PEFerence
The Renewable Innovation

PEF – A Circular Bio-Based Plastic with Improved Properties and Environmental Performance

PEF WORLD CONGRESS | 30 OCTOBER 2024

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Bio-based Industries Consortium

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Goal

I. Quantitatively assess the potential environmental performance of selected PEF-based packaging solutions aiming at supporting technical and capital decisions during **process development** of Avantium's YXY Technology and commercialization of PEF-based applications.

II. Provide a **comparison** of selected PEF-based applications against their fossil counterparts in order to aid marketing efforts of the bio-based alternative.

- **Standards |** ISO 14040, ISO 14044, EN 16760:2015
- **Critically reviewed |** by 3 independent reviewers TüV (DE), ifeu (DE), Ecomaters (NL)

Products

FDCA

PEF resin

PEF monolayer bottles

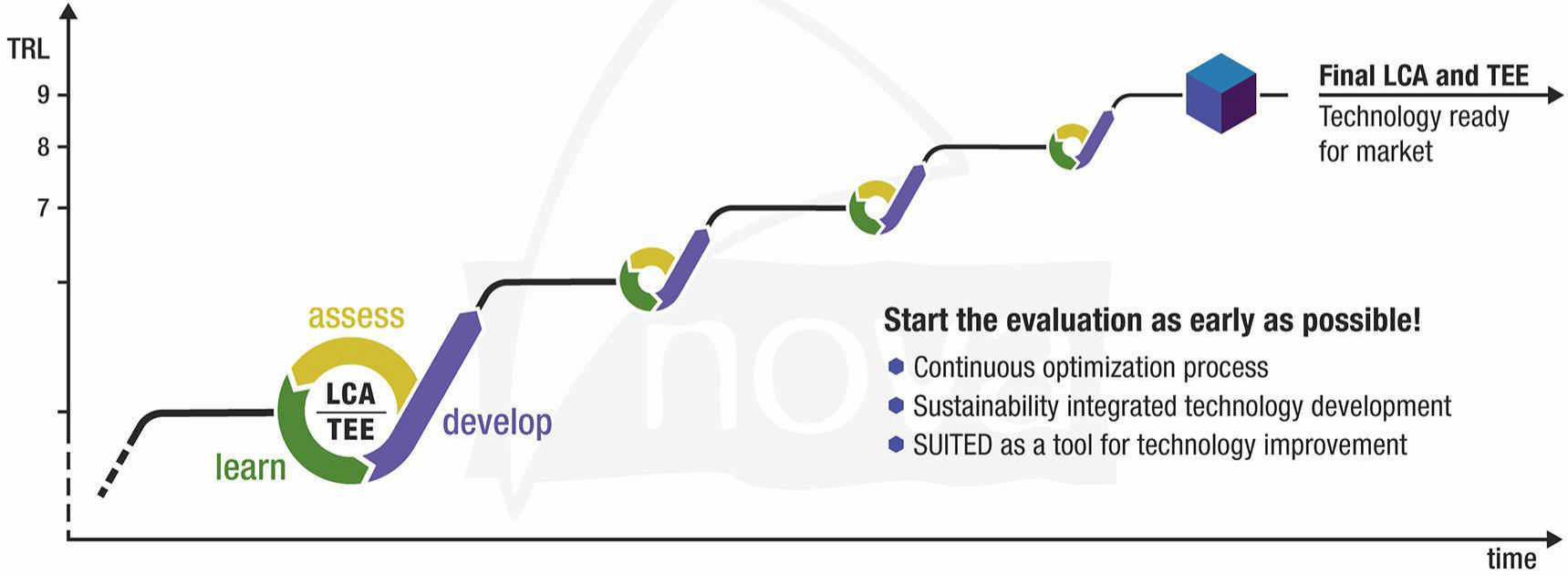
PET/PEF multilayer bottles

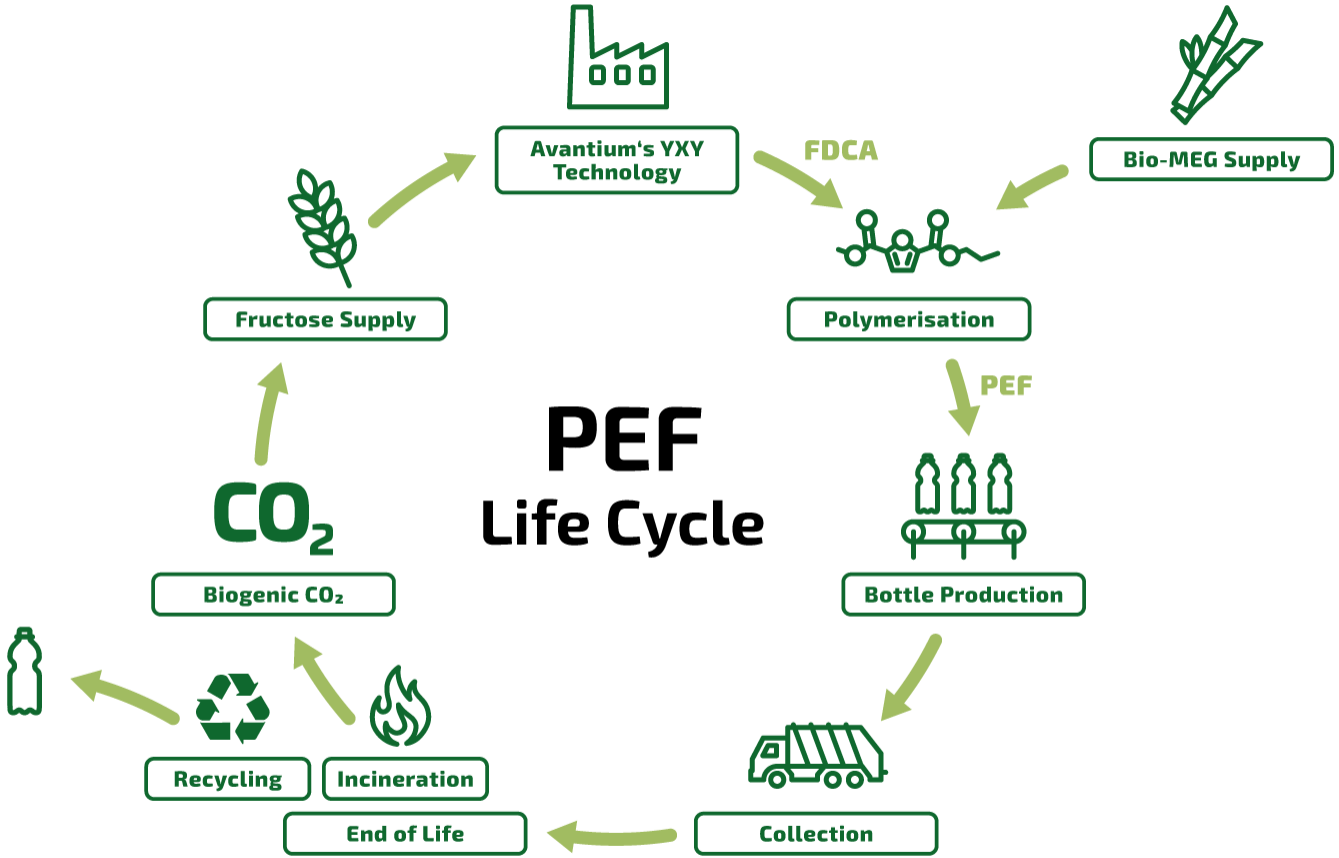
…

ISO 14040/44 Compliant

SUITED

SUstainability Integrated TEchnology Development





available at www.renewable-carbon.eu/graphics

Scope

Geographical and technological context

- Fructose production in NW Europe via starch wet milling
- 100 kT/a FDCA plant based in Delfzijl, NL
- PEF polymerisation in Europe by Toll manufacturing

Time frame | 2025-2028

Energy

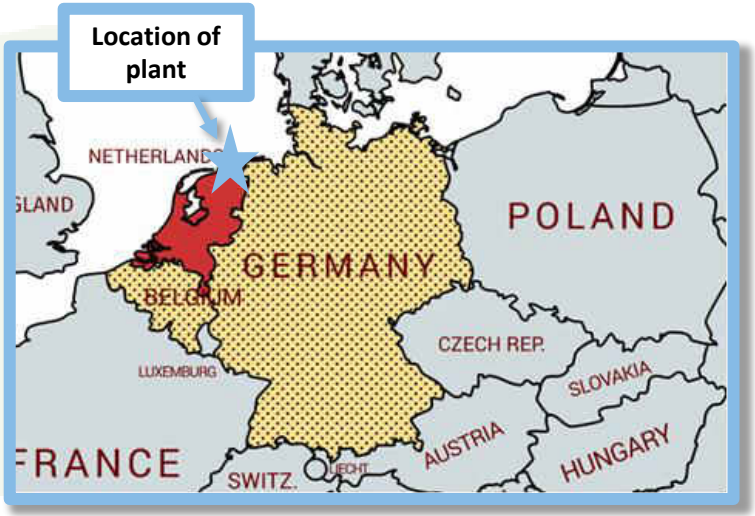
- Heat supply: steam from NG
- Electricity supply: current NL mix

Reference products | PET resin & PET bottles

System boundaries | Cradle-to-Gate & Cradle-to-Grave

EoL Scenario | Netherlands [65% Recycling Rate]

Allocation | Mass allocation (baseline)

