# LIFE CYCLE ASSESSMENTS OF BIOFUELS FOR PASSENGER CARS

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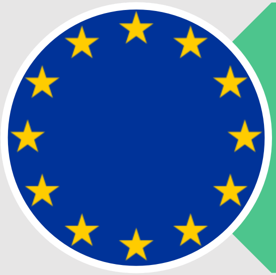
Assessment on WAste and REsources

# Background

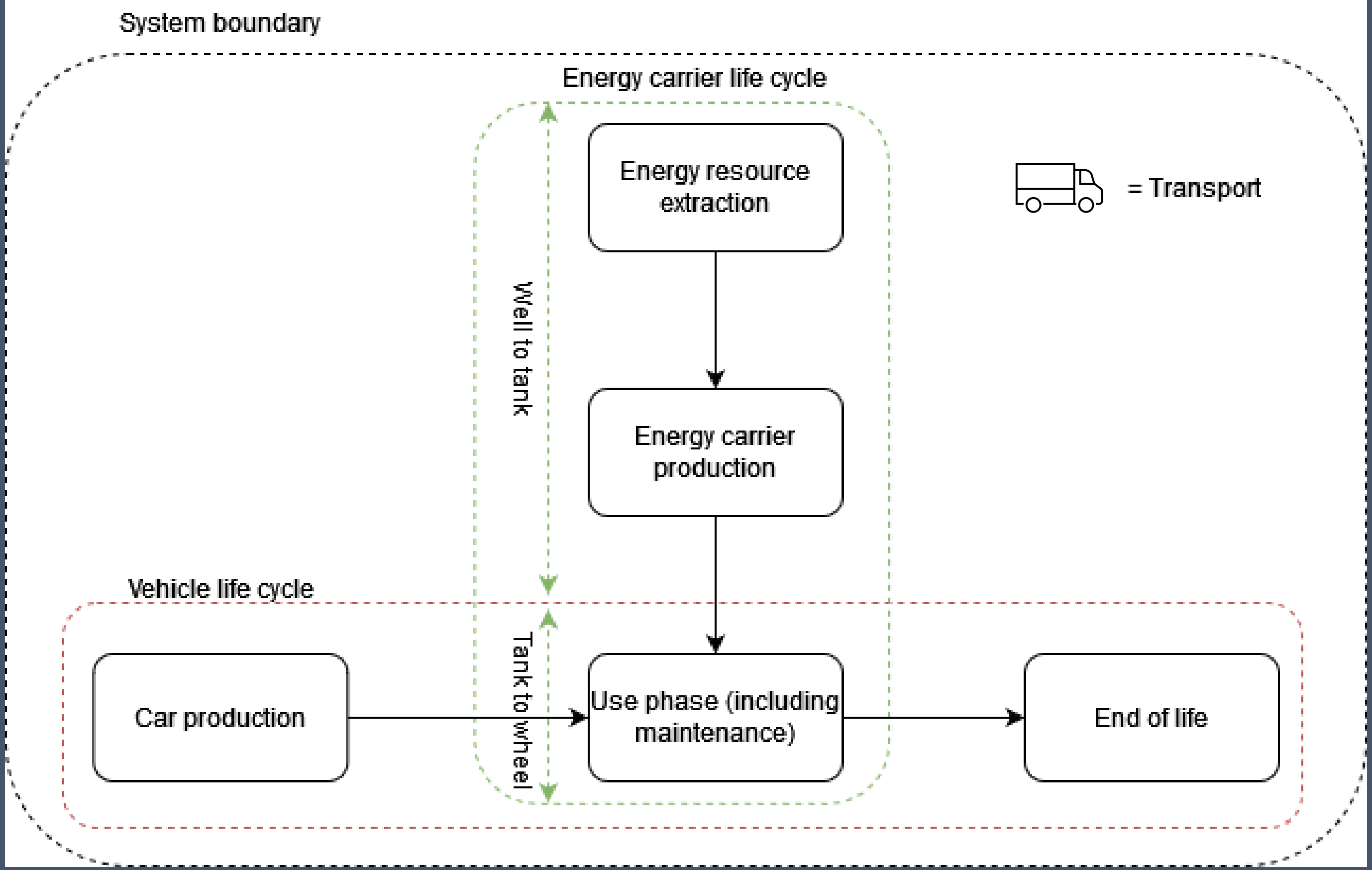
Passenger cars are responsible for around 12% of total EU emissions of $CO_2$



