Comparative Life Cycle Assessment of Mosquito nets | Review

Project: Accelerating the Reduction of the Environmental Impact of Humanitarian Action

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Science and Technology for Humanitarian Action Challenges (HAC)

Project website: https://climateactionaccelerator.org/accelerating-the-reduction-of-the-environmental-impact-of-humanitarian-action/

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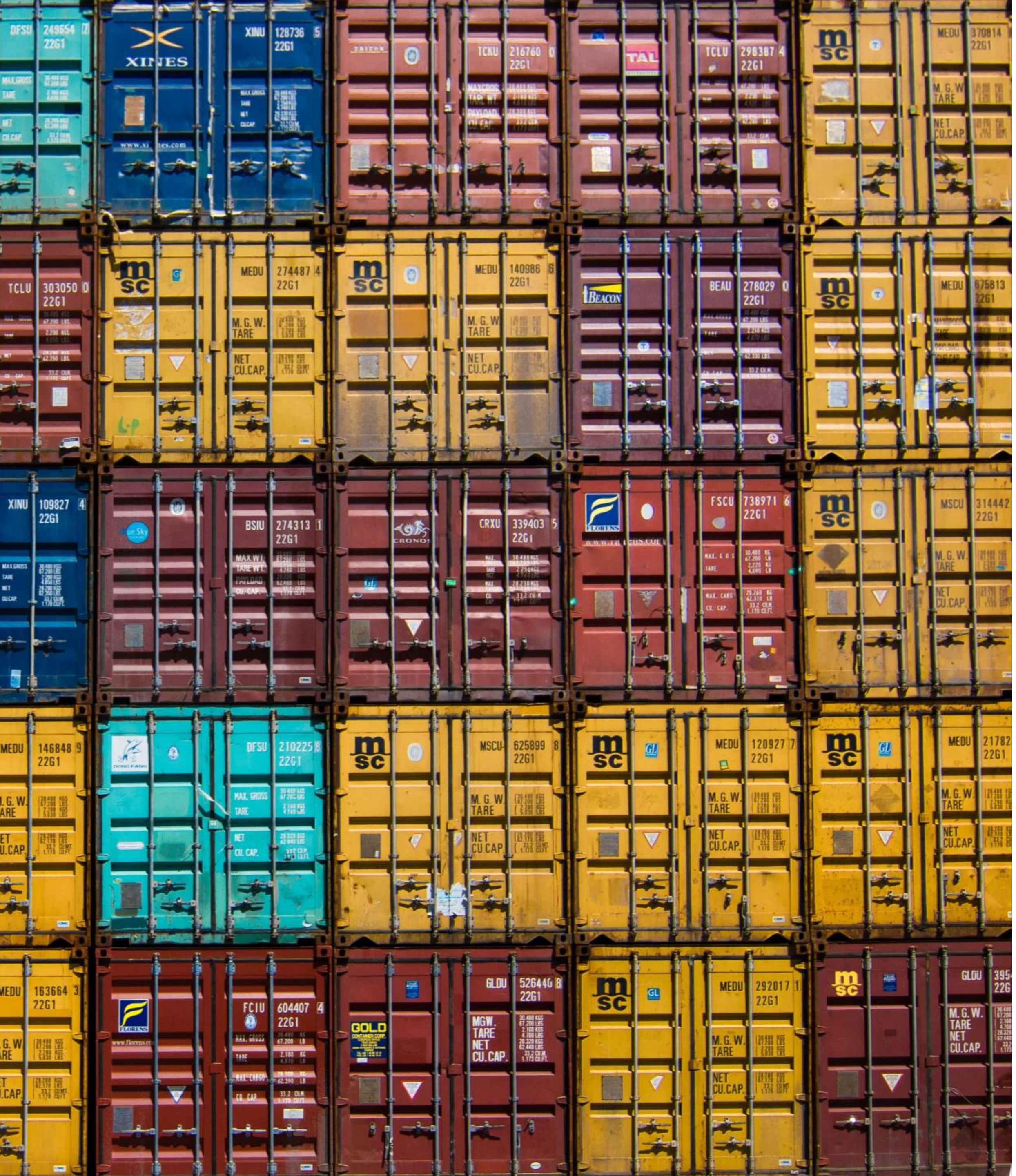


Acknowledgement

The project team warmly thanks UNITAID for generously sharing data and insights from the life cycle assessment of mosquito nets conducted as part of the report *"From Milligrams to Megatons."* The findings from this existing LCA served as a basis for the present analysis.

The content of this document is the sole responsibility of the project team.

https://unitaid.org/uploads/Report_From-milligrams-to-megatons_A-climate-and-nature-assessment-of-ten-key-health-products.pdf

Contents

Introduction

Objectives and scope

This analysis aims to enhance understanding of the item's impacts on climate, human health, and plastic leakage. It also identifies potential levers to reduce these impacts. However, assessing the feasibility of implementing these levers falls outside the scope of this project.

By no means is it suggested that life-saving assistance to the most vulnerable populations across the world should be reduced for decarbonisation purposes. Effective emissions and other impact reductions should not result in any reduction in the quality, quantity or timeliness of assistance, but rather should explore ways to reinforce or maintain aid, while identifying low-carbon, sustainable, and resilient alternative options.

Objectives and scope

Objectives:

- To establish GHG Emission Factors for **mosquito nets (LLINs)** adapted to the humanitarian context
- To analyse the environmental impact of the product's life cycle and identify key levers for impact reduction through a comparative analysis between two types of materials.

Scope & System Boundary:

- **Cradle-to-grave*** system for the assessment of impact across the complete life cycle.
  - The materials, production, distribution, use and disposal of the product are in scope of the study
  - Any additional processes after production are not in scope e.g. unplanned storage, etc.
  - The procurement of the packaging is modelled, upstream activities related to the packaging are out-of-scope
  - The study focuses on one unit of the product and does not include larger-scale supply activities i.e. shipping per container, etc.

*In life cycle assessment, **cradle-to-grave** refers to evaluating a product's environmental impacts from raw material extraction through manufacturing, use, and final disposal. In contrast, **cradle-to-gate** focuses only on the stages up to the product's departure from the manufacturing site, excluding use and end-of-life phases.

Methodology

The results are calculated following the Environmental Footprint 3.1 indicator system in two categories:

- **Climate Change**: Global Warming Potential (GWP100)
- **Impact on Human Health**:
    - Human Toxicity: Carcinogenic and Non-carcinogenic
    - Ionising Radiation
    - Particulate Matter Formation
    - Photochemical Oxidant Formation
  - Weighted using the approach detailed in the EF methodology – with a percentage assigned to each sub indicator (see reference)
  - Normalized for one citizen so as to aggregate and represent as a single score for human health

Plastic leakage: Experimental projection of the amount of plastic leaked into nature via mismanagement of waste

References:
"European Platform on LCA | EPLCA.". https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html
Joint Research Centre (European Commission), Alessandro Kim Cerutti, Rana Pant, and Serenella Sala. 2018. Development of a Weighting Approach for the Environmental Footprint. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/945290

End-of-life

This study aims to model the impact differences between various waste management methods tailored closer to humanitarian contexts. The following end-of-life options were modelled in the analysis, as appropriate:

- **Open dump** (unmanaged)
- **Open burning** (unmanaged)
- **Unsanitary landfill** (minimal management)
- **Sanitary landfill** (managed site)
- **Municipal incineration** (managed plant)
- **Recycling** (as modelled)

For plastics, the differences in measured impact between each end-of-life scenario are similar. (For more info on the impacts and sources of end-of-life impact measurement please see annex.)

