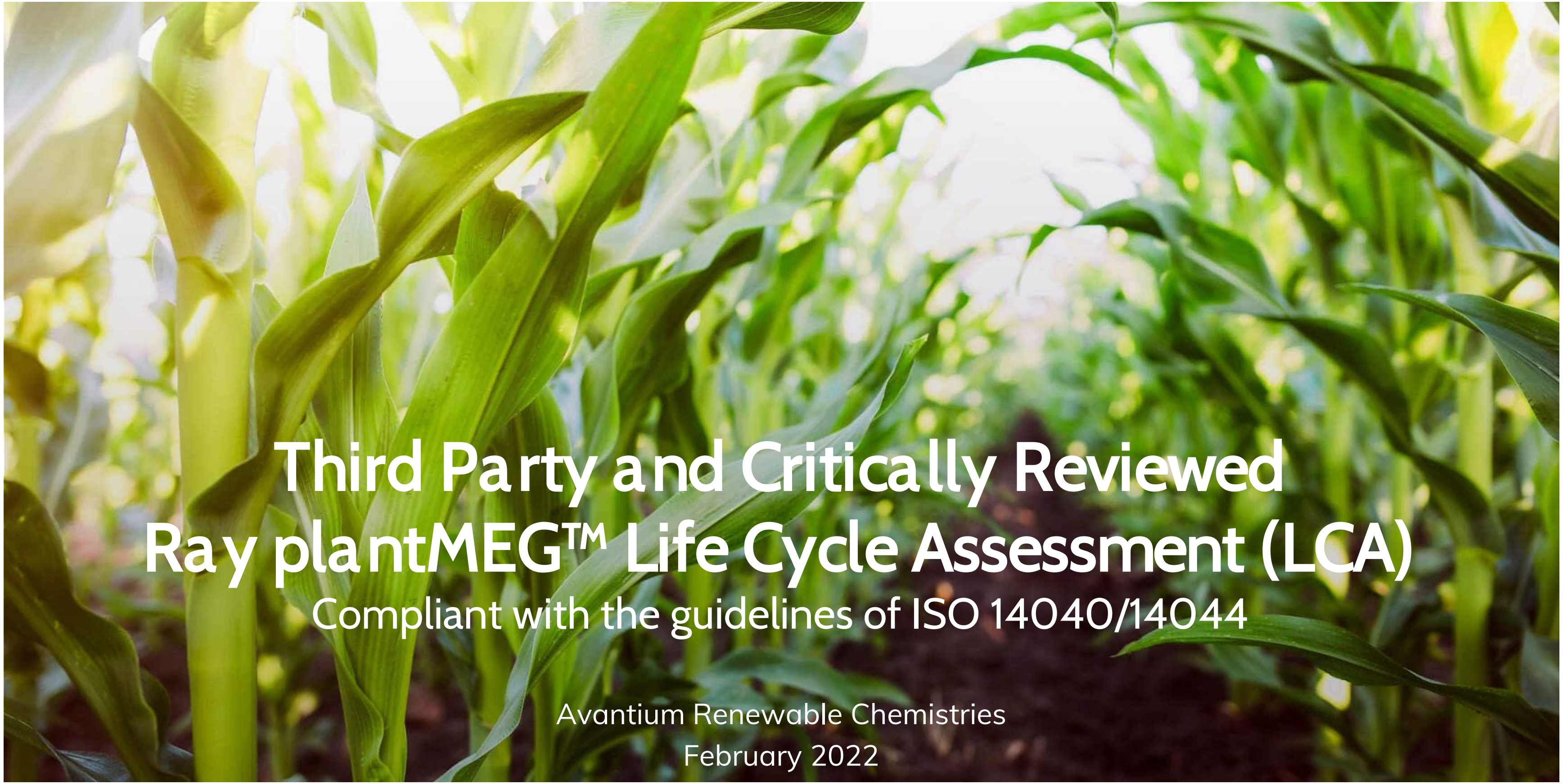

Third Party and Critically Reviewed Ray plantMEG™ Life Cycle Assessment (LCA)