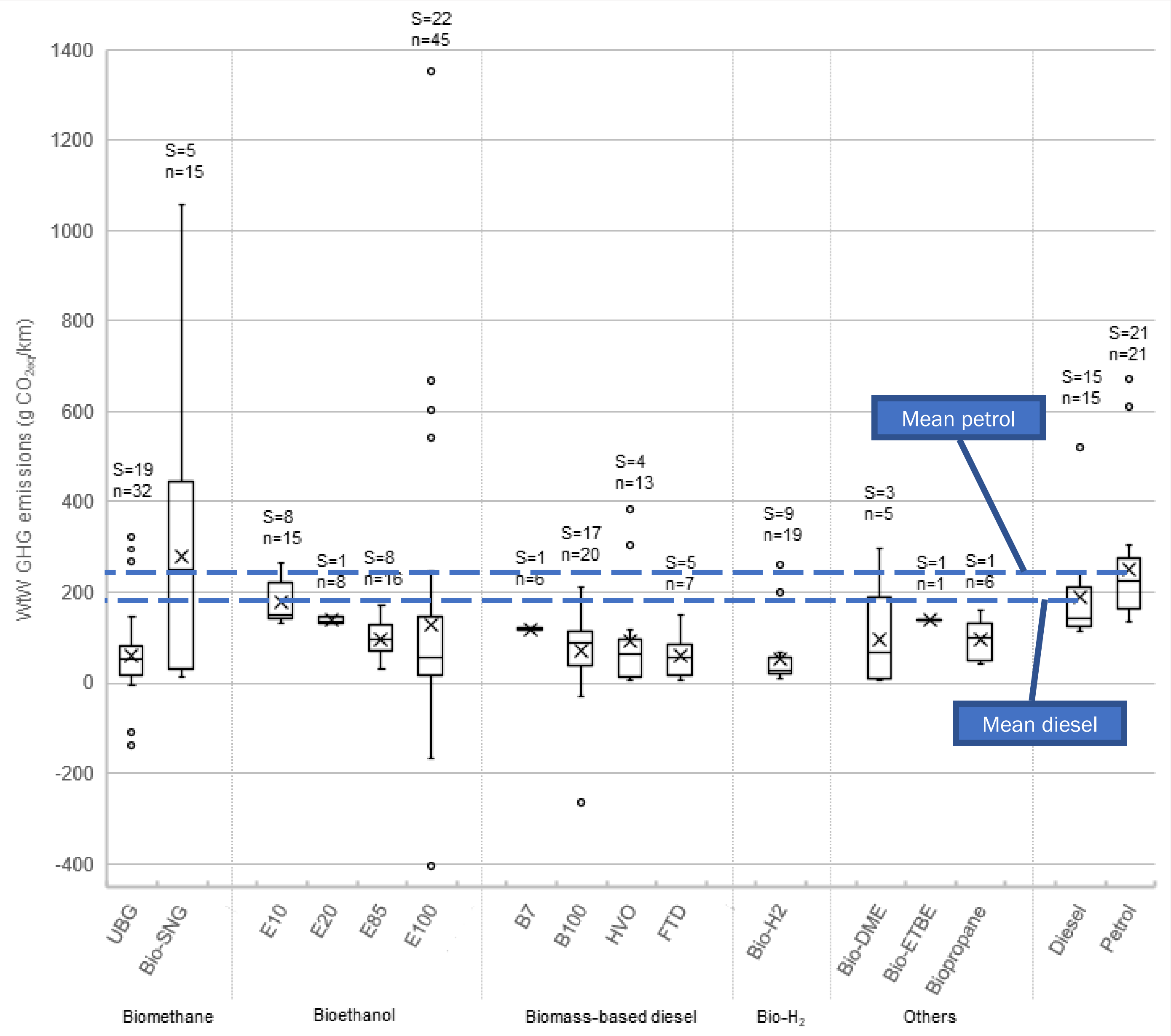
Directive (EU) 2018/2001 established for transport a minimum 14% share of renewables, by 2030

The use of biofuels could reduce GHG emissions of the fleet of internal combustion engine vehicles (ICEVs)

# SYSTEM BOUNDARY OF AN LCA OF A PASSENGER CAR



# WTW impacts of biofuels




WTW GHG emissions (g $CO_2$ eq/km) values grouped for type of biofuel (neat or blended). S = number of studies; n = number of results; Bio-$H_2$ = biohydrogen; Bio-SNG = bio-synthetic natural gas; DME = dimethyl ether; ETBE = ethyl tert-butyl ether; EXY = XY% of bioethanol + (100-XY)% of petrol; BXY = XY% of FAME + (100-XY)% of diesel; FTD = Fischer-Tropsch diesel; HVO = hydrotreated vegetable oil.