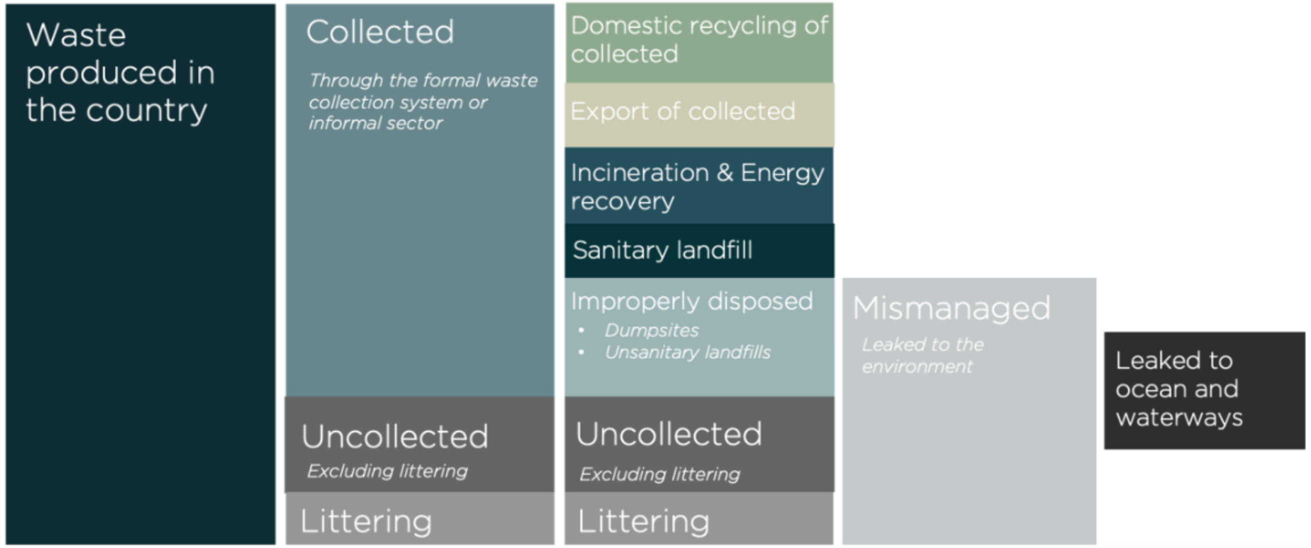
According to the LCA methodology, the analysis of greenhouse gas (GHG) emissions (Global Warming Potential)—is limited to a 100-year timeframe. As a result, any additional impact from plastic degradation in landfills occurring beyond this period is neither measured nor compared to other waste disposal methods.

Plastic leakage

This project aims to estimate the mismanaged waste that may occur at the end of life of products distributed by humanitarian organisations.

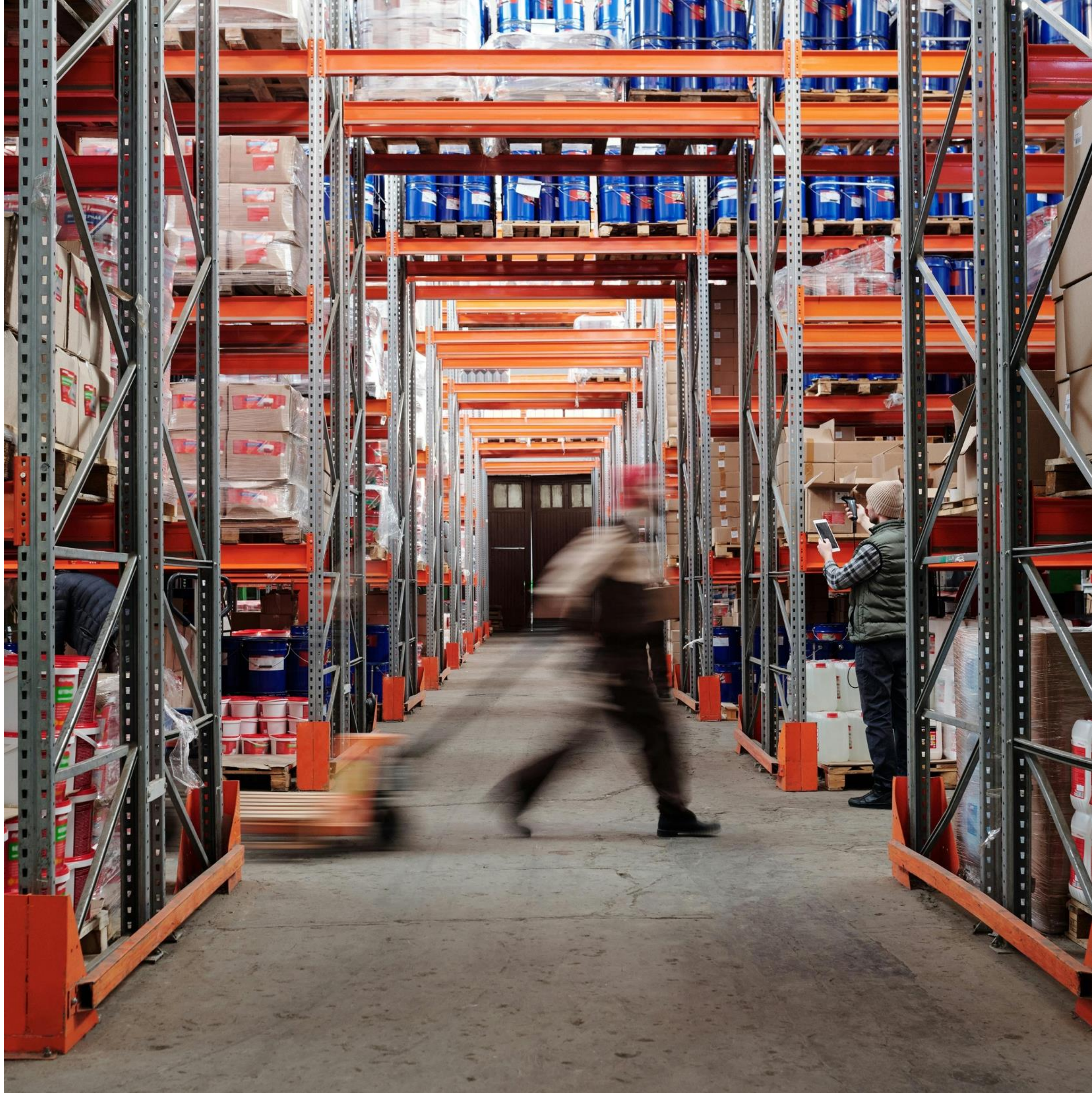
The modelled scenarios are analysed for plastic leakage by selecting the waste management method that is modelled and calculating the projected leakage (or lack thereof) due to the same.

For more information, please refer to: "Global Plastic Environmental Analytics Platform." Plasteax. https://plasteax.earth/.