Compliant with the guidelines of ISO 14040/14044

Avantium Renewable Chemistries

February 2022

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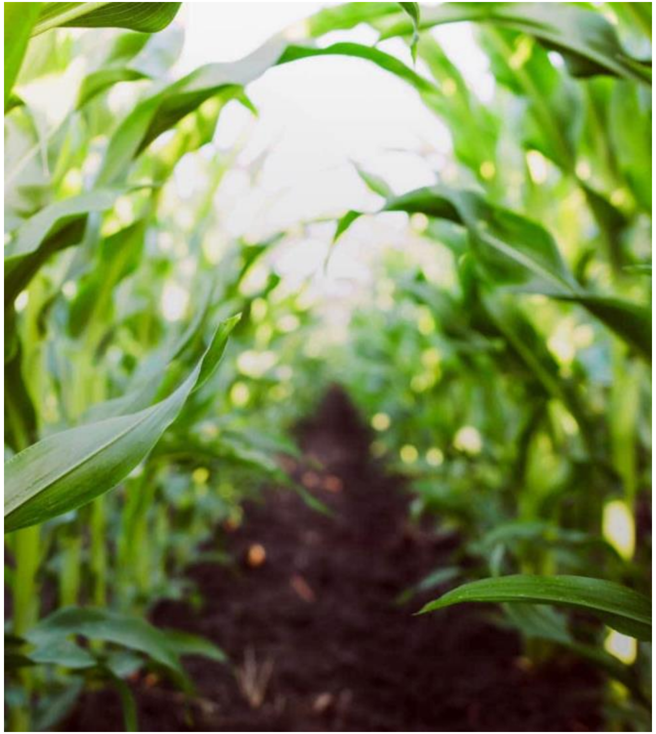


Executive Summary of Ray plantMEG™ Life Cycle Assessment

Avantium N.V, a leading technology company in renewable chemistry, recently conducted a third party and critically reviewed Life Cycle Assessment (LCA) study on the environmental impacts of its plantMEG™ (mono-ethylene glycol) from its Ray Technology™

The Life Cycle Assessment (LCA) is based on the following key assumptions and considerations

- Cradle-to-grave LCA with a regional and application focus on Europe and PET bottles, respectively
- Time reference of 2025, in view of the commercial Ray Technology™ deployment timelines
- Use of Cosun Beet Company beet sugar, green electricity, natural gas-based steam and green hydrogen
- European Commission Targets (for 2025) on PET bottle collection and recycling are used to define the End-of-Life scenario
- End-of-life allocation is performed as per the Circular Footprint Formula (CFF) and Substitution Approach

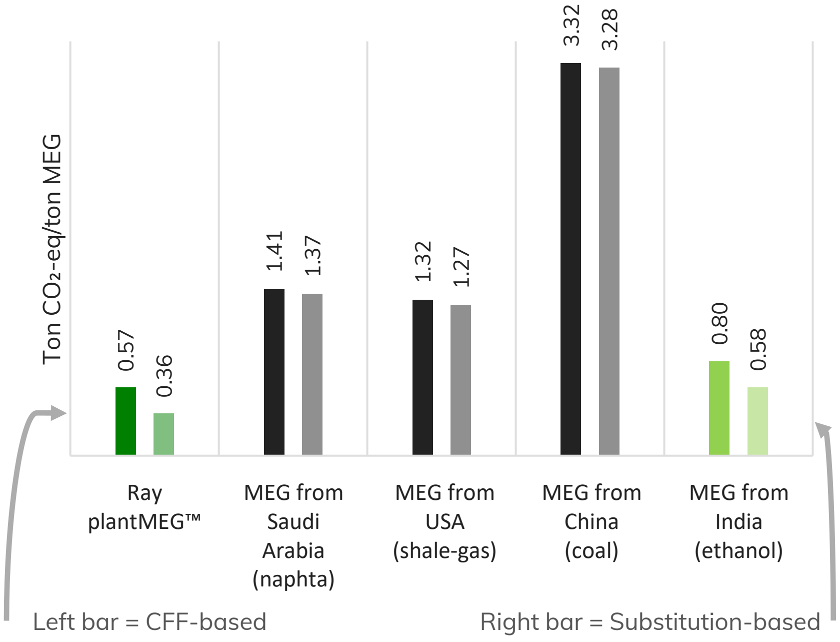
The LCA shows a greenhouse gas (GHG) emission reduction of up to 83% over the life cycle when Avantium's plantMEG™ is compared with its fossil-based incumbents

- Climate change impact of Ray plantMEG™ is lowered with 56-83%[1] compared to fossil-MEG using the Circular Footprint Formula,)
- Climate change impact of plantMEG™ is lowered even futher using the Substitution Approach, performing 72-89% better than fossil-MEG
- Next to being best-in-class in climate change impact, Ray plantMEG™ outperforms all incumbent technologies in the water scarcity impact category
- The agricultural dependency of biobased technologies like Ray Technology™ drives the Terrestrial Eutrophication and Land Use impact in comparison to fossil technologies. Ray plantMEG™ is still advantaged in comparison to ethanol-based MEG across all these impact categories

1. Range depending on incumbent fossil-feedstock source

Climate change impact of Ray plantMEG™ is lowered with 56-83% compared to fossil-MEG