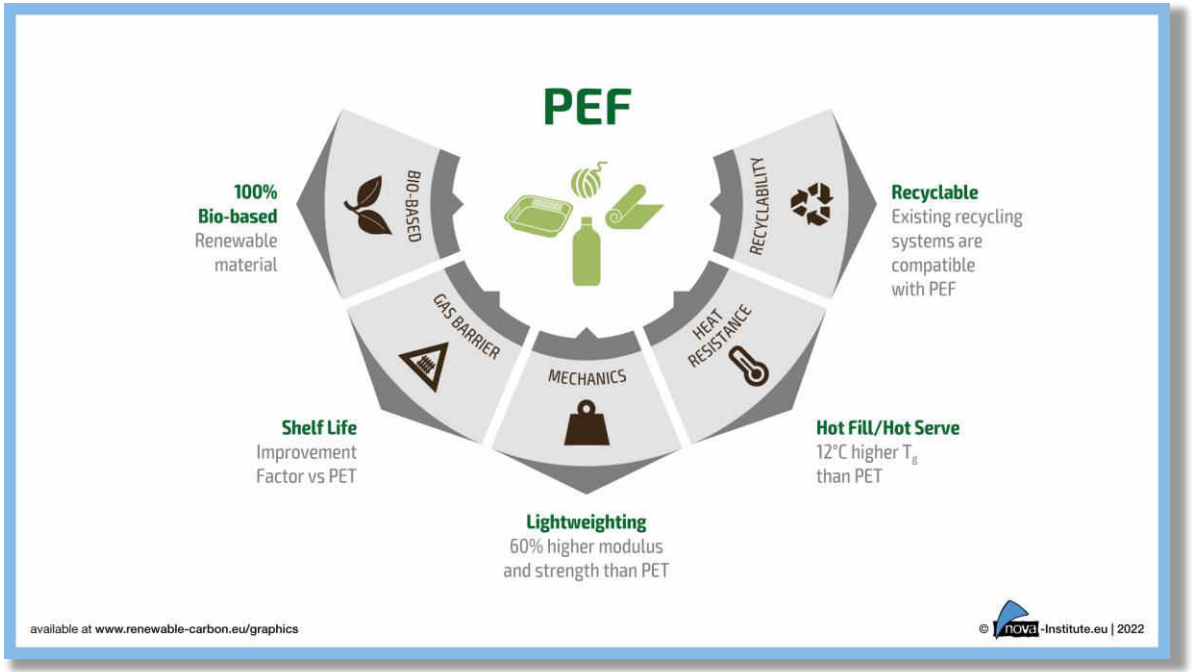


Data Sources and Quality

Life Cycle Stage	Process	Source
Fructose feedstock supply	Wheat production	Ecoinvent
	Wet milling	Agribalyse
	Fructose production	**Tereos**
YXY Technology	YXY sugar dehydration	**ARNP**
	YXY oxidation	**ARNP**
	YXY FDCA purification	**ARNP**
Bio-MEG supply	Sugarcane cultivation	Ecoinvent
	Sugarcane refinery	Ecoinvent
	Bio-ethanol dehydration to ethylene	Literature
	Ethylene oxide production	Ecoinvent
	Ethylene glycol production	**Indian Glycols**/Ecoinvent
Bottle manufacturing	Polymerisation	Ecoinvent
Items production	Stretch blow moulding	Ecoinvent
End-of-Life	Plastic waste collection	**Eunomia**/Ecoinvent
	Plastic waste sorting	**Eunomia**/Ecoinvent
	Mechanical recycling	**Eunomia**/Ecoinvent
	Incineration with recovery of energy	**Eunomia**/Ecoinvent
Benchmark	PET	**PlasticsEurope**/Ecoinvent

- No data gaps. Complete for all impact categories
- Core data from primary sources
- Data Quality Assessment
- Overall average good data quality
- Validated by reviewers

PEF bottles | Functional Unit



Functional Unit

500 mL monolayer bottles

Storing and delivering of beverage (CSD drinks) by means of single-use **recyclable** bottles

