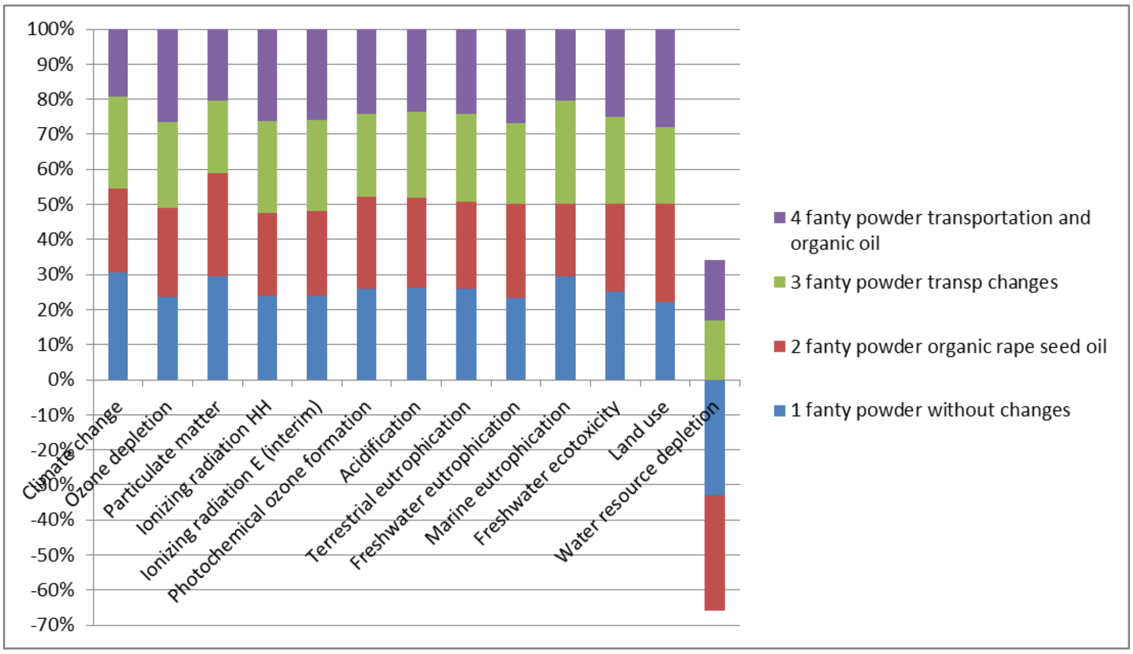
Appendix A30: Figure 30 – Raw Materials Impact (Rape Seed + Kaolin Modification)



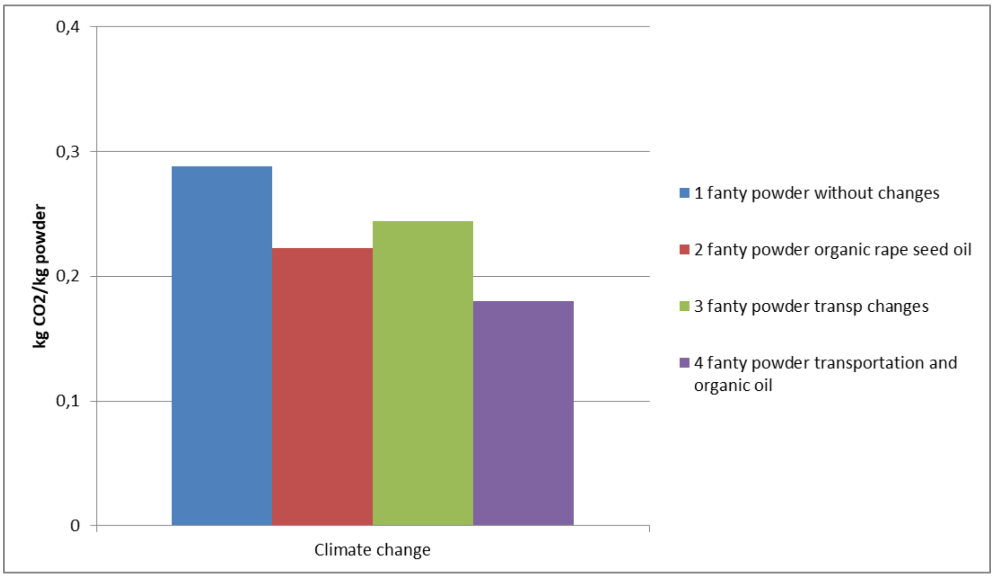

Appendix A31: Figure 31 – Raw Materials (Rape Seed + Kaolin Modification) Vs Climate change