Source: EA – Earth Action

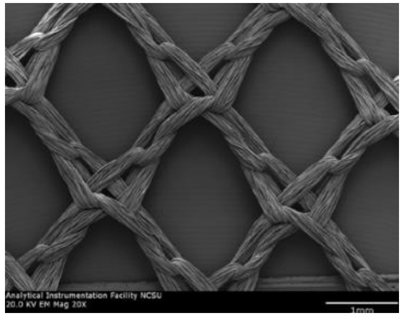
LCA Results

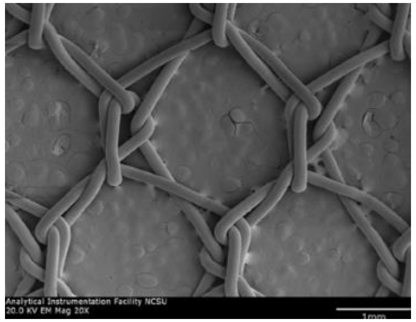


Key Product Parameters & Assumptions

LIFE-CYCLE STAGE	PARAMETER	DESCRIPTION OF MODEL
GENERAL	Field Context	Assessing the impact of the two main type of Long-Lasting Insecticide Nets (LLIN) distributed by humanitarian organisations and pre-qualified by WHO.
Raw Material	Bill of Materials	• Virgin PET (net weight 530g, 100 D) OR • Virgin PE (net weight 350g 150 D) Insecticide: Alpha-Cypermethrin and Chlorfenapyr (6g/net)
	Packaging	PE Film with packing tape
Production	Manufacturing Location	China
	Manufacturing Processes	Modelled as electricity consumption
Supply & Distribution	Transport Chain	TRUCK at origin for materials and final product SEA shipping to regional DC in Africa TRUCK at destination for storage and distribution
Use	Lifespan	Virgin PET: 2 years (holes begin to emerge in the PET fabric) Virgin PE: 3 years (standard life of insecticides in the net)
	Usage Processes	None
Waste Management	Product Disposal Method	Open burning
	Packaging Disposal Method	Open burning

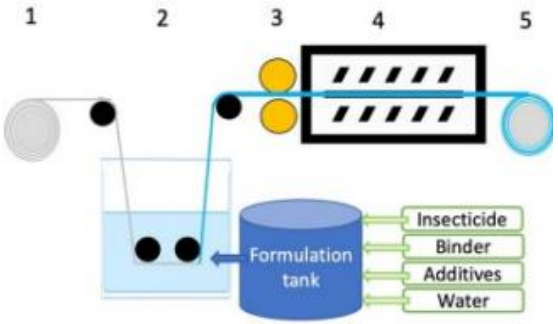
Key Product Parameters & Assumptions

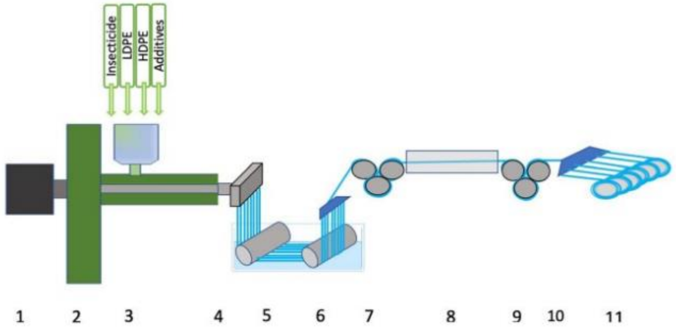




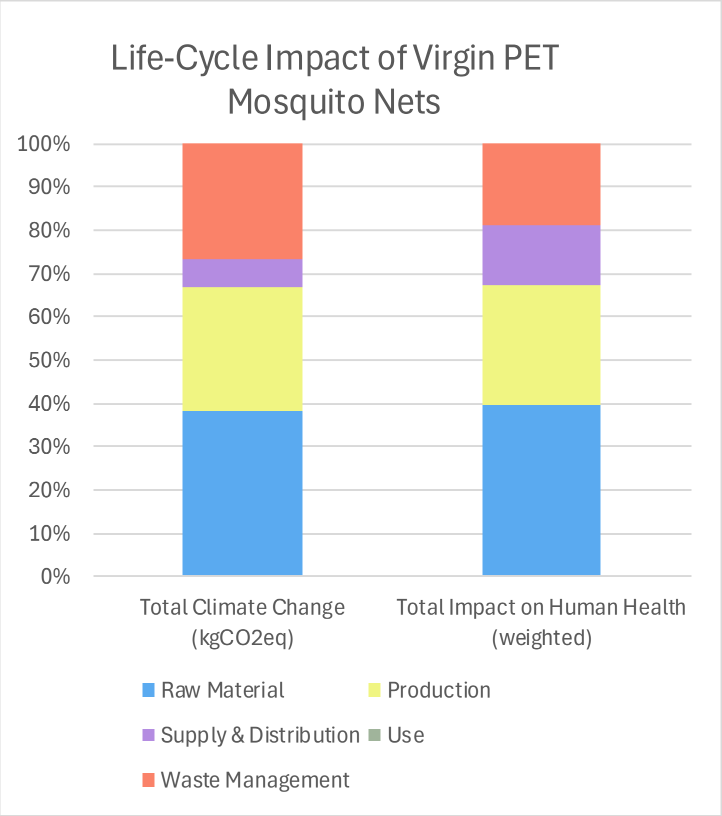
Polyester (Polyethylene Terephthalate, PET) LLINs are made from yarns composed of multiple filaments twisted together during the production process. In PET LLINs, the insecticide is applied as a surface coating.

Polyethylene (PE) LLINs are typically made from single-filament yarns extruded with additives, colorants, and insecticide. As a result, the insecticide is distributed throughout the yarn, a process known as 'incorporation' technology.

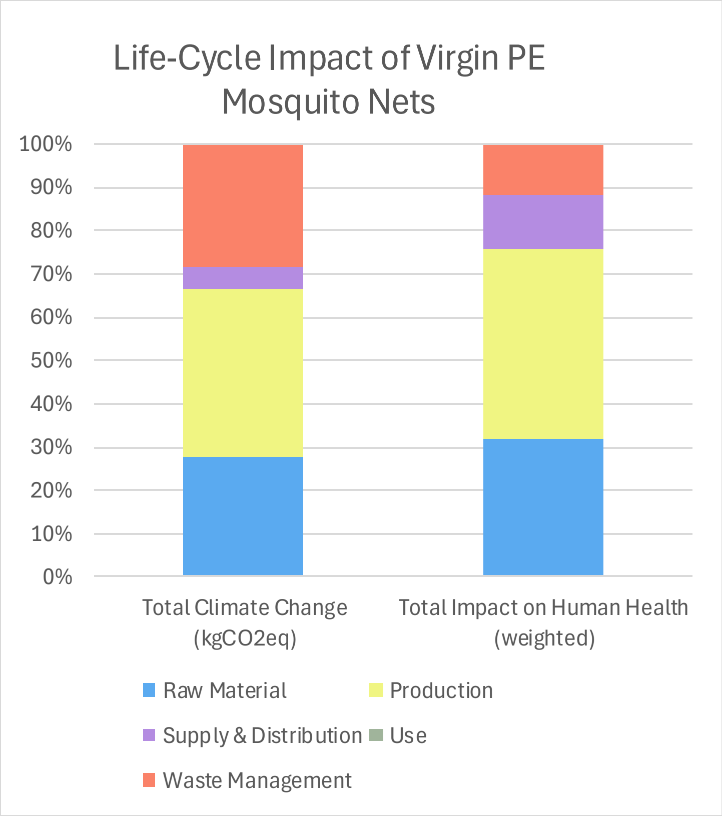




Baseline Results



- Both being polyethylene products, the distribution of impact is very similar between virgin PET and virgin PE mosquito nets.
- The emission factor is lower for virgin PE, whilst it also has a longer lifespan.
- Insecticides account for 2-3% of impacts (GHG and Human Health)
- Plastic leakage
    - It is assumed that nets are incinerated, thereby avoiding leakage for the product.
    - The packaging is assumed to be dumped/littered causing leakage for all scenarios.