Same Quality

Mechanical integrity: without breaking/damage during handling/transport

Barrier Property: ensuring a shelf life of minimum 12 weeks CO_2 shelf life

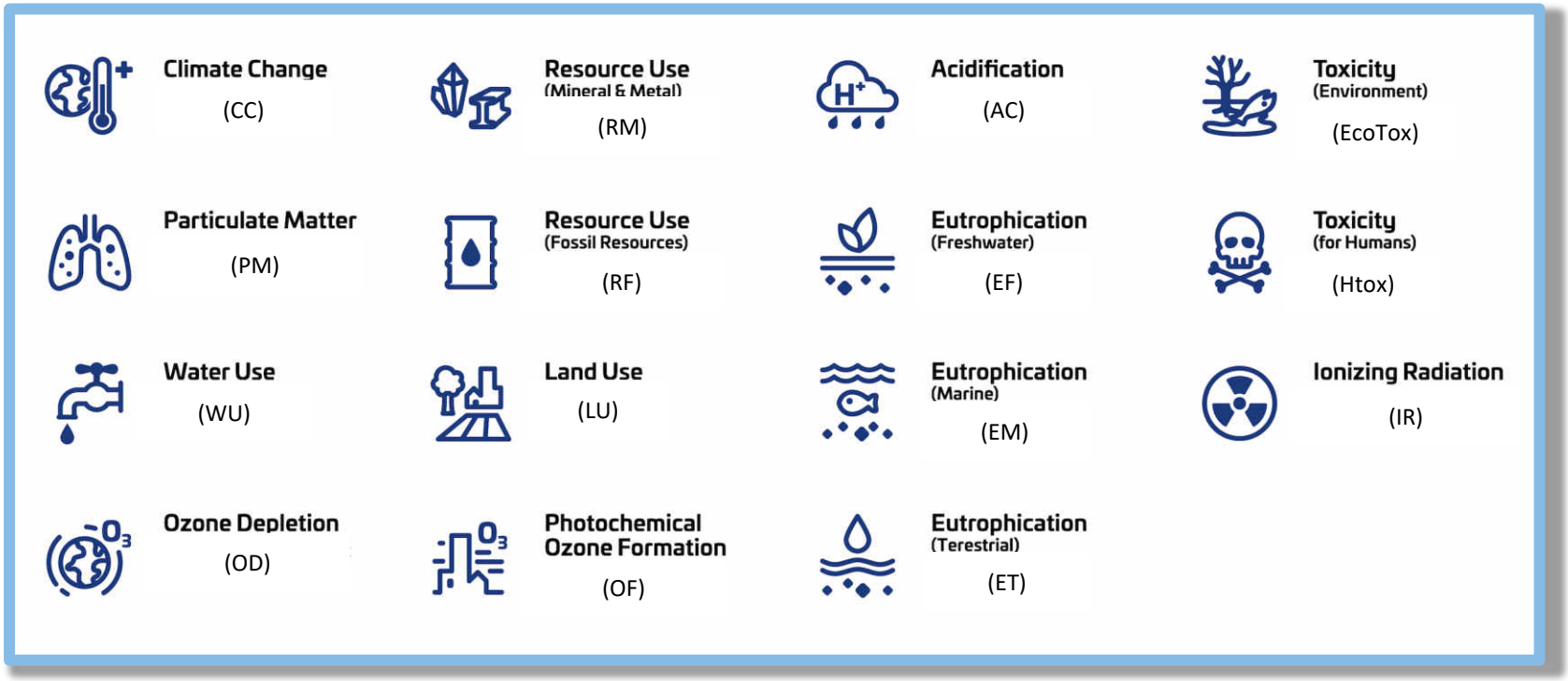
Bottle weight

PEF: 16-19 g

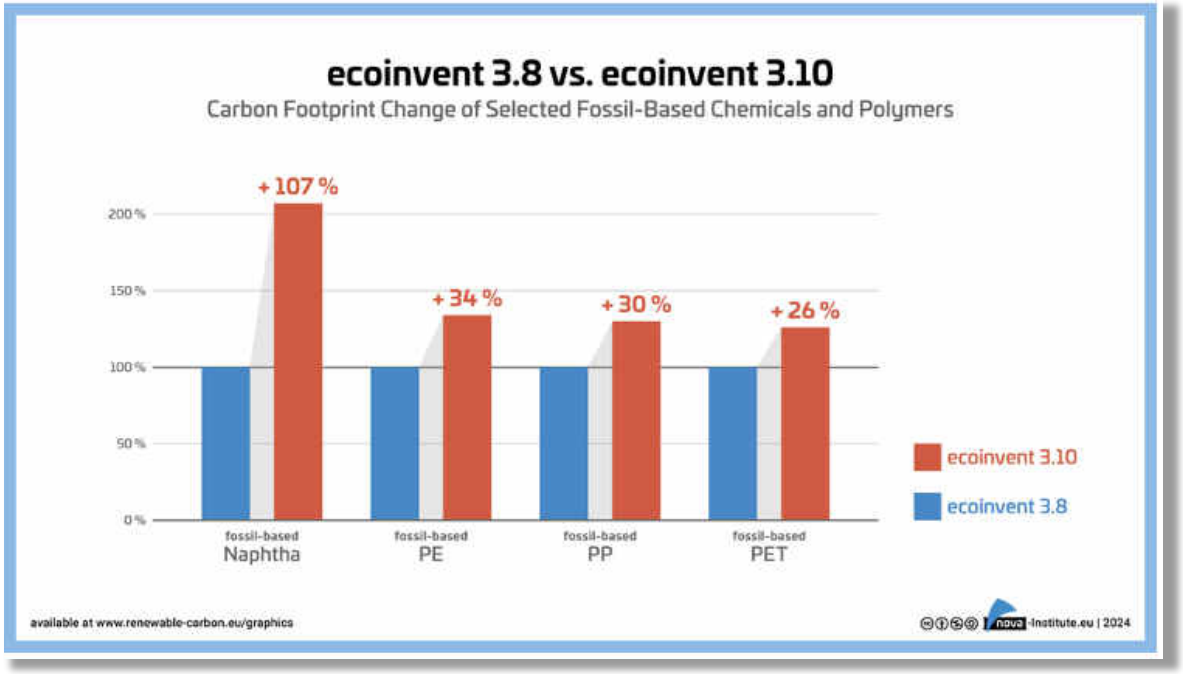
PET: 20-24 g

Environmental Impacts

EF3.1 Life Cycle Impact Assessment method (Climate change incl. and excl. Biogenic C Uptake)

