1st LCA for Transportation Symposium

LCA ANALYSIS – ROLE OF FUELS AND POWERTRAINS

NOVEMBER 3RD, 2021 – CYPRIEN TERNEL, ANNE BOUTER

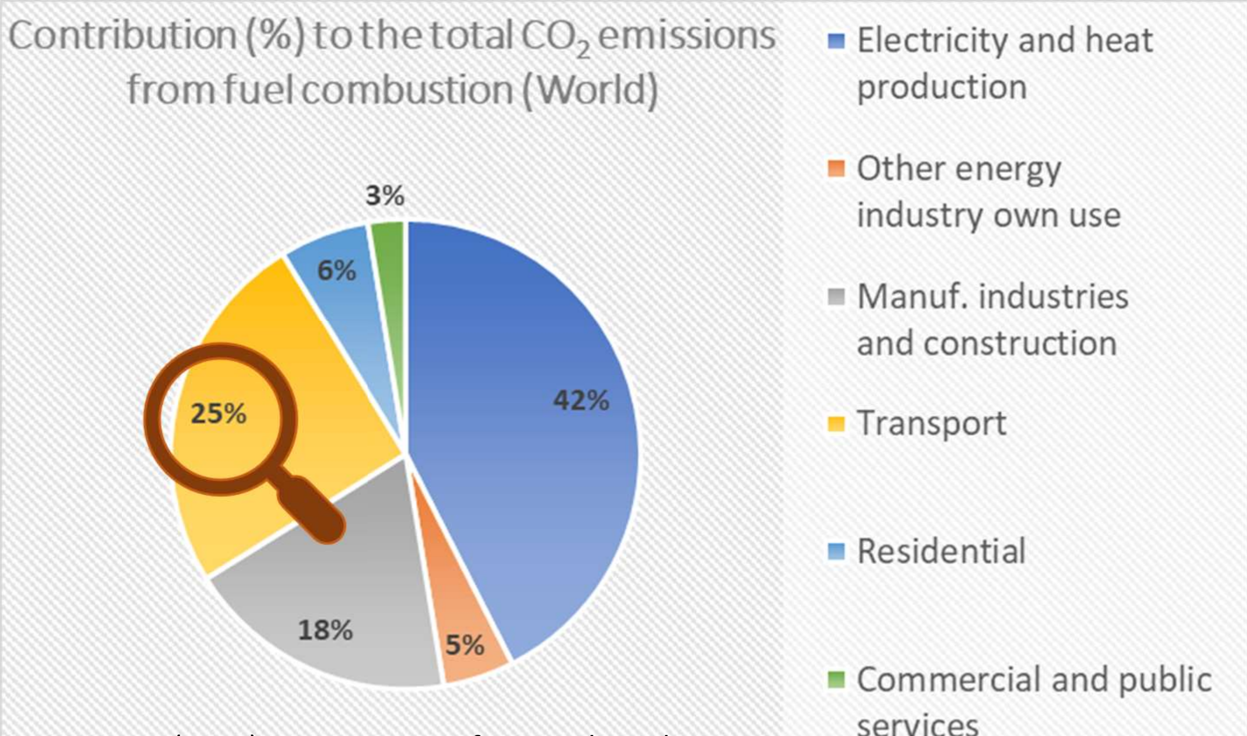
LIFE-CYCLE ANALYSIS for Transportation Symposium

IFP Energies nouvelles

Carnot ifpen Transports Energie

INTRODUCTION

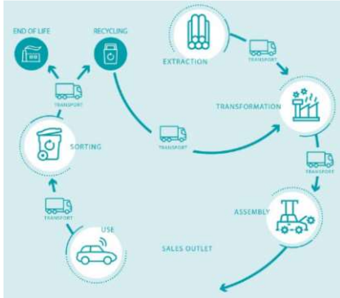
- The Paris Agreement sets out objectives to limit greenhouse gas (GHG) emissions in all sectors by fostering low carbon technologies.