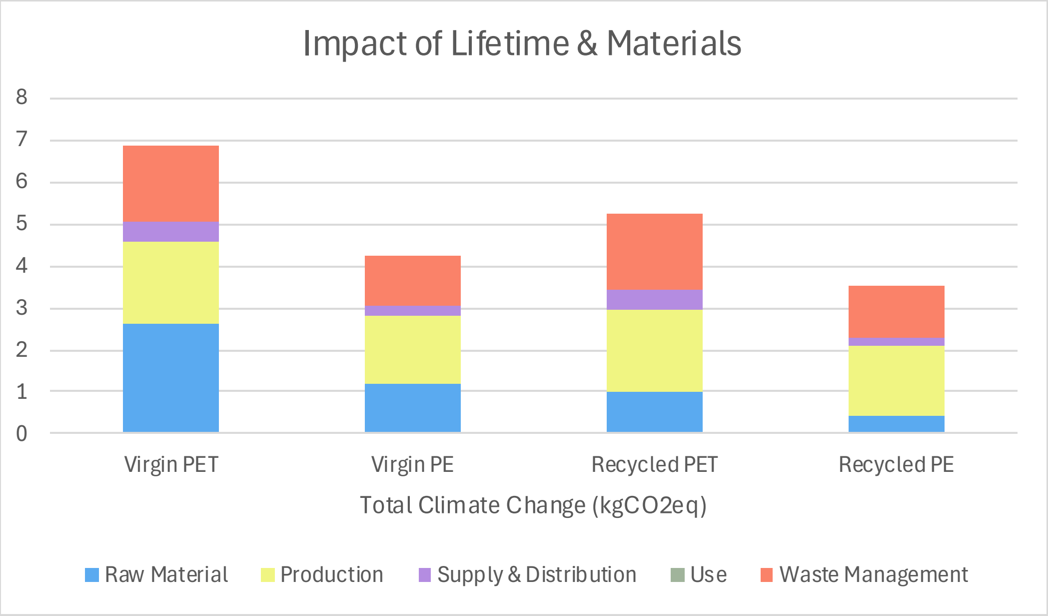
Emission factors		Unit
Cradle-to-grave	4.58	kgCO2eq/unit
Cradle-to-gate	3.10	kgCO2eq/unit

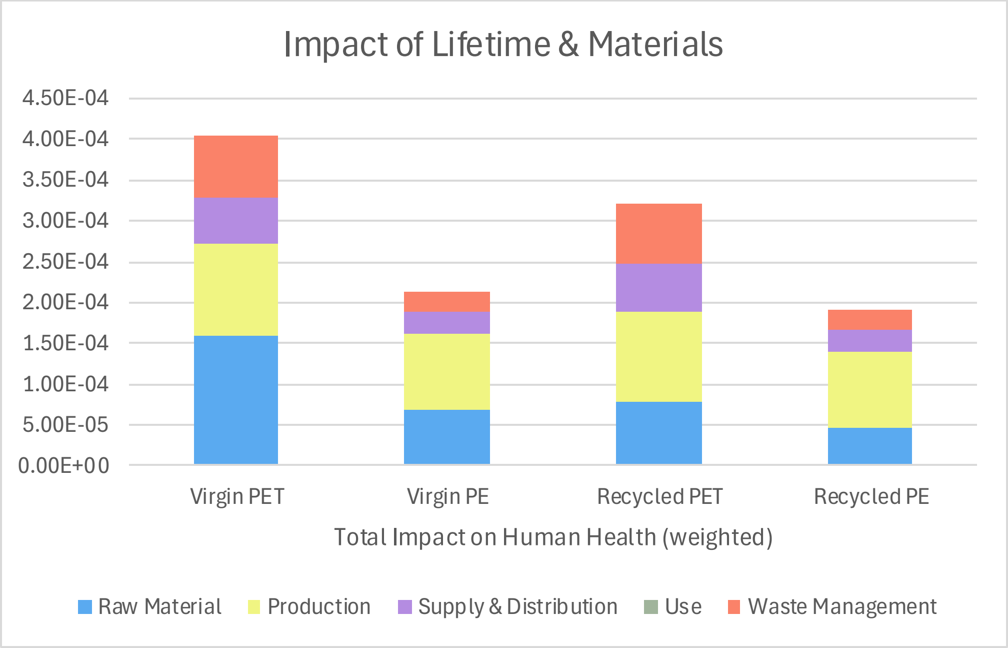
Emission factors		Unit
Cradle-to-grave	4.24	kgCO2eq/unit
Cradle-to-gate	2.85	kgCO2eq/unit

Variations per lifecycle stage

	Raw Material	Production	Use Life	Supply & Distribution	Waste Management
Baseline	Virgin PET	Average energy mix	No washing	TRUCK – SEA – TRUCK	Open Burning
	Virgin PE	Solar energy for production		TRUCK – AIR – TRUCK	Recycling in Europe
	Recycled PET				
	Recycled PE				