Climate change impact

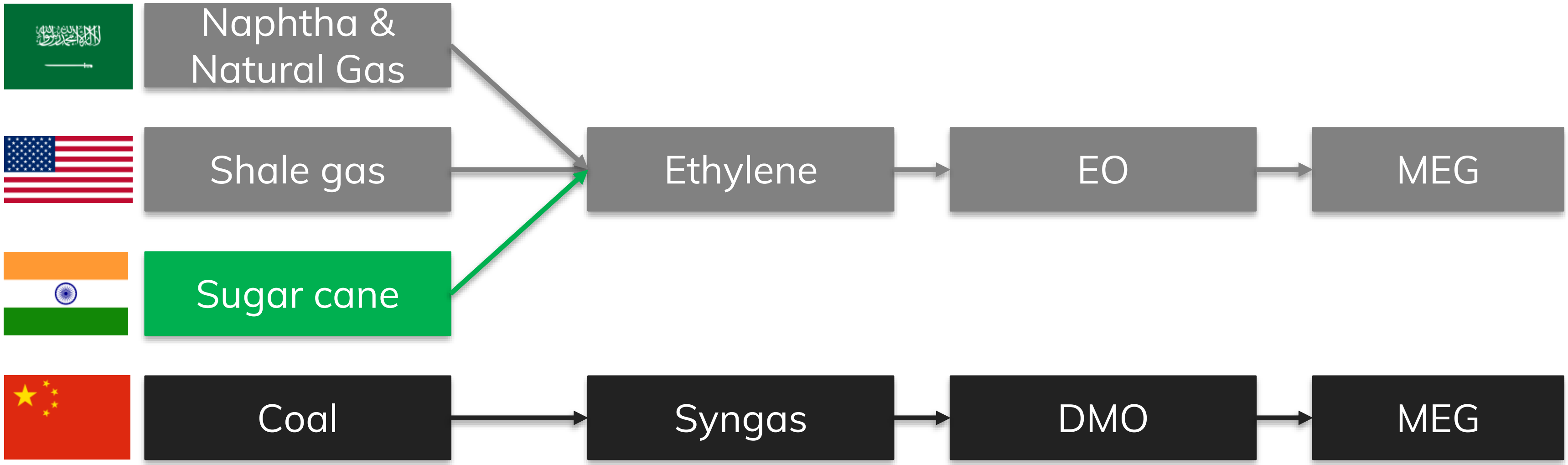


	Ray plantMEG™ vs. US MEG	Ray plantMEG™ vs. Saudi MEG	Ray plantMEG™ vs. Coal based
Carbon footprint formula (CFF)	56% reduction	59% reduction	83% reduction
Substitution	72% reduction	74% reduction	89% reduction

Source: Final outcomes of environmental cradle-to-grave life cycle analysis, performed with Sphera and subjected to independent panel review. Economic Allocation Is applied across all technologies. End of Life emissions are determined based on the EU PET Bottle Collection and Recycling Targets for 2025 and Circular Footprint Formula (CFF) and Substitution approach, Ray plant-MEG™ based on Dutch beet sugar, assumes green H_2

Introduction

A set of relevant incumbent technologies has been selected for the comparative assessment



The end-of-life scenario is based on 2025 European Commission target setting in the Single Use Plastics Directive

	2019	2025	2030
Bottle Collection	64%	77%	90% 2029
Plastic Recycling	46% For PET	50%	55%
Recycled content incorporation	14.5%	25%	30%

Source: ICIS, December 2020 (LINK)

End-of-Life Allocation Approaches

Circular Footprint Formula (CFF) approach

- This allocation method predefines allocation factors of credits and burdens between two life cycles and aims to describe market realities that capture both aspects of recycling-the recycled content and recyclability at the end of life.

Substitution approach (or “avoided burden” approach)

- This approach is based on the perspective that material that is recycled into secondary material at end-of-life will substitute for an equivalent amount of virgin material. Hence a credit is given to account for this material substitution.

A broad range of environmental impact categories have been assessed

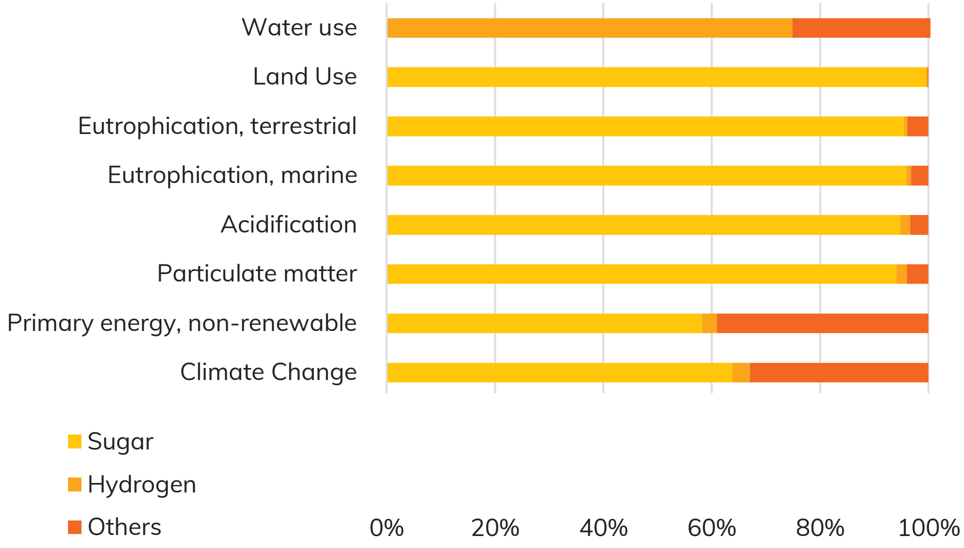
Impact Category	Unit of Measurement
▪ Climate Change	kg CO_2-eq
▪ Water Scarcity	m^3
▪ Eutrophication	
▪ Terrestrial	Mole of N-eq
▪ Marine	Kg of N-eq
▪ Land Use	Pt
▪ Acidification	Mole of H-eq
▪ Primary Energy Demand	
▪ Non-Renewable	MJ
▪ Particulate Matter	Disease incidences