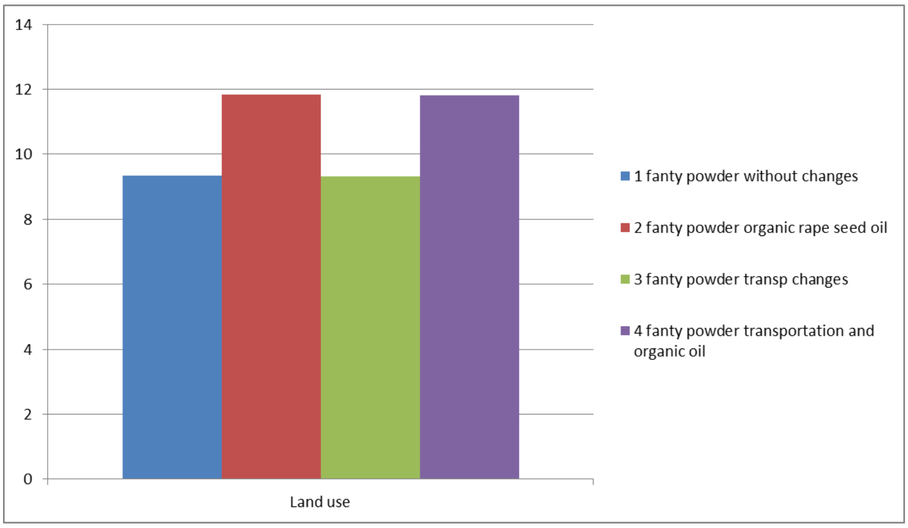
## Appendix A32: Figure 32 – Comparison of the 4 scenarios



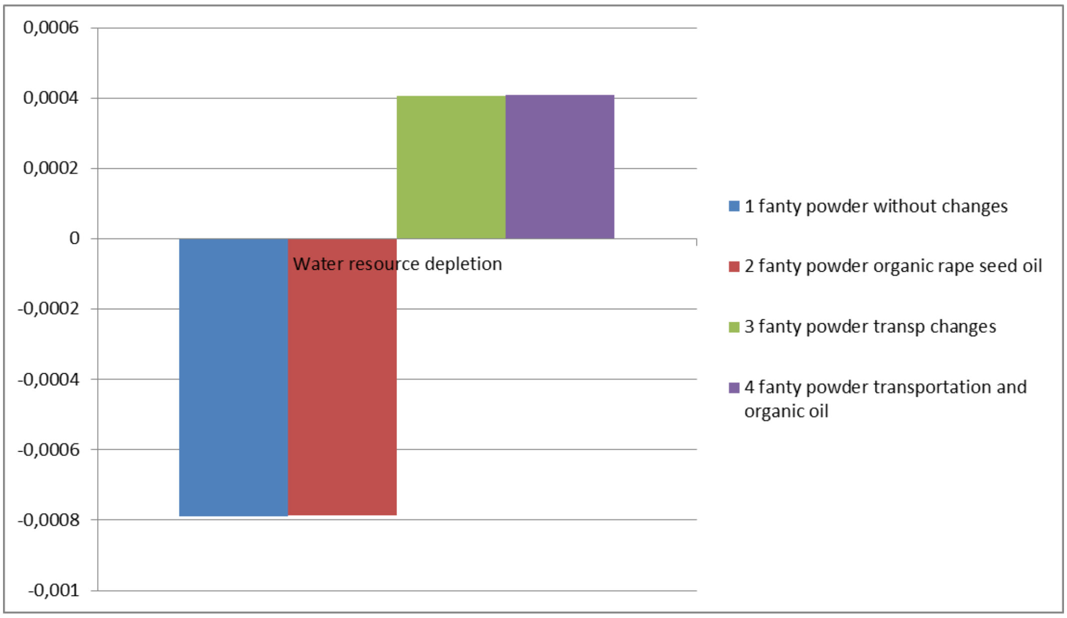

## Appendix A33: Figure 33 – 4 Scenarios against Climate change



Appendix A34: Figure 34 – 4 Scenarios Vs Land Use




Appendix A35 : Figure 35 – 4 Scenarios Vs Water Resource depletion



Appendix A36 : Figure 36 – 4 Scenarios Vs Ionization Radiation