Materials



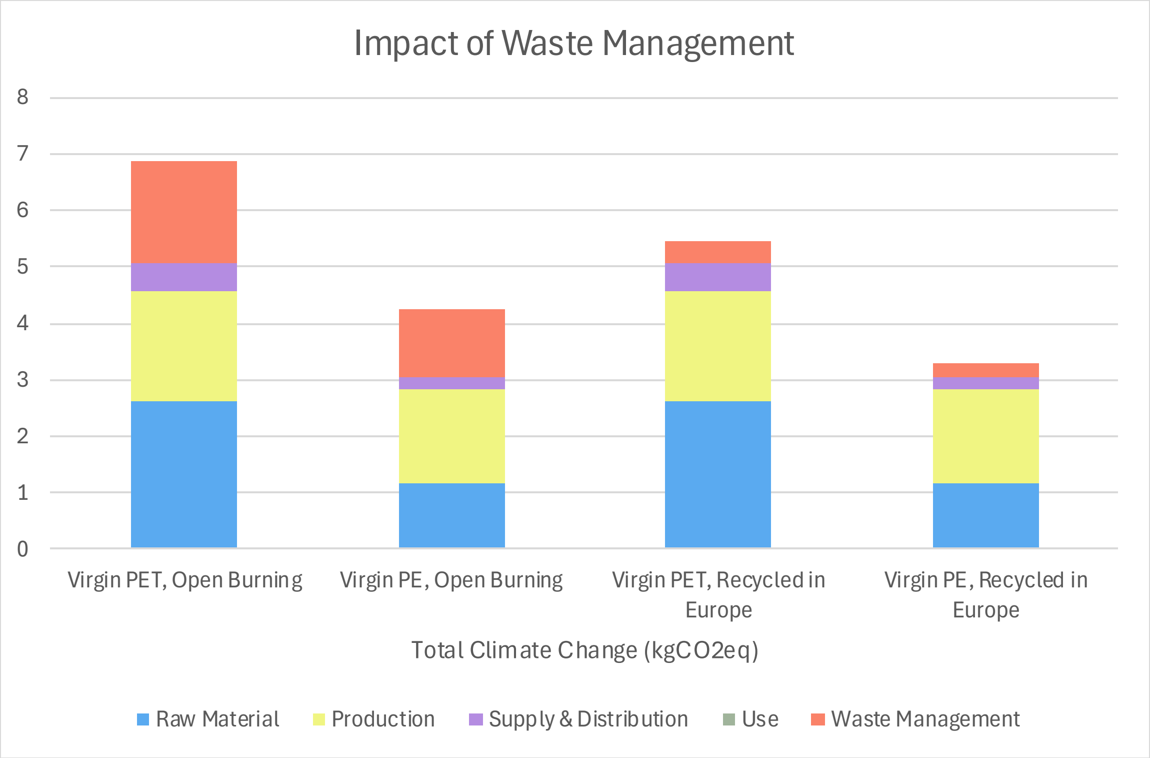


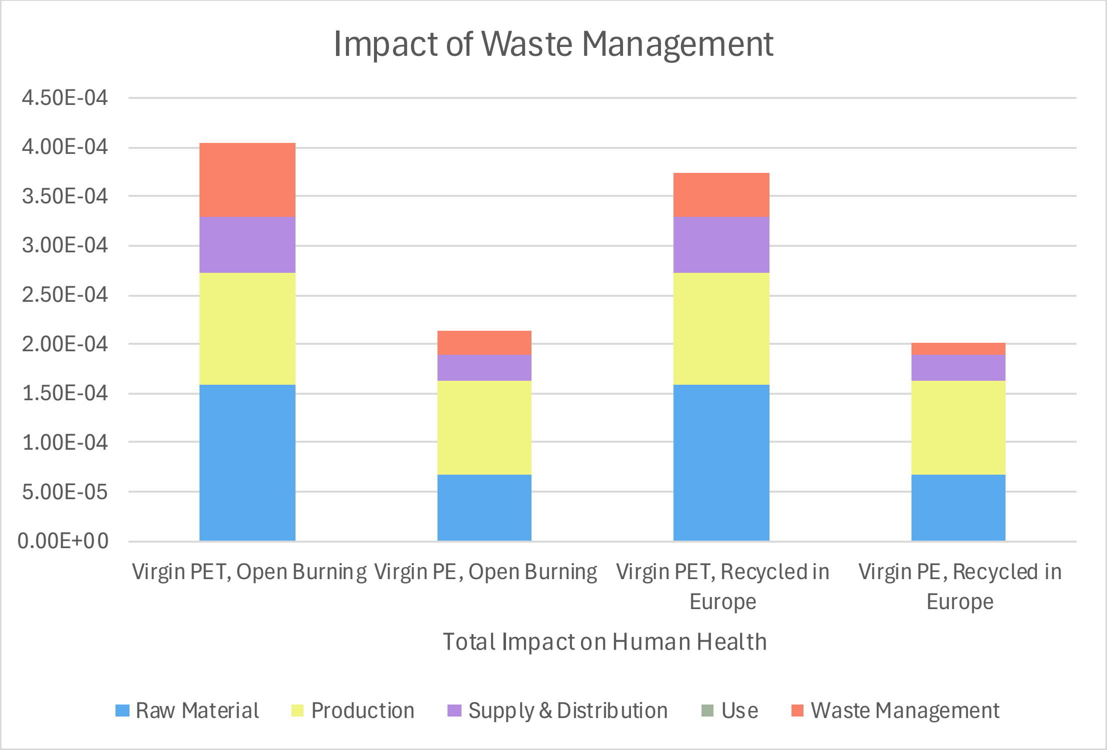
Lifetime and Materials

- While 100% recycled materials are not currently feasible, assessing their maximum theoretical impact helps illustrate the potential scale of this lever for LLINs.
- Using PE nets instead of PET nets, reduces the GHG emissions impact by **38%**, and human health impacts by **47%.**
- Comparing against their virgin plastic versions, we observe that for the defined functional unit (3 years of protection), switching to recycled plastics results in the following reductions:
  - Recycled PET: **24%** reduction in GHG emissions & **20%** reduction in impact on human health
  - Recycled PE: **17%** reduction in GHG emissions & **10%** reduction in impact on human health

Note: Since virgin PET nets have an assumed lifespan of only 2 years—after which holes begin to form in the fabric—this study compares 1.5 virgin PET nets with 1 virgin PE net, which lasts 3 years and meets the defined functional unit of 3 years.

Waste management

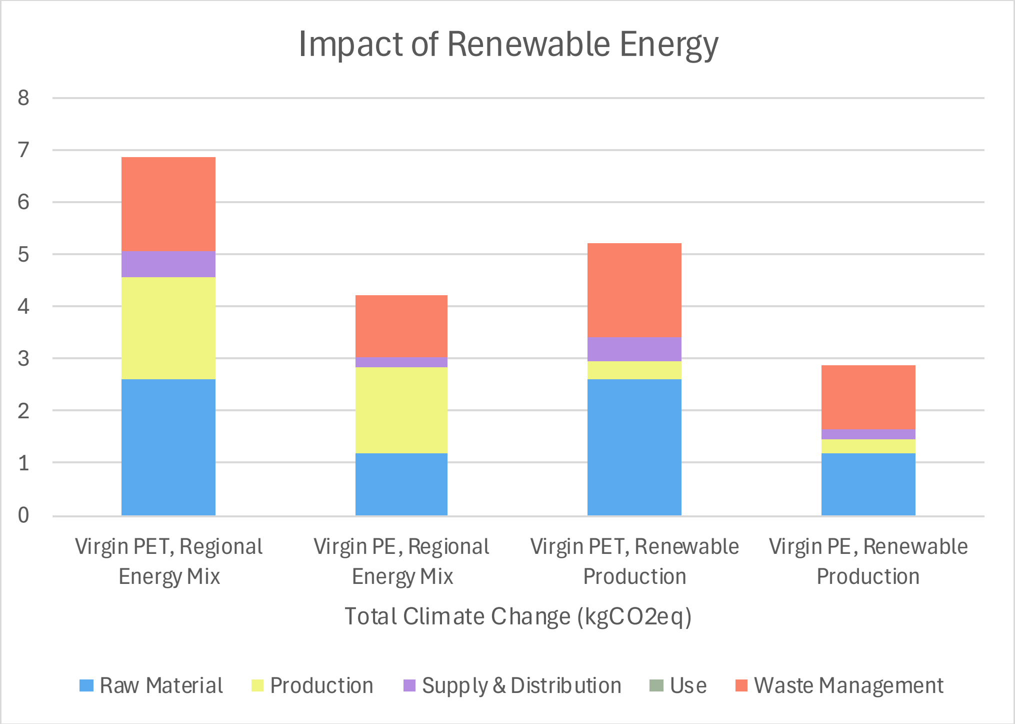


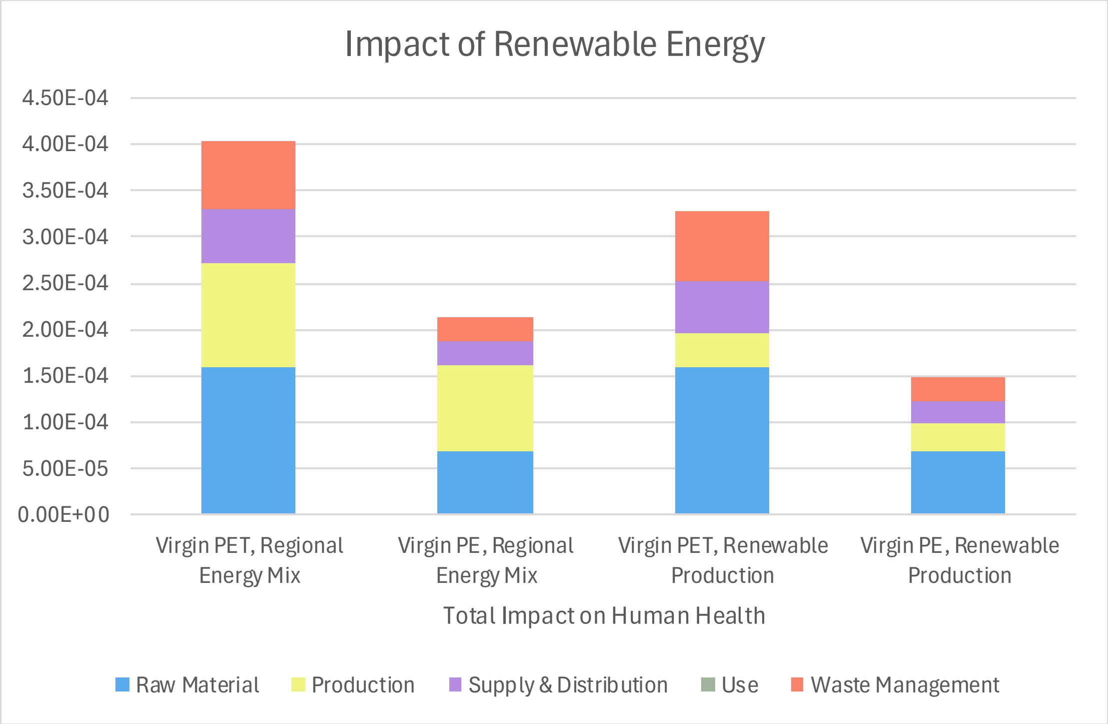


Waste Management

- At baseline, both product types are considered to be burnt in open pits at the end of their lives. To neutralise this impact, this study models an alternative scenario where, at the end of the 1st use life of the product, the items are collected and taken to Europe for polyethylene recycling. Even if it is also theoretical, it represents the maximum achievable reduction in this field.
- This results in a net reduction of **21%** of GHG emissions and **~6%** impact on human health for both variations of mosquito nets.