All figures are expressed on a "per ton MEG" basis

The carbohydrate feedstock is the most significant contributor to most of the LCA impact categories

As sugar is the most important feedstock in the Ray Technology™ it logically is the most significant contributor to the majority of the LCA impact categories

Sugar and Hydrogen contribution to LCA impact categories



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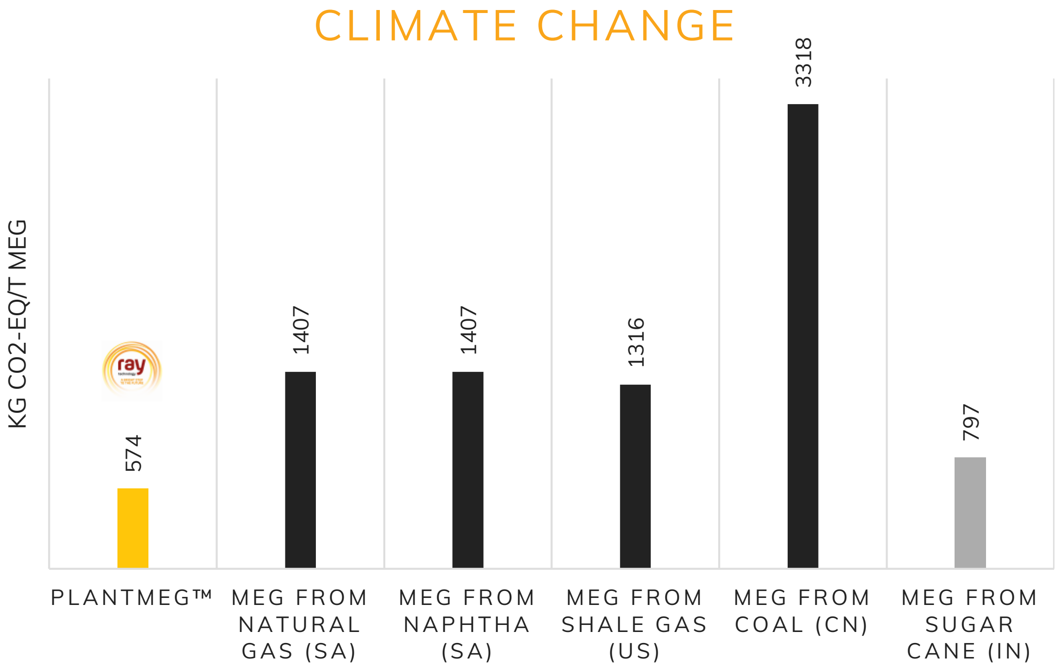
Climate Change Impact

Ray plantMEG™ is best-in-class on the Climate Change Impact Category

- Ray Technology™ outperforms all incumbent technologies
- The climate change reduction for Ray Technology is largely driven by the feedstock contribution.
- The thermal energy use of Ray Technology™ drives the vast remainder of the carbon footprint (28%)



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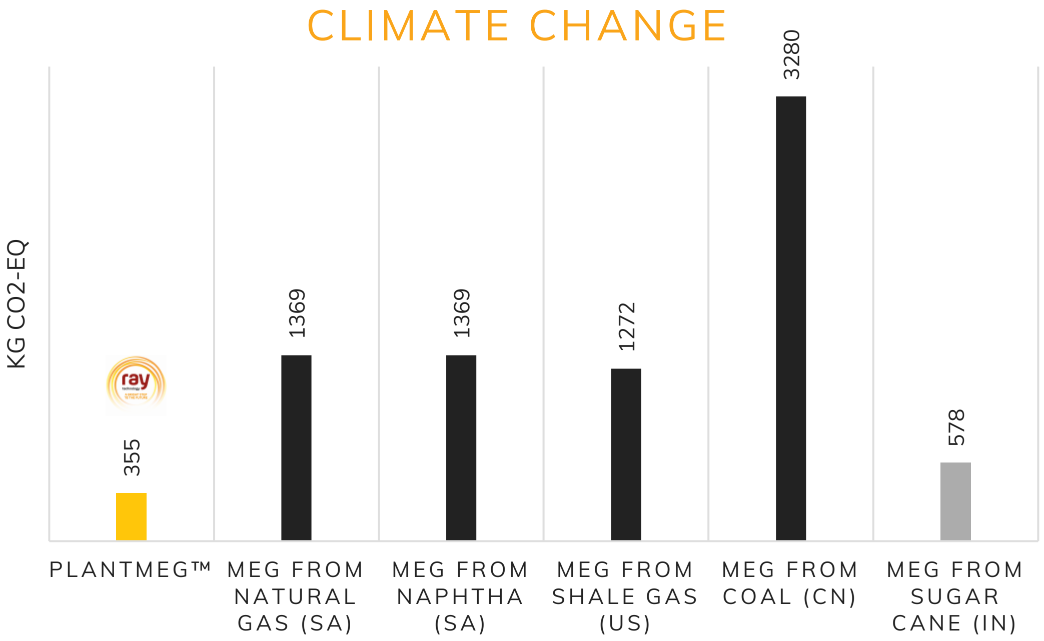
The positive climate change impact of Ray plantMEG™ is amplified by the use of the Substitution approach