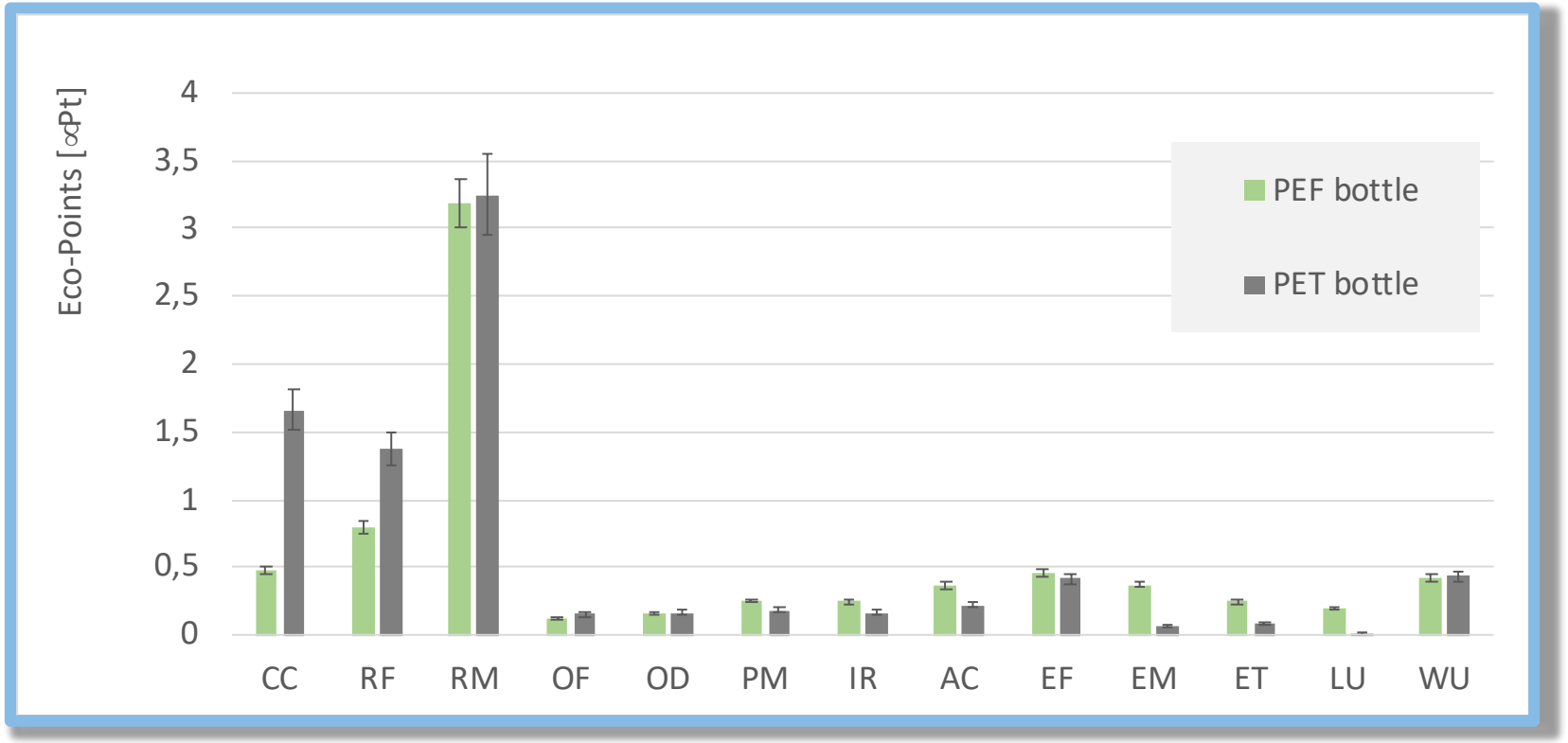


Additional CH_4 emissions in petrochemicals

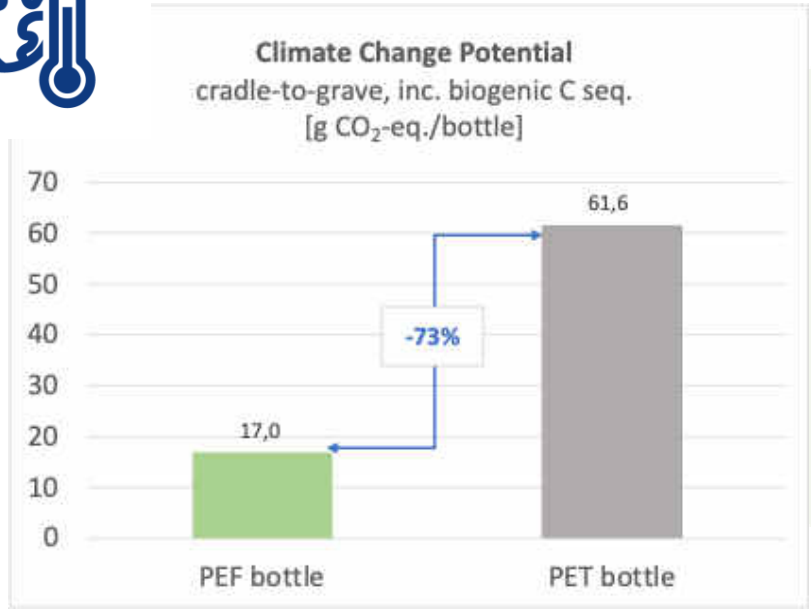


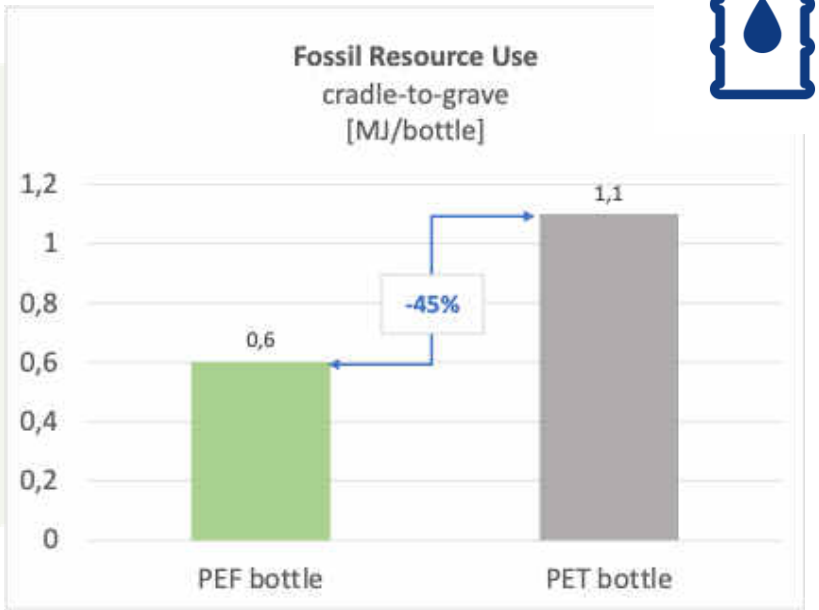
- Recent update of the ecoinvent database → new data on the supply of crude oil and natural gas have been implemented including unintended **methane emissions** during extraction and processing
- Significant higher carbon footprint for fossil-based products