Energy for Production

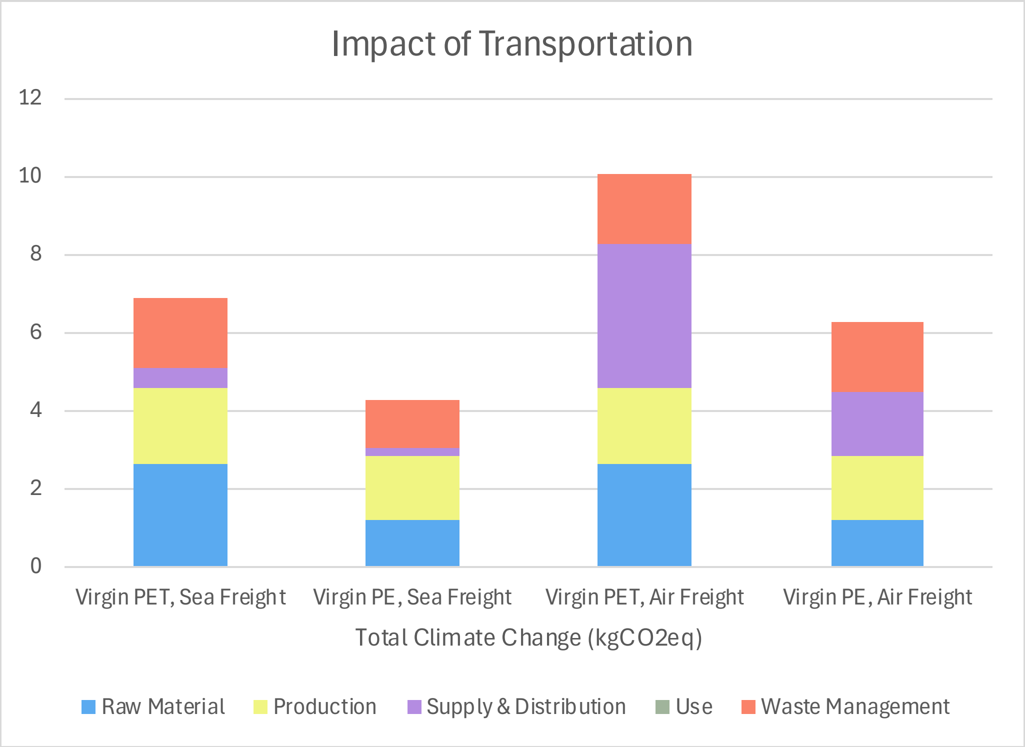


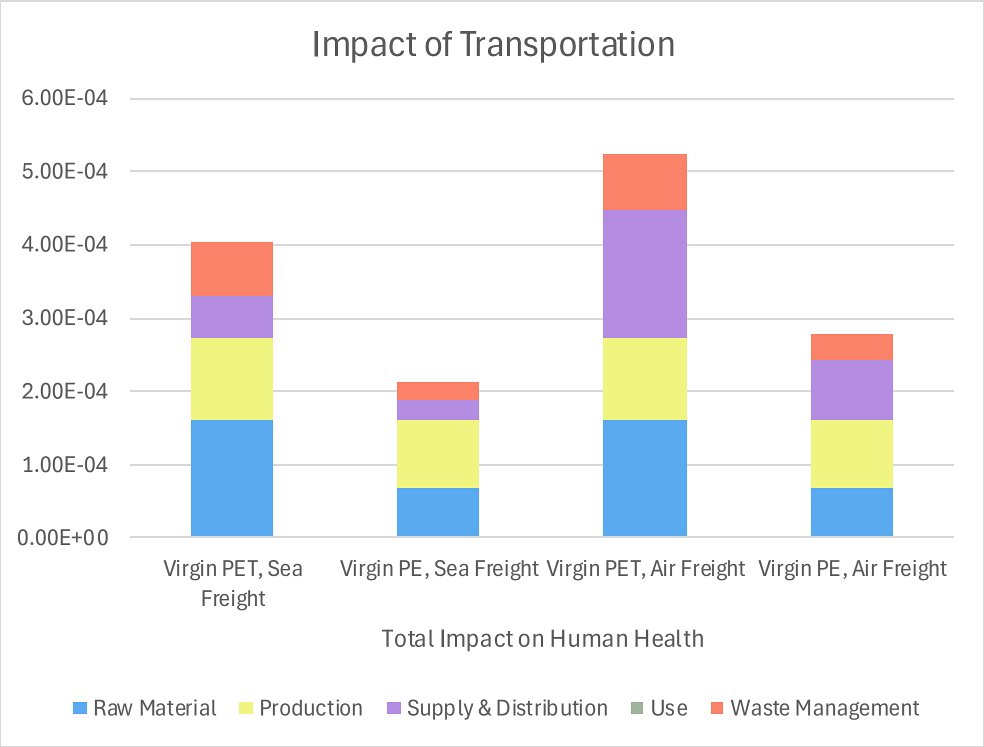


Energy for Production

- Switching the energy source of the production of the electricity or the heat used during the production phase can lead to a reduction of environmental impacts. This is particularly the case when energy sources intensive in fossil fuel are replaced with renewable energy sources
- <u>Comparing against their virgin versions,</u> using solar panels to produce the electricity needed to manufacture the nets results in the following impact reductions:
  - Virgin PET: **24%/19%** reduction in GHG emissions & human health respectively
  - Virgin PE: **32%/30%** reduction in GHG emissions & human health respectively