The use of the Substitution approach amplifies the difference, in favor of biobased production technologies like Ray Technology, due to its biogenic carbon content



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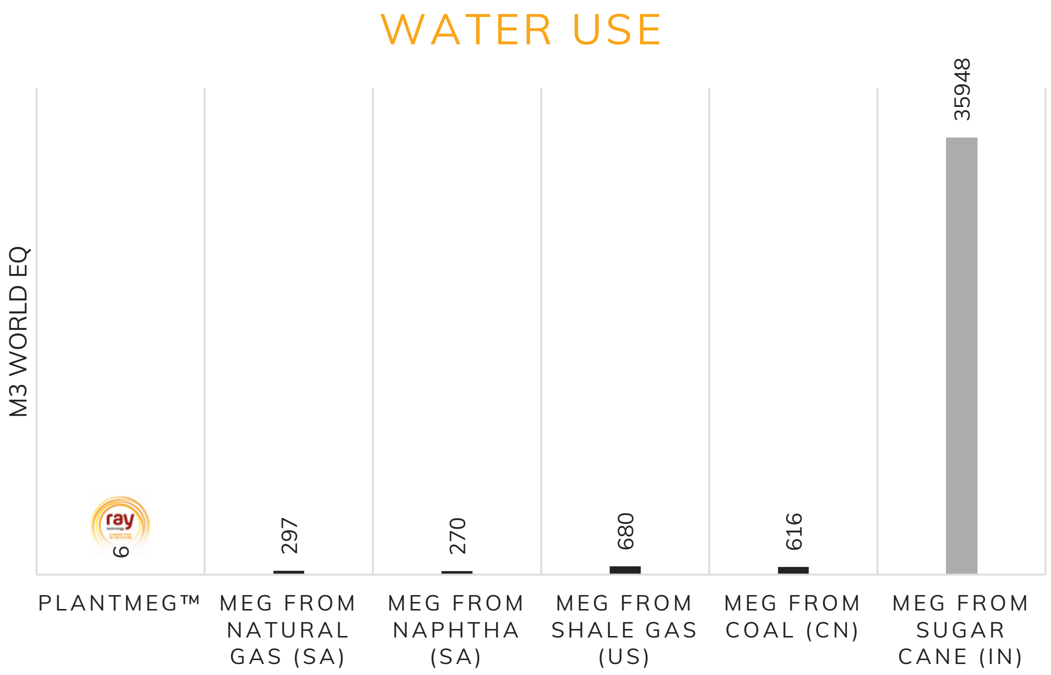
Other Environmental Impact Categories

Water Scarcity

- Ray Technology™ strongly outperforms all incumbent MEG production technologies from a Water Scarcity perspective
- This is driven by the limited relevance of water scarcity in North-Western Europe, the inherent limited net use of water in Ray Technology™ and the advantaged water footprint of Cosun Beet Company beet sugar (compared to Indian cane sugar)



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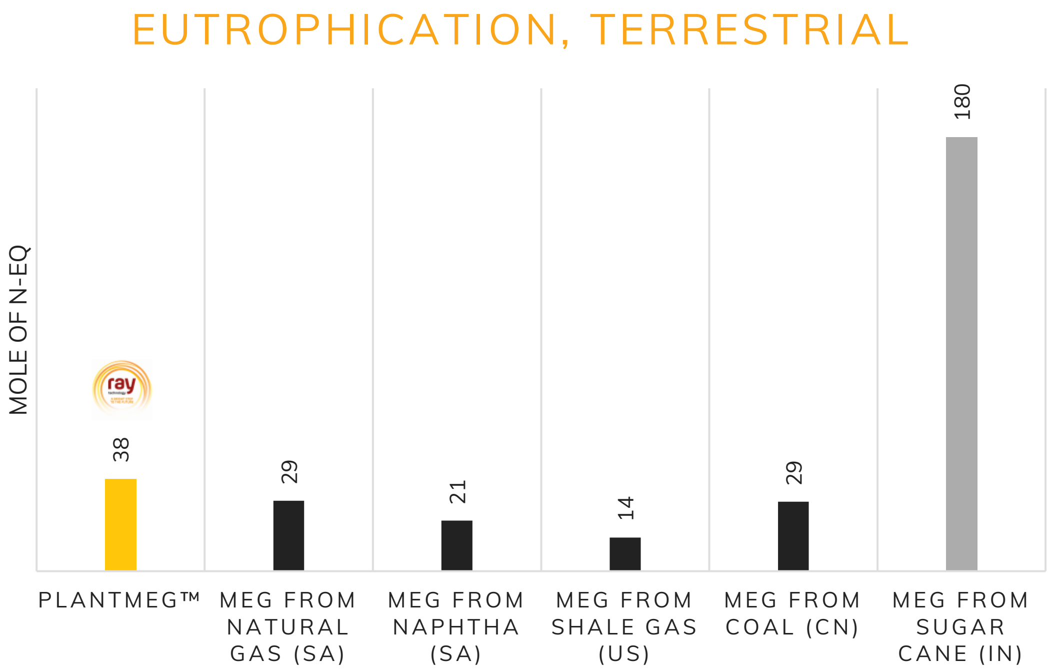
Eutrophication - Terrestrial