Source: IEA (2020), *CO_2 Emissions from Fuel Combustion*

- The EU has set ambitious targets for reducing net emissions by at least 55% by 2030 compared to 1990.
- Transportation sector is brought to center stage as it accounts for almost a **quarter** of global CO_2 emissions.
- Deployment of low-carbon vehicles' technologies is exploding, as well as alternative fuels.
- Directives ruling for both fuels and powertrains must be considered.
- Life cycle assessment (LCA) methodology is a **powerful tool to assess several options to decrease environmental impacts of transportation sector.**

LIFE CYCLE ASSESSMENT
A POWERFUL TOOL

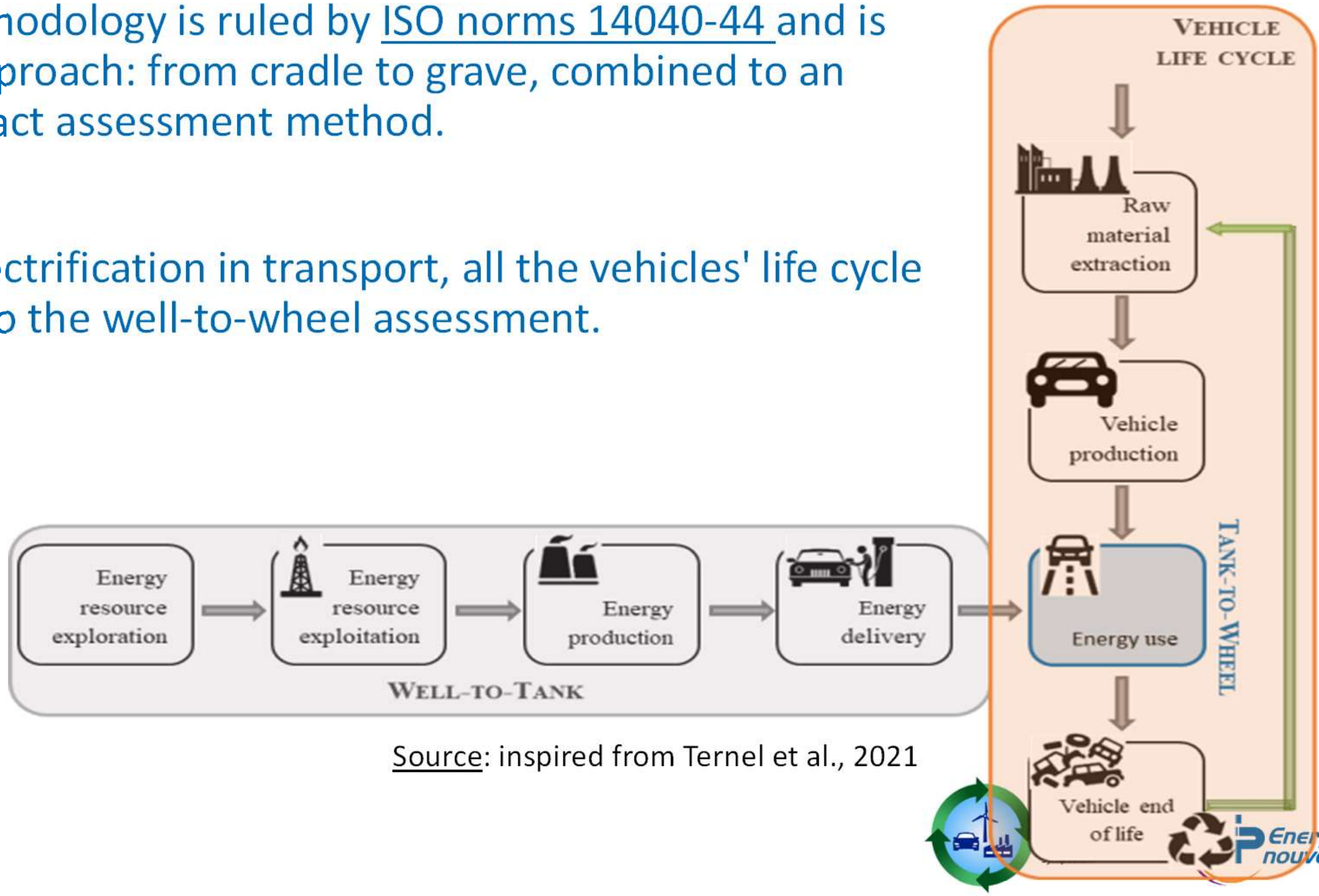


SUSTAINABLE MOBILITY

- Life Cycle Assessment (LCA) methodology is ruled by ISO norms 14040-44 and is defined by its multiple stages approach: from cradle to grave, combined to an environmental multicriteria impact assessment method.