Puricelli et al., 2021. A review on biofuels for light-duty vehicles in Europe.

# WTW impacts of biofuels

Environmental performance of biofuels compared to fossil fuels (petrol, diesel, natural gas) on a WTW basis for non-GHG-related impact categories. Red arrows mean higher impact for biofuels, green arrows mean lower impact for biofuels, question marks mean a mixed picture. The most appropriate symbol was chosen basing on the results of the reviewed LCAs that reported a comparison with fossil fuels.

| Biofuel | Abiotic depletion | Acidification | Ecotoxicity | Energy use | Eutrophication | Freshwater eutrophication | Marine and terrestrial eutrophication | Fossil resource depletion | Human toxicity | Land use | Ozone depletion | Particulate matter formation | Photochemical oxidant formation | Water consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bioethanol | ? | ↑ | ↑ | ? | ↑ | ↑ | ↑ | ↓ | ↑ | ↑ | ↓ | ? | ? | ↑ |
| Bio-$H_2$ | | ? | | ? | ? | | | | | | | ↑ | | |
| Bio-SNG | | ↑ | | | ↑ | | | | | | | ↑ | | |
| FAME | ? | ↑ | | ? | ↑ | ? | ? | ↓ | ↑ | ↑ | ? | ? | ↑ | ? |
| FT diesel | ↓ | ? | | ? | ? | | | | | | ↓ | ? | ↑ | |
| Upgraded biogas | ↓ | ↑ | ? | ? | | ? | ? | ↓ | ? | ↑ | ↓ | ? | ? | ↑ |

Puricelli et al., 2021. A review on biofuels for light-duty vehicles in Europe.

# RED, PEF, and EPD: Conflicting rules for determining the carbon footprint of biofuels give unclear signals to fuel producers and customers

Miguel Brandão[1]*, Tomas Ekvall[2,3], Sofia Poulikidou[4], Kristin Johansson[4], Johan Nilsson[4], Pavinee Nojpanya[4], Anna Wikström[3,5] and Tomas Rydberg[4]

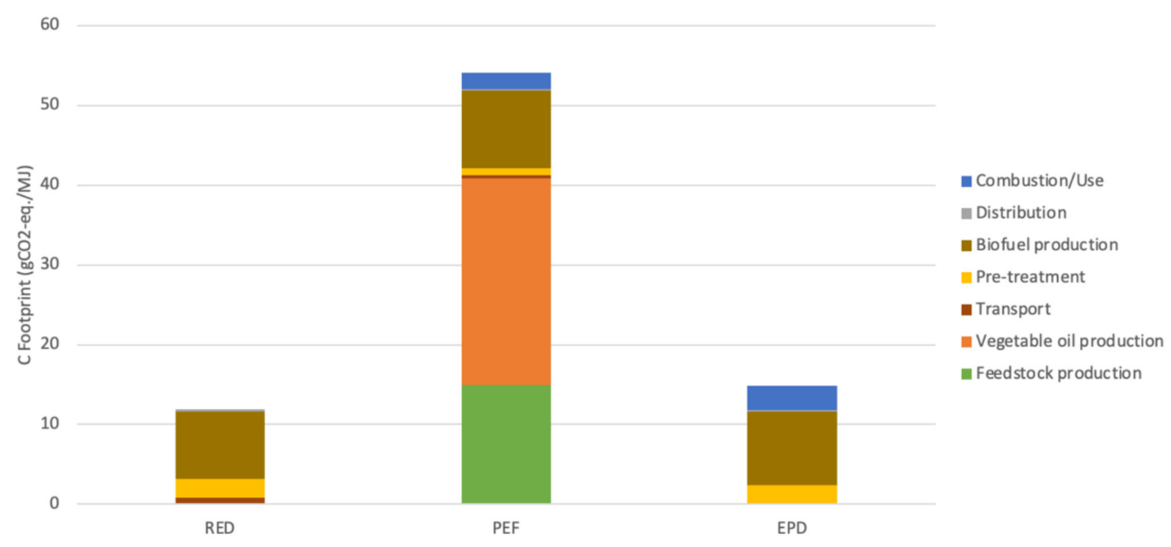



FIGURE 4
Carbon footprint of UCO HVO, as modeled by RED II, PEF, and EPD. The CFF results includes part of the climate impact of virgin oil production.