Normalised & Weighted Impacts

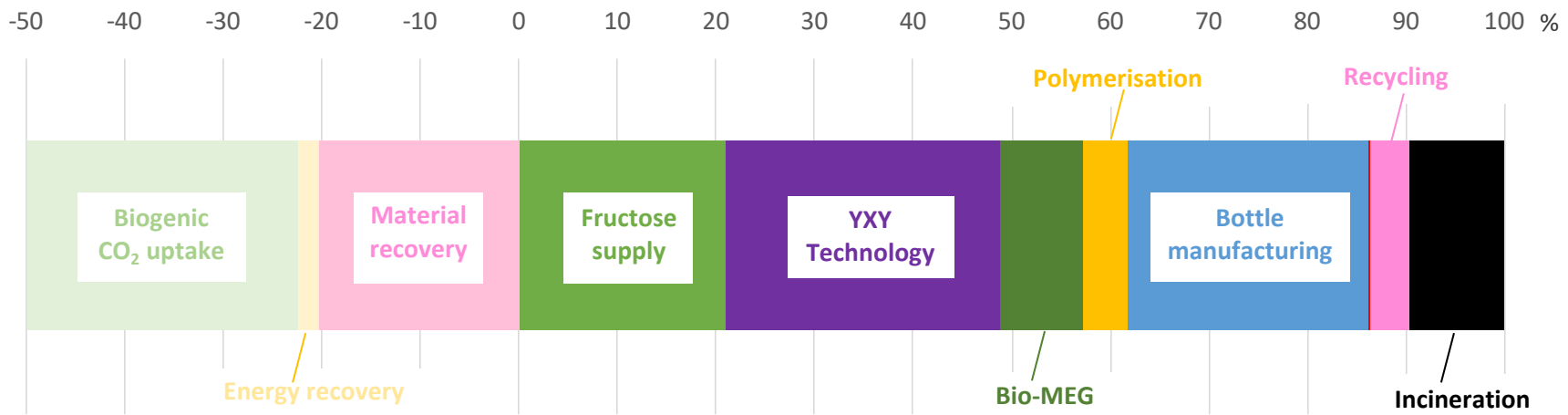


Impact Assessment





Environmental Hotspots – Climate Change



Sensitivity analyses

Valorisation of co-products

Economic allocation

Mass allocation

End-of-life Scenarios

End-of-life Treatments

Recycling rates

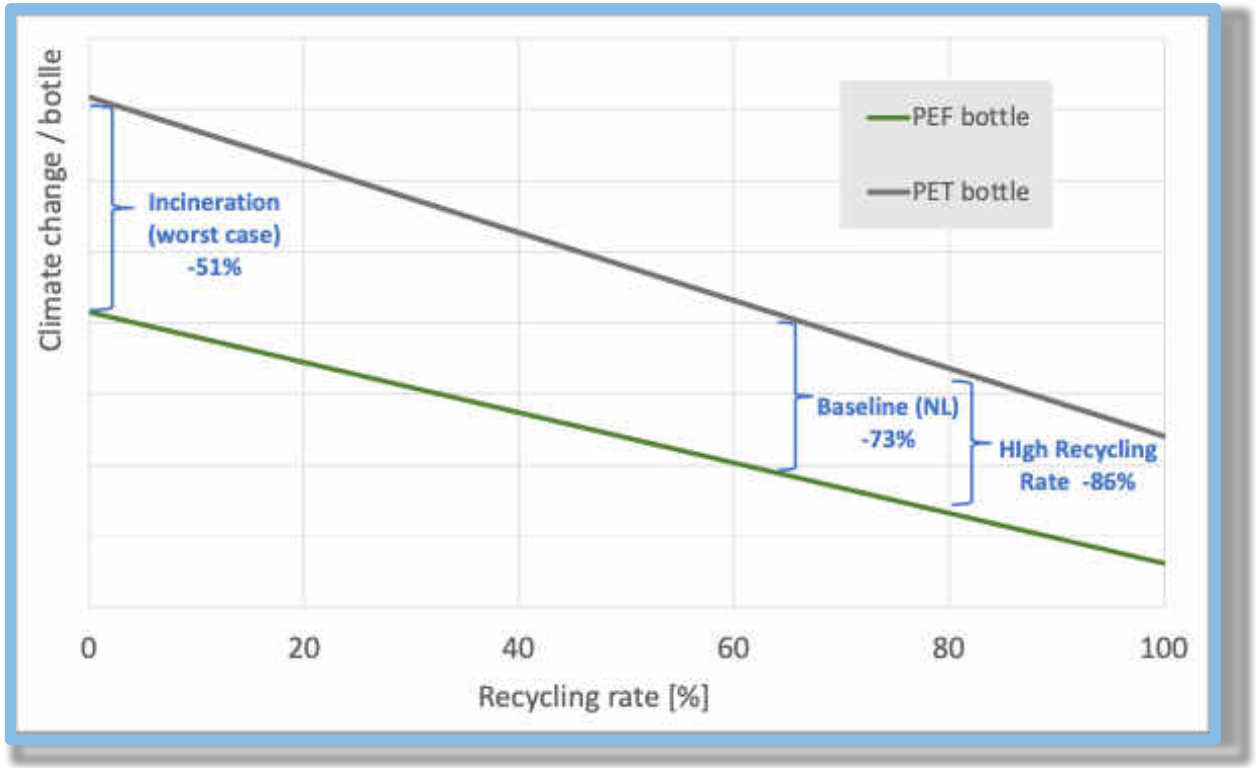
Bottle size

Bottle weights

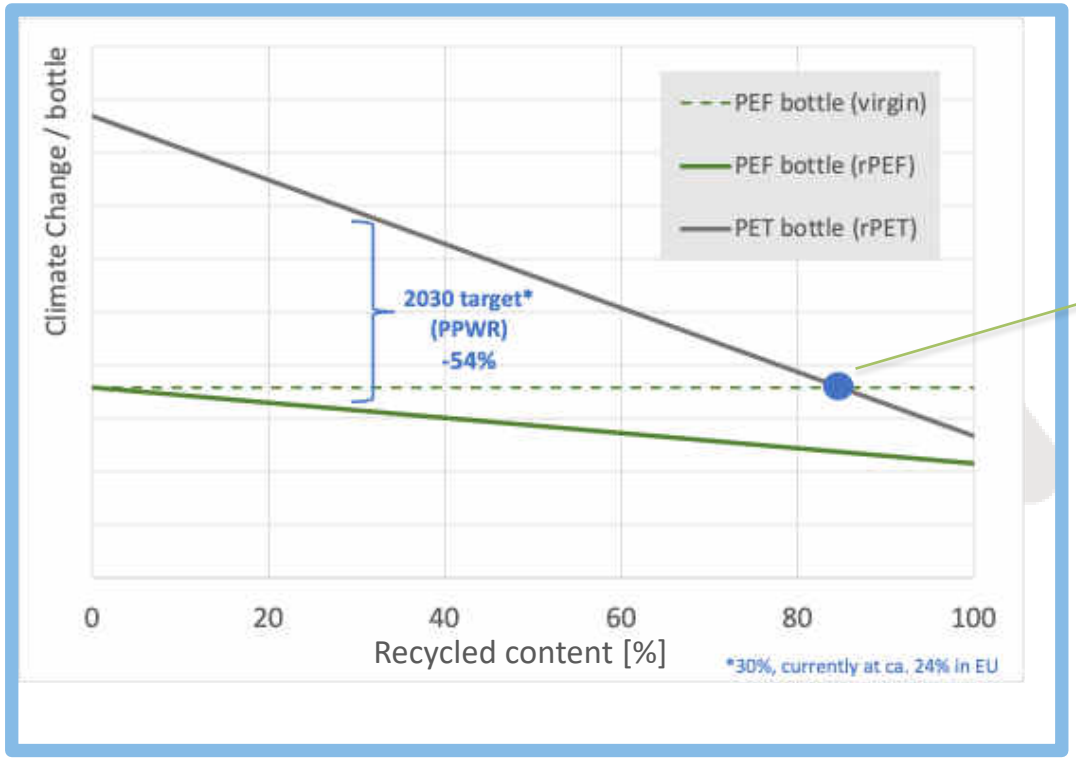
Monolayer & Multilayer

Other products

Recycling rates



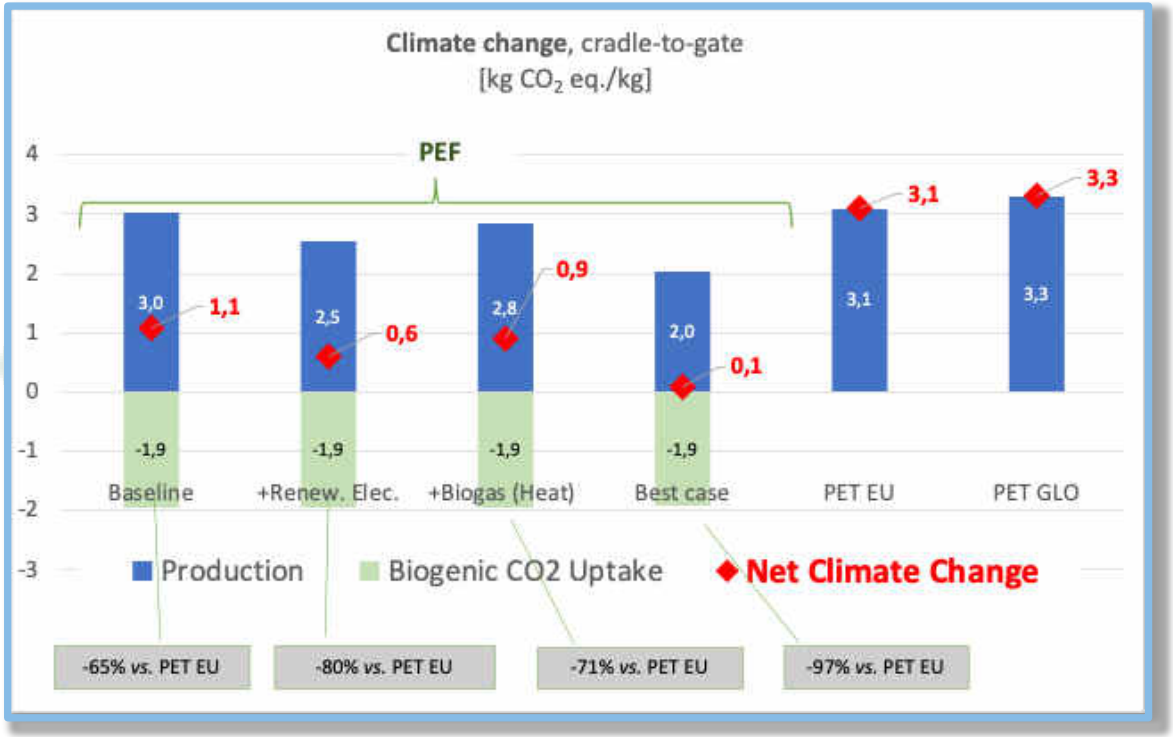
Recycled content



Only a PET bottle with ca. **85% recycled content** will equal the Carbon Footprint of a virgin PEF bottle

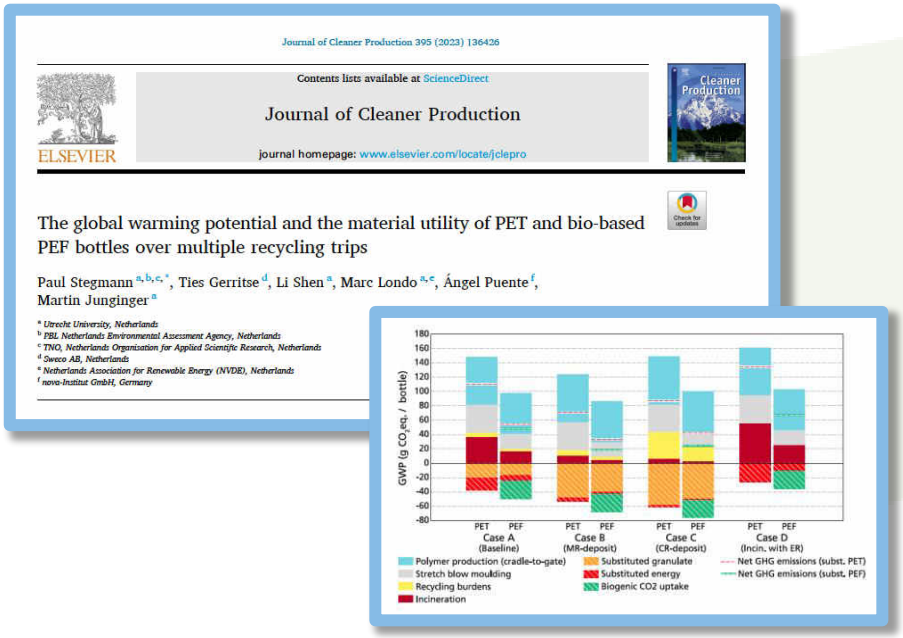
Climate Change – Resin Outlook

- The baseline already shows a carbon footprint **reduction of 65%** versus PET produced in Europe
- Despite the small scale and young process technology, PEF resin can compete with highly commoditized PET