Impact Assessment



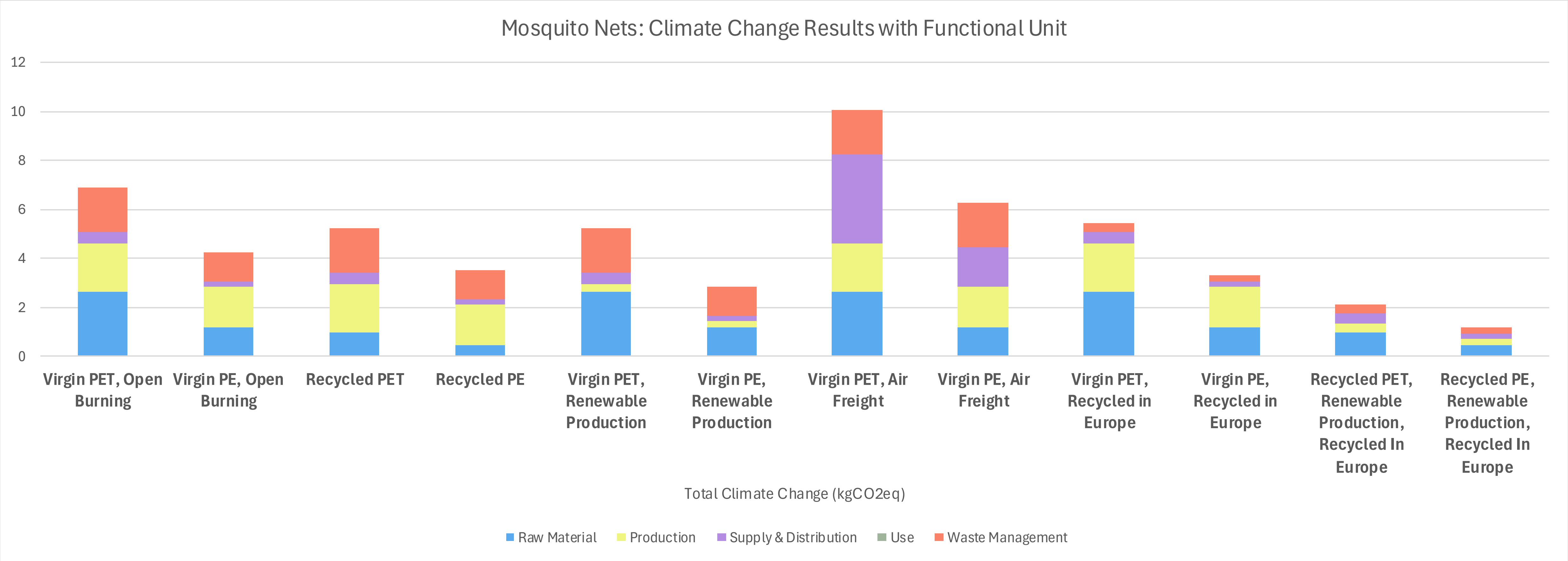


Transportation & Geography

- The nets are made in China and transported to Africa by sea freight. If this transport chain were replaced by air freight, impacts would increase significantly for both categories.
- Taking Virgin PET nets as a reference, switching from sea to air transport changes the impact as follows:
    - Virgin PET: **46%/29%** increase in GHG emissions & human health respectively
    - Virgin PE: **47%/31%** increase in GHG emissions & human health respectively

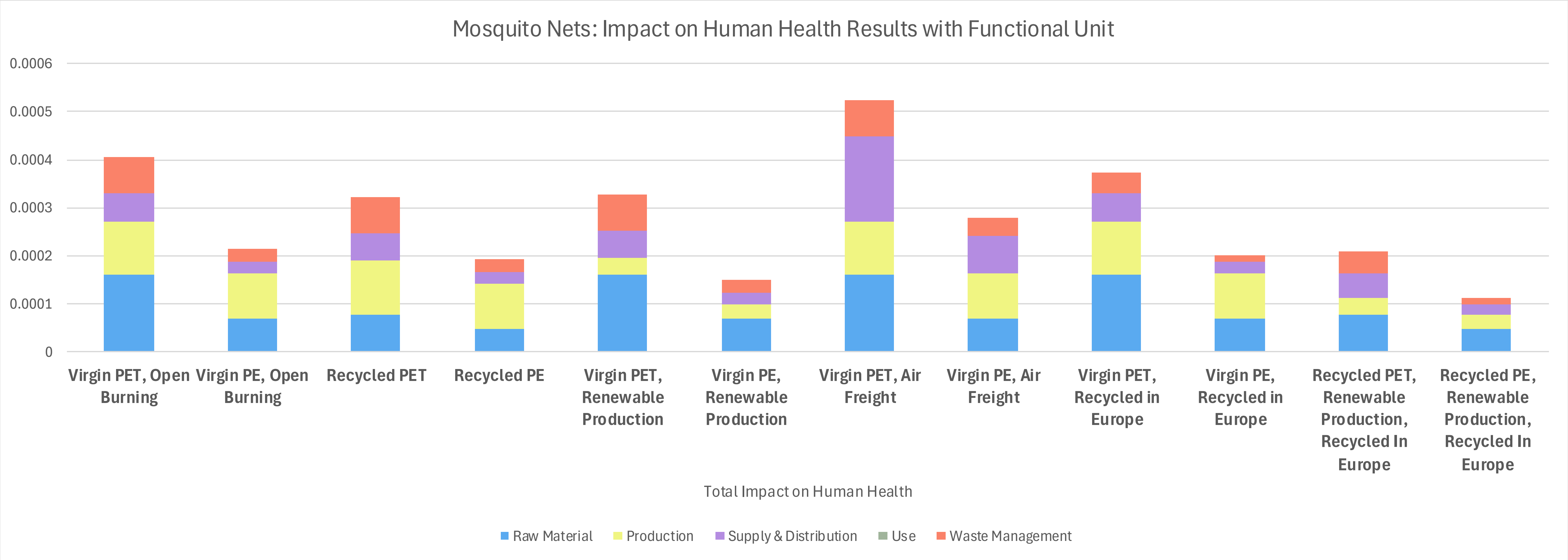
All Results: Climate Change

Functional Unit: 3 Years of Protection
Virgin PET nets needed: 1.5
Virgin PE nets needed: 1



All Results: Impact on Human Health

Functional Unit: 3 Years of Protection
Virgin PET nets needed: 1.5
Virgin PE nets needed: 1



Key conclusions

- Mosquito nets are made from either PET, with an assumed lifespan of 2 years, or PE, which are assumed to last 3 years.
- PE nets may seem less favourable due to their more impact-intensive production. However, they prove to be the better option from an environmental and human health perspective due to their longer lifespan and lighter in materials.
- Switching from PET to PE net may achieve a reduction of **38%** reduction in GHG emissions & **47%** reduction in impact on human health
- Most of the environmental impact is concentrated in the material and production phases, with around 60% of the impact coming from virgin material use.
- Switching to recycled plastics results in the following reductions (compared to the virgin net):
  - Recycled PET: **24%** reduction in GHG emissions & **20%** reduction in impact on human health
  - Recycled PE: **17%** reduction in GHG emissions & **10%** reduction in impact on human health
- Switching to renewable energy in the production process results in the following reductions (compared to the virgin PET net):
  - Virgin PET: **24%/19%** reduction in GHG emissions & human health respectively
  - Virgin PE: **33%/30%** reduction in GHG emissions & human health respectively

Key conclusions (continued)

The use of recycled inputs should be approached carefully, as they often face limitations in terms of quality, cost, and availability.

This study did not consider the diversity of end-of-life pathways that exist for mosquito nets, as mosquito nets are frequently repurposed for uses such as fishing, fencing, or clothing before final disposal.

While the scenario of sending waste to Europe for recycling is rather hypothetical, it underscores the need to prioritise local infrastructure development to address plastic waste sustainably. Some manufacturers have piloted take-back or circular programs that could be leveraged and scaled in the future.

This study did not consider additional environmental or human health impacts of insecticides or dyeing processes.

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Thank you!

1. UNHCR, 2024. *Greening Opportunities for Mosquito Nets*. Available at: https://www.unhcr.org/sites/default/files/2024-03/greening-opportunities-for-mosquito-nets.pdf
2. Tungu, P.K., Mwingira, V.S., Minja, E.G., Magesa, S.M., Kishamawe, C., Mosha, F.W. and Maxwell, C.A., 2014. *Comparative performance of three long-lasting insecticidal nets (LLINs) in Tanzania*. *Parasites & Vectors*, [online] 7, p.547. Available at: https://parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-014-0547-x
3. Pulford, J., Kurumop, S., Ura, Y., Siba, P.M. and Hetzel, M.W., 2021. *Ownership and use of long-lasting insecticidal nets (LLINs) after a mass distribution campaign in Papua New Guinea*. *Malaria Journal*, 20, p.22. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC7791654/
4. Unitaid, 2023. *Product profiles: Climate & Nature Risk and Impact Assessment of Health Products*