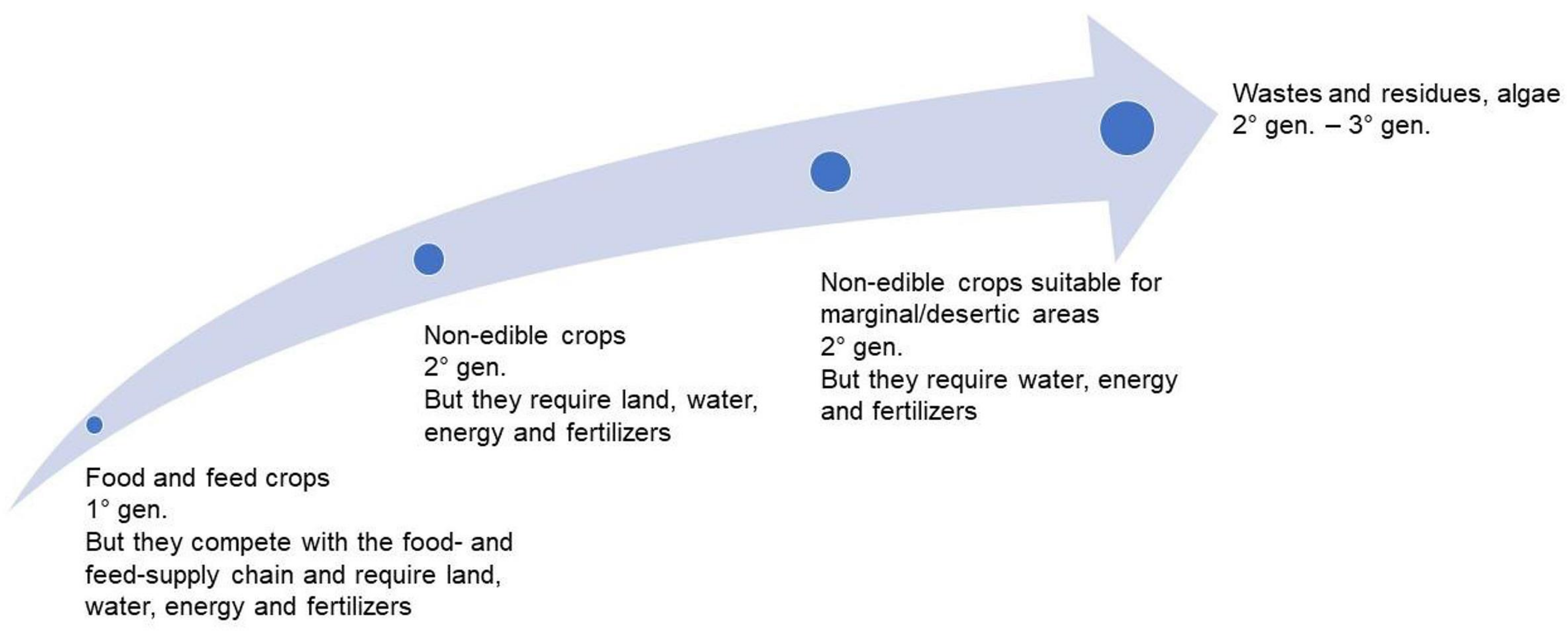
# DIFFERENT METHODOLOGIES, DIFFERENT RESULTS

# Land use change

- Land use change (LUC): conversion of a land to another purpose
- Substantial amounts of GHGs can be released or stored due to this process
- Direct LUC: when a land is converted to energy crops
- Indirect LUC: when a land dedicated to another crop is converted to energy crops
- In the EU, biofuels with high ILUC-risk, produced from food and feed crops for which a significant expansion of their feedstock production area into land with high carbon stock is observed, will be phased out by 2030