- **Further reduction** on Carbon Footprint is seen on application basis, where PEF properties enable improved performance and light weighting
- 30% additional GHG reductions expected by switching to **2G feedstocks**



Recent Publication

Scientific article: *Journal of Cleaner Production* 395 (2023) 136426



Highlights

- Application matters when comparing different plastics: highlights the importance of considering the **application-specific benefits** in the use phase when comparing novel with conventional plastics.
- It is important to **consider the EoL** already during product design
- Bio-based PEF would offer **50–74% lower life cycle GHG** emissions after one recycling trip compared to PET, depending on the waste management case.
- Switching from PET to PEF is a robust strategy to reduce the GHG emissions of plastic bottles

Take-Aways

- Despite the small scale and **young process technology**, PEF resin can compete with highly commoditized PET (improvement potential)
- PEF **improved performance** (barrier, mechanical properties) enable lighter designs → material savings
- **Significant CO_2 savings** and remarkably **less finite resource consumption** of fossil fuels compared to PET bottles
- These impact potentials are two of the most relevant environmental impact categories in the current **political and societal agenda** driving the transition from fossil to renewable carbon
- Impacts linked to **agricultural activities** were found to be significantly less relevant and contribute to a minor extent to the total environmental impact of PEF bottles
- PEF relies **100% of Renewable Carbon** and contributes to stop the release of additional CO_2 to the atmosphere → will play a role in absolute reduction of global GHG
- Preliminary assessments indicate that 30% additional GHG emission reduction could be achieved by switching to **2G feedstocks**

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Thank you for your attention!

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