- Technologies, relying on biomass feedstock, typically result in more terrestrial eutrophication compared to fossil technology due to the dependence on and impact of agriculture
- This also applies to Ray Technology and Indian ethanol-based MEG production technology, although Ray plantMEG™ is still more favored from a terrestrial eutrophication perspective



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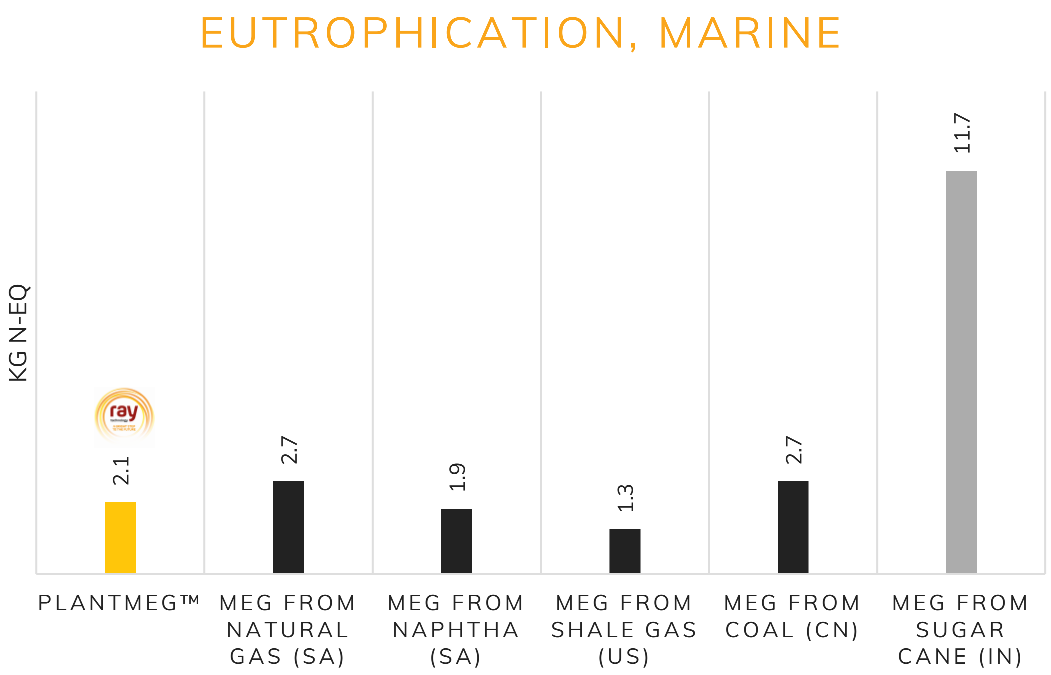
Eutrophication - Marine

- Technologies, relying on biomass feedstock, typically result in more freshwater eutrophication compared to fossil technology due to the dependence on and impact of agriculture
- This also applies to Ray Technology and Indian ethanol-based MEG production technology, although Ray plantMEG™ is more advantaged from a freshwater eutrophication perspective