European Parliament and Council of the EU, 2018. Directive (EU) 2018/2001

# The evolution of feedstocks for biofuels



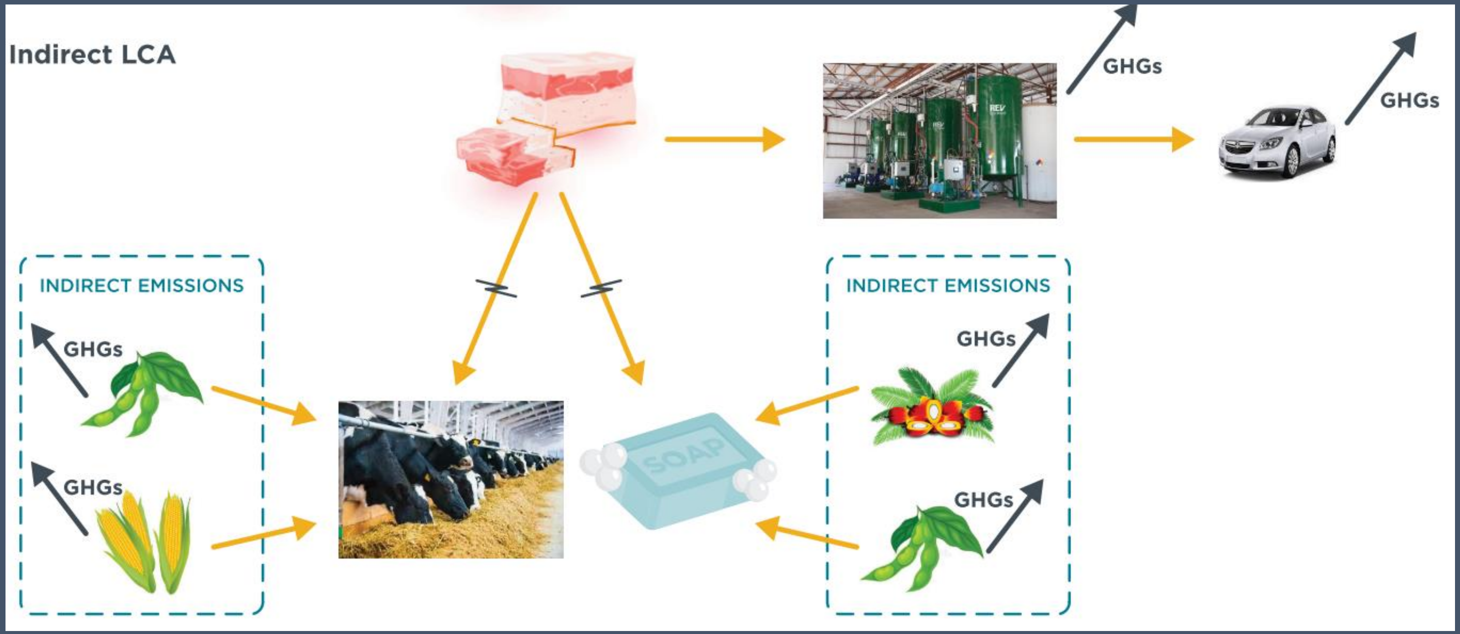

Puricelli et al., 2021. A review on biofuels for light-duty vehicles in Europe.

# The evolution of feedstocks for biofuels

eni.com

*News:*

- *24/11/2016 - Eni currently uses **palm oil** for the production of Green Diesel, given the large availability of this product on the market.*
- *25/10/2022 - Eni has definitively ended the procurement of palm oil to produce hydrogenated biofuels. Eni's biorefineries are already fuelled with '**waste & residue**' raw materials, such as **used cooking oil and animal fats**, for more than 85% of their processes as well as other regulated biomasses. In November, the first load of vegetable oil produced in Kenya will arrive at the Gela biorefinery, where castor, croton and cotton seeds are pressed. These agri-feedstocks **do not compete with the food chain**. They are **grown in degraded areas**, harvested from wild trees or are derived from the enhancement of agricultural by-products.*




# Indirect emissions from feedstocks diversion

O’Malley et al., 2021. Indirect emissions from waste and residue feedstocks: 10 case studies from the United States.

# A case study

## Goal definition

- Environmental impacts of using a C-segment GDI Euro 6d-TEMP passenger car fed by four blends of petrol
- Comparison between internal combustion engine vehicle (ICEV) and a C-segment battery electric vehicle (BEV) with 57.5 kWh of battery capacity

| | Unit of measure | Fuel A | Fuel B | Fuel C | Fuel D |
|---|---|---|---|---|---|
| Petrol | % v/v | 96.4 | 85.0 | 78.2 | 92.5 |
| ETBE or bio-ETBE | % v/v | 3.6 | - | - | - |
| Bio-ETBE | % v/v | - | - | 21.8 | - |
| Bionaphtha | % v/v | - | 7.0 | - | - |
| Bioethanol | % v/v | - | 8.1 | - | 4.8 |
| Methanol or biomethanol or e-methanol | % v/v | - | - | - | 2.7 |

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Puricelli et al., 2021. The effects of innovative blends of petrol with renewable fuels on the exhaust emissions of a GDI Euro 6d-TEMP car
Puricelli et al., 2022. Life Cycle Assessment of innovative fuel blends for passenger cars with a spark-ignition engine: A comparative approach.