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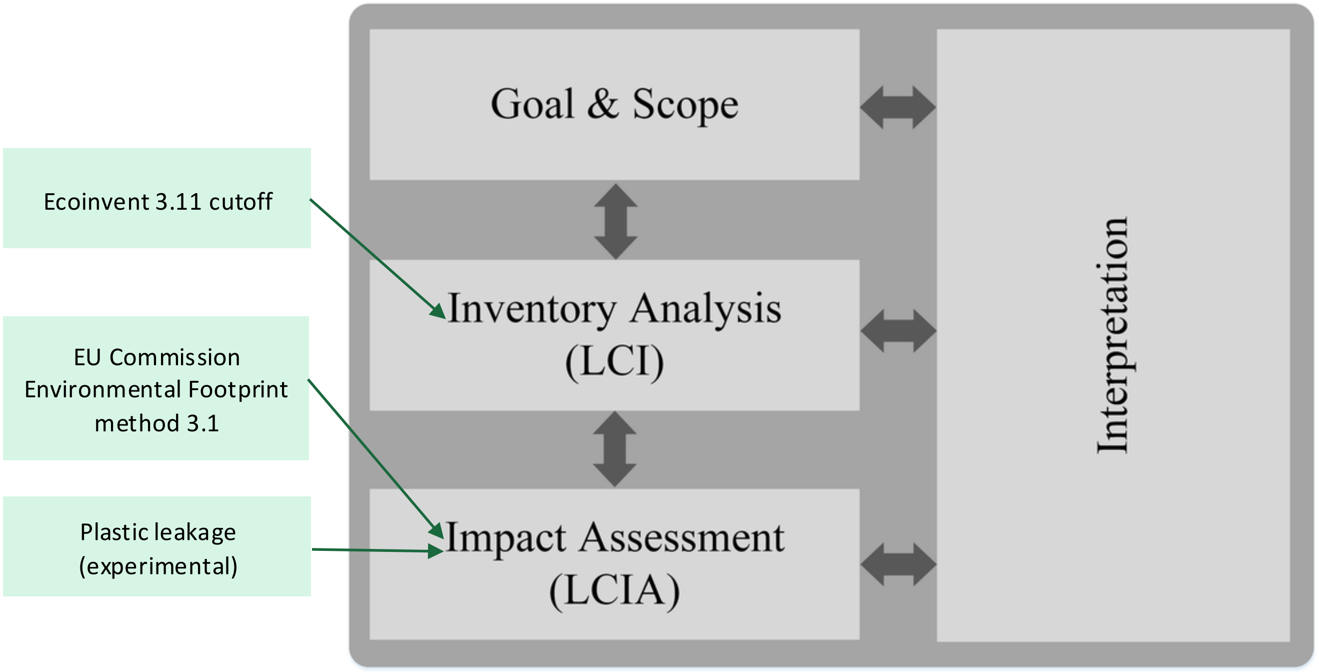
Methodology

The primary database used is Ecoinvent 3.11

The studies utilize the data from the **cut-off system model which allocates the entire impact of the material to its primary user** without any ‘rewards’ for its potential for being recycled.

Consequently, any recycled materials do not carry the burden of the impact of the primary use of the material and rather track the impacts from the recycling process onward.



Life cycle assessment (LCA) steps according to ISO 14040, 14044, and 14067.

References:
“Ecoinvent v3.11.” n.d. Ecoinvent. https://ecoinvent.org/ecoinvent-v3-11/

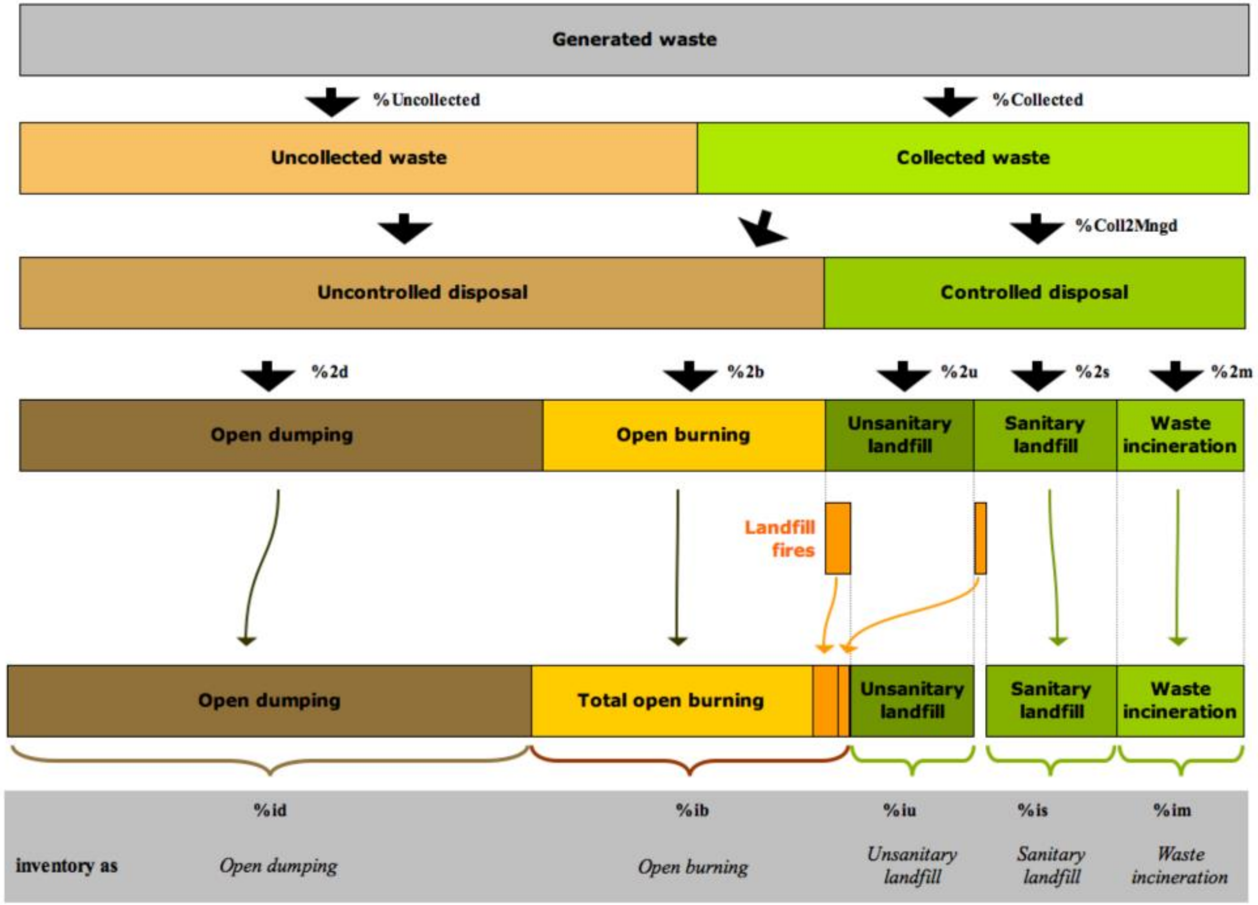
End-of-life waste management

This study aims to model the impact differences between **managed and mismanaged** waste tailored closer to humanitarian contexts.

The end-of-life impact for *a mix of plastic waste* reduces as below:

Method	GHG Emissions	Impact on Human Health
Open Burning	~HIGHEST~	~HIGHEST~
Municipal Incineration	-2.60%	-96.03%
Unsanitary Landfill	-93.80%	-99.40%
Open Dumping	-95.50%	-99.87%
Sanitary Landfill	-96.22%	-99.06%

Open burning creates maximum impact for both categories, but beyond that there are differences between climate change and human health on the specific magnitude of reduction.



Doka, G., 2018, Inventory parameters for regionalised waste disposal mixes

This study uses values for specific types of plastic wherever necessary, however the proportions of impact follow similar trends across the types of plastic product. This is therefore the standard impact implication for plastic products at end-of-life. Whenever possible, recycling is also modelled as a waste treatment option within the scope of the study.

NOTE: The methods listed above have differences in how long it takes for the plastic to be removed. It is part the LCA methodology that measurements are limited to a 100 years, therefore any further impact due to the degradation of plastic in landfills is not measured or compared with other methods of disposal.