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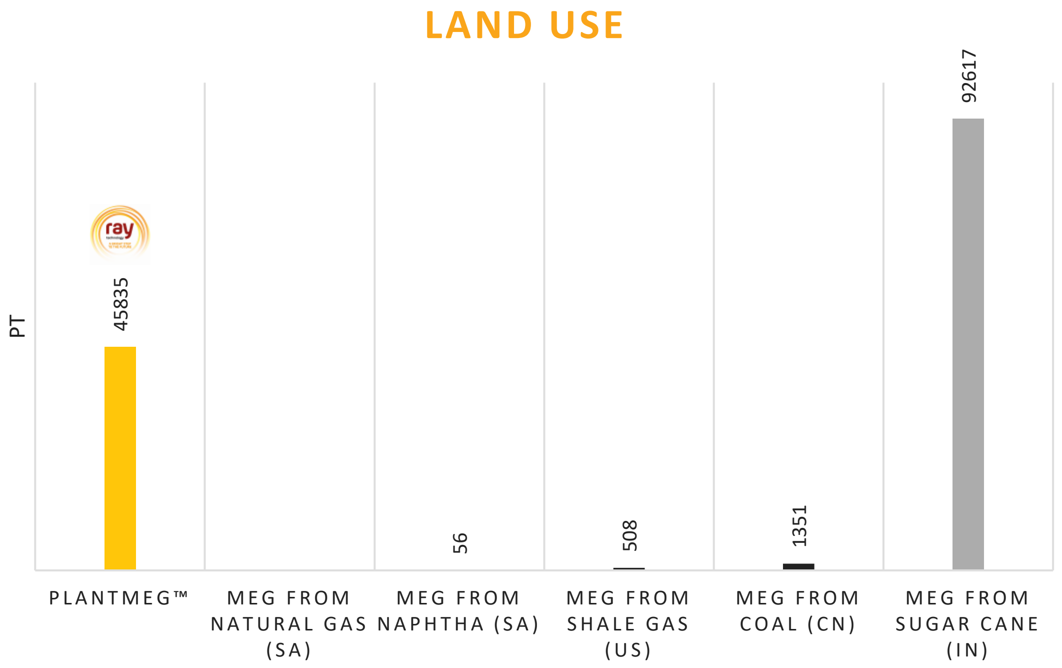
Land Use

- Technologies, relying on biomass feedstock and agriculture, typically result in more land use compared to fossil technologies
- Nevertheless, Ray plantMEG™ is more advantaged than ethanol-based MEG



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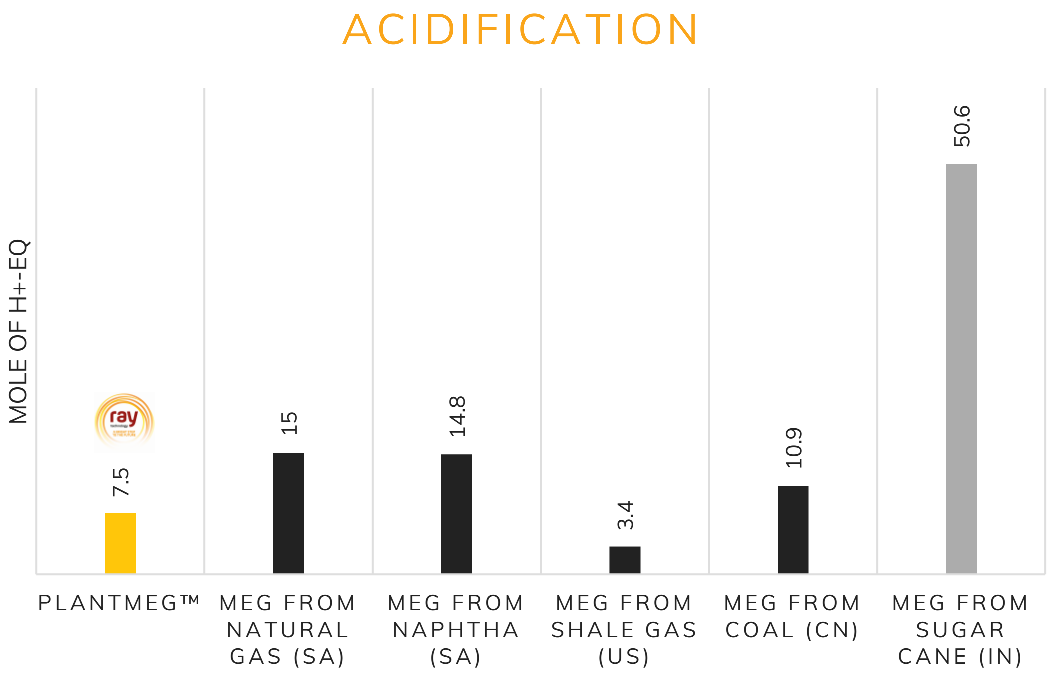
Acidification

- Ray plantMEG™ acidification impact is in similar order of magnitude as fossil incumbents but several times more favorably positioned than ethanol-based MEG since Dutch beet sugar outperforms significantly Indian sugar cane in this aspect.