# Scope definition

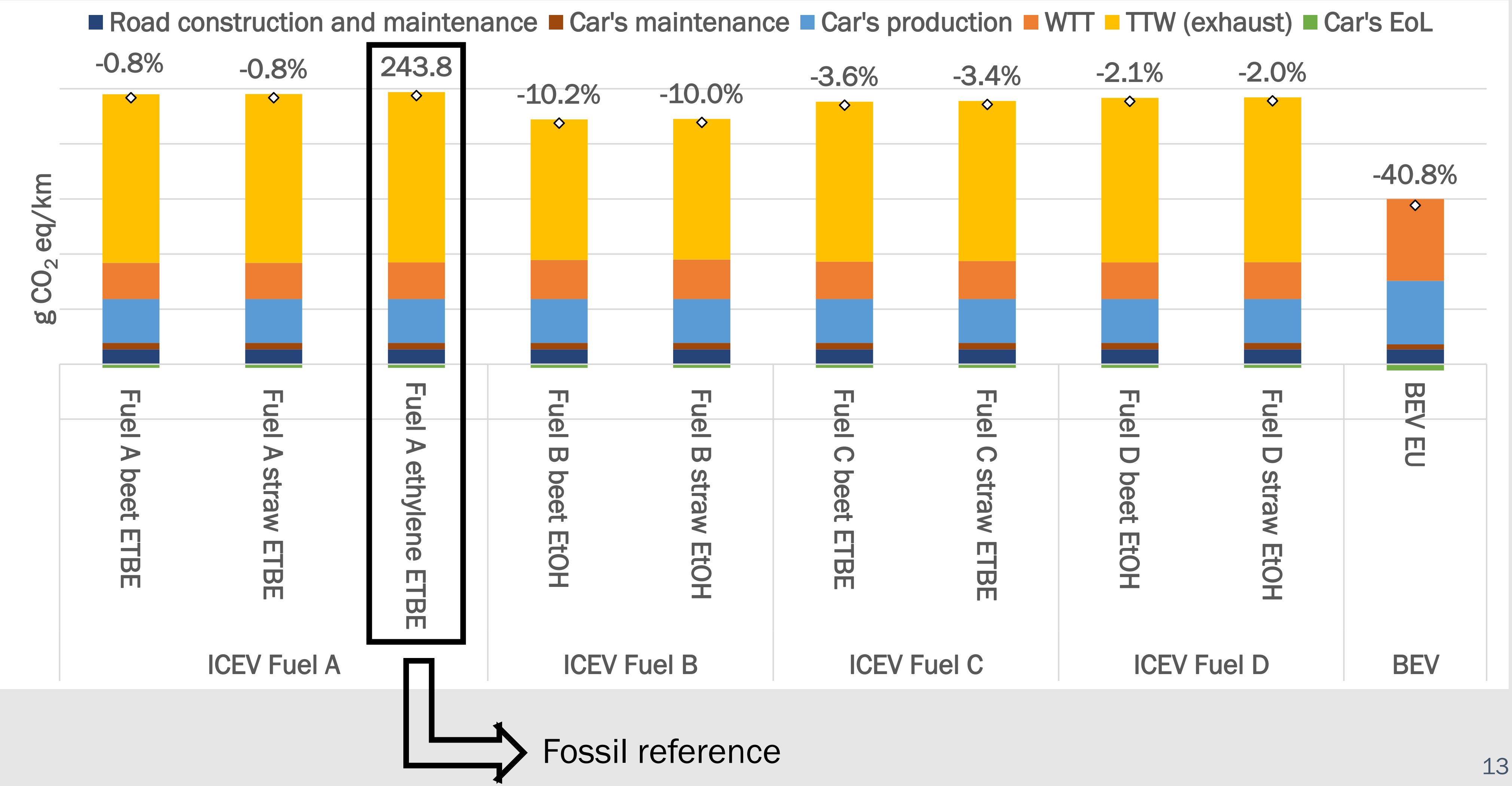
- The functional unit is “driving 1 km in Europe with a C-segment car that fulfils the Euro 6d-TEMP standard”
- The lifetime mileage of the car is 210,000 km
- The time horizon is 2020
- The geographical scope is Europe
- 16 impact categories (EF method 3.0)

Puricelli et al., 2022. Life Cycle Assessment of innovative fuel blends for passenger cars with a spark-ignition engine: A comparative approach.