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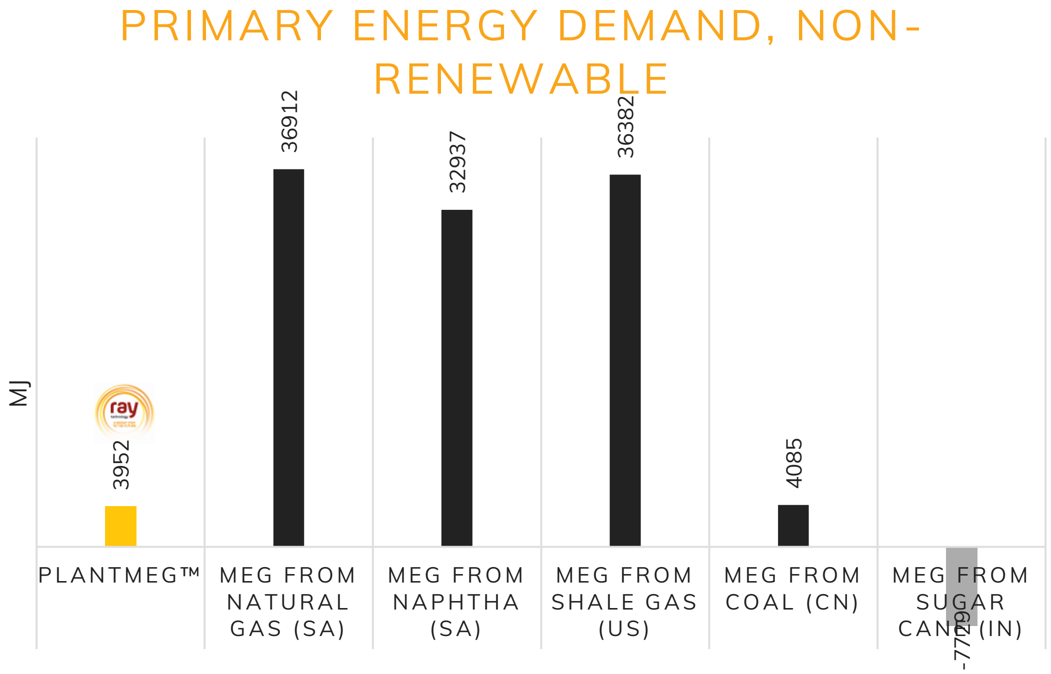
Primary Energy Demand, Non Renewable

- Primary Energy Demand (non-renewable) of Ray plantMEG™ is more favorable than the conventional fossil EO processes
- The negative value for ethanol-based MEG is driven by bagasse (sugarcane by-product) incineration and corresponding credits



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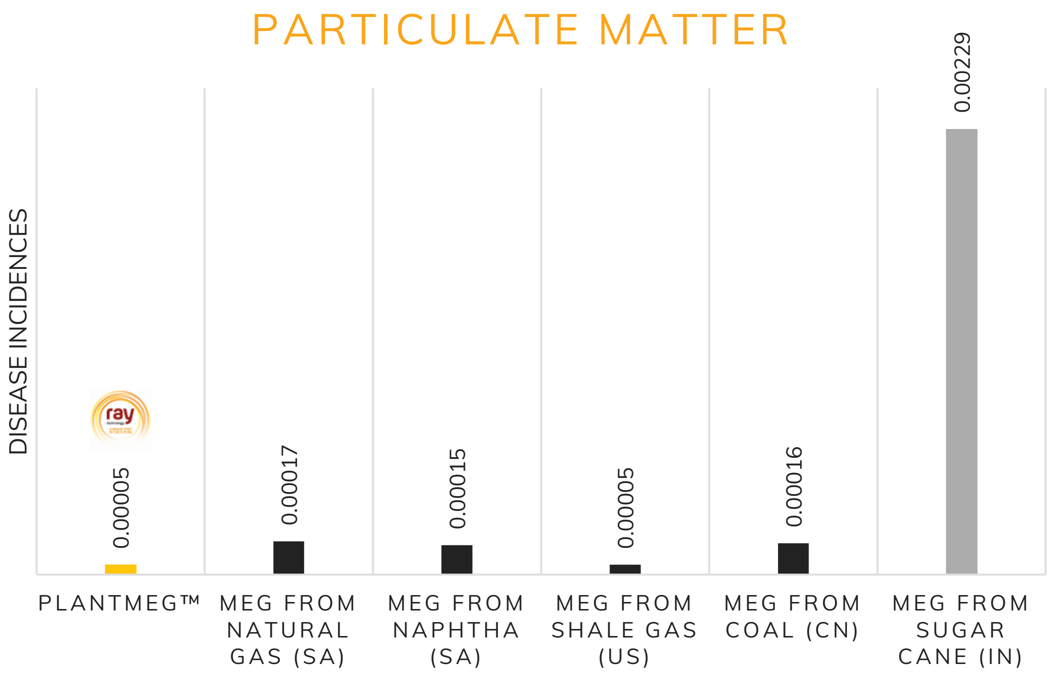
Particulate Matter

- Primary Energy Demand (non-renewable) of Ray plantMEG™ is performing in a similar order of magnitude as the incumbent fossil process and outperforming the ethanol-based route since Dutch beet sugar outperforms significantly Indian sugar cane in this aspect.



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Acknowledgement

Acknowledgement

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IMPRESS

Bio-based Industries
Consortium

VEHICLE

SNN
SAMENWERKINGSVERBAND
NOORD-NEDERLAND
• Stimuleert • Faciliteert • Verbindt

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