# Results

## Climate change

| | Unit of measure | Fuel A | Fuel B | Fuel C | Fuel D |
|---|---|---|---|---|---|
| ETBE or bio-ETBE | % v/v | 3.63 | - | - | - |
| Bio-ETBE | % v/v | - | - | 21.79 | - |
| Bionaphtha | % v/v | - | 7.0 | - | - |
| Bioethanol | % v/v | - | 8.06 | - | 4.80 |
| Methanol or biomethanol or e-methanol | % v/v | - | - | - | 2.71 |

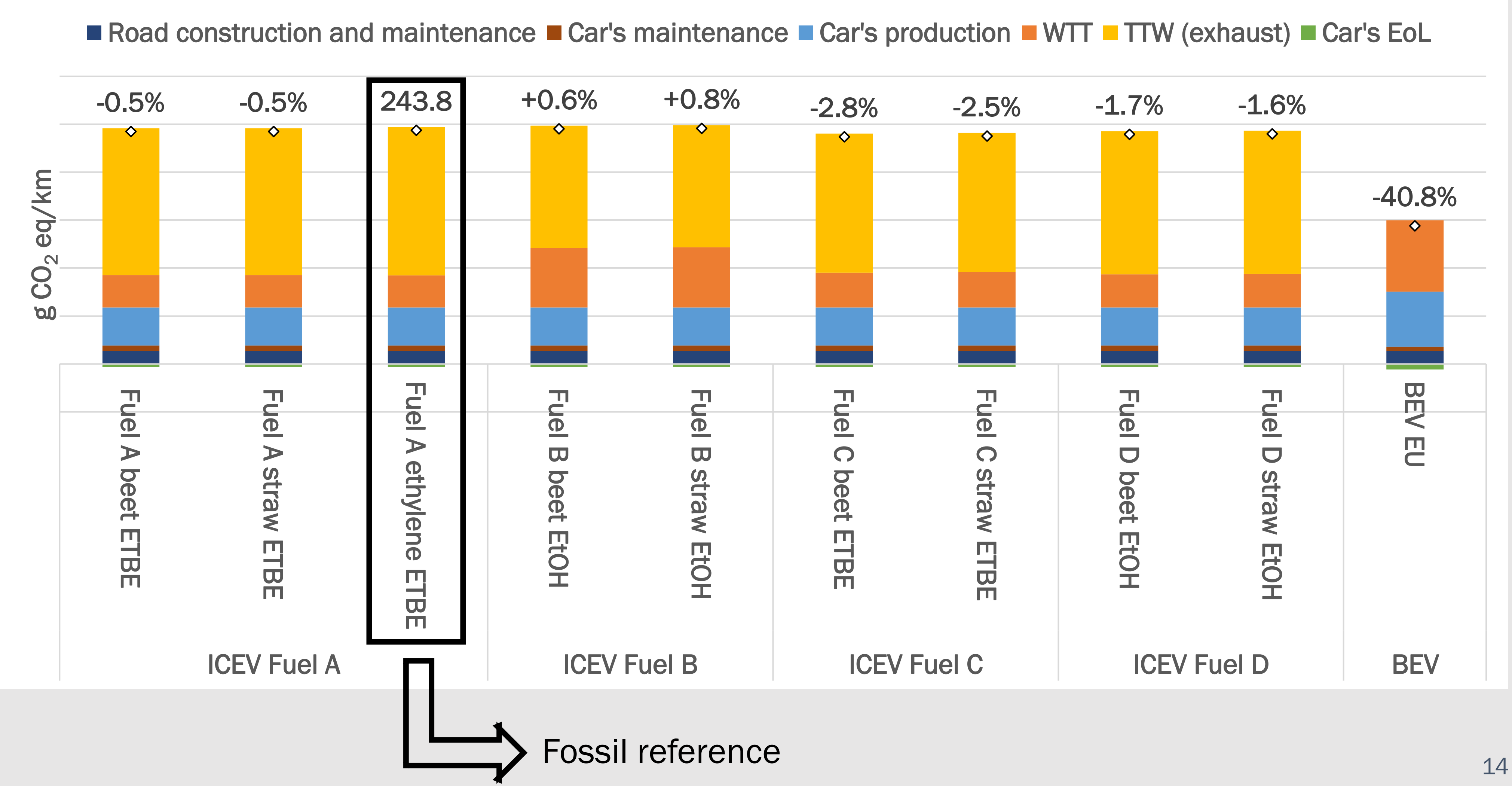



Puricelli et al., 2022. Life Cycle Assessment of innovative fuel blends for passenger cars with a spark-ignition engine: A comparative approach.

# Results

## Climate change – LUC included

| | Unit of measure | Fuel A | Fuel B | Fuel C | Fuel D |
|---|---|---|---|---|---|
| ETBE or bio-ETBE | % v/v | 3.63 | - | - | - |
| Bio-ETBE | % v/v | - | - | 21.79 | - |
| Bionaphtha | % v/v | - | 7.0 | - | - |
| Bioethanol | % v/v | - | 8.06 | - | 4.80 |
| Methanol or biomethanol or e-methanol | % v/v | - | - | - | 2.71 |

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# Results

## Overall results – Percentage difference compared with fossil reference

| | Climate change | Ozone depletion | Ionising radiation | Photochemical ozone formation | Particulate matter | Human toxicity, non-cancer | Human toxicity, cancer | Acidification | Eutrophication, freshwater | Eutrophication, marine | Eutrophication, terrestrial | Ecotoxicity, freshwater | Land use | Water use | Resource use, fossils | Resource use, minerals and metals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel A beet ETBE | -0.8 | 0.0 | 0.0 | -0.3 | 5.2 | -0.8 | 0.0 | 10.6 | -0.9 | 7.6 | 26.1 | 0.4 | 1.7 | -4.2 | -0.9 | 0.0 |
| Fuel A straw ETBE | -0.8 | 0.3 | 0.1 | -0.1 | 0.5 | 1.1 | 0.5 | 0.5 | -0.7 | 4.0 | 1.5 | 1.3 | 0.9 | 0.6 | -0.8 | 0.0 |
| Fuel B beet EtOH | -10.2 | -12.9 | -8.9 | 2.6 | 30.9 | -3.4 | 0.7 | 52.7 | 1.4 | 116.7 | 140.1 | 5.5 | 23.5 | 28.0 | -11.8 | 1.3 |
| Fuel B straw EtOH | -10.0 | -11.5 | -8.5 | 3.5 | 8.0 | 5.8 | 3.5 | 3.9 | 2.3 | 99.2 | 20.9 | 9.7 | 19.3 | 51.3 | -11.3 | 1.4 |
| Fuel C beet ETBE | -3.6 | -5.3 | -4.6 | 0.1 | 30.5 | -4.5 | 0.0 | 61.8 | 0.2 | 48.2 | 159.4 | 2.0 | 9.8 | -5.3 | -5.1 | 0.7 |
| Fuel C straw ETBE | -3.4 | -3.5 | -4.1 | 1.2 | 1.7 | 7.2 | 3.5 | 0.4 | 1.3 | 26.2 | 9.5 | 7.3 | 4.6 | 24.0 | -4.5 | 0.8 |
| Fuel D beet EtOH | -2.1 | -3.3 | -2.1 | 0.5 | 15.7 | -2.0 | 0.3 | 31.5 | 0.1 | 25.1 | 79.7 | 1.2 | 6.7 | -3.1 | -3.5 | 0.4 |
| Fuel D straw EtOH | -2.0 | -2.4 | -1.8 | 1.0 | 1.4 | 3.8 | 2.0 | 1.0 | 0.6 | 14.2 | 5.3 | 3.8 | 4.0 | 11.4 | -3.2 | 0.5 |
| BEV | -40.8 | -69.6 | 131.7 | -30.5 | -10.9 | 3.7 | 3.5 | -1.8 | 221.5 | 32.9 | 12.9 | -61.6 | 4.5 | 108.5 | -24.6 | -57.3 |

Variations lower than -5%

Variations higher than +5%

Variations between -5% and +5% (not substantial)

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# Conclusions

- Biofuels, if made from the right feedstock, can contribute to the decarbonisation of the road transport sector
- For the other impact categories, the picture is mixed
- The methodological approach of an LCA study should always be declared; and decided according to the goal definition
- The risk of indirect emissions should always be verified, because those emissions could nullify the emission savings

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# Thank you very much for your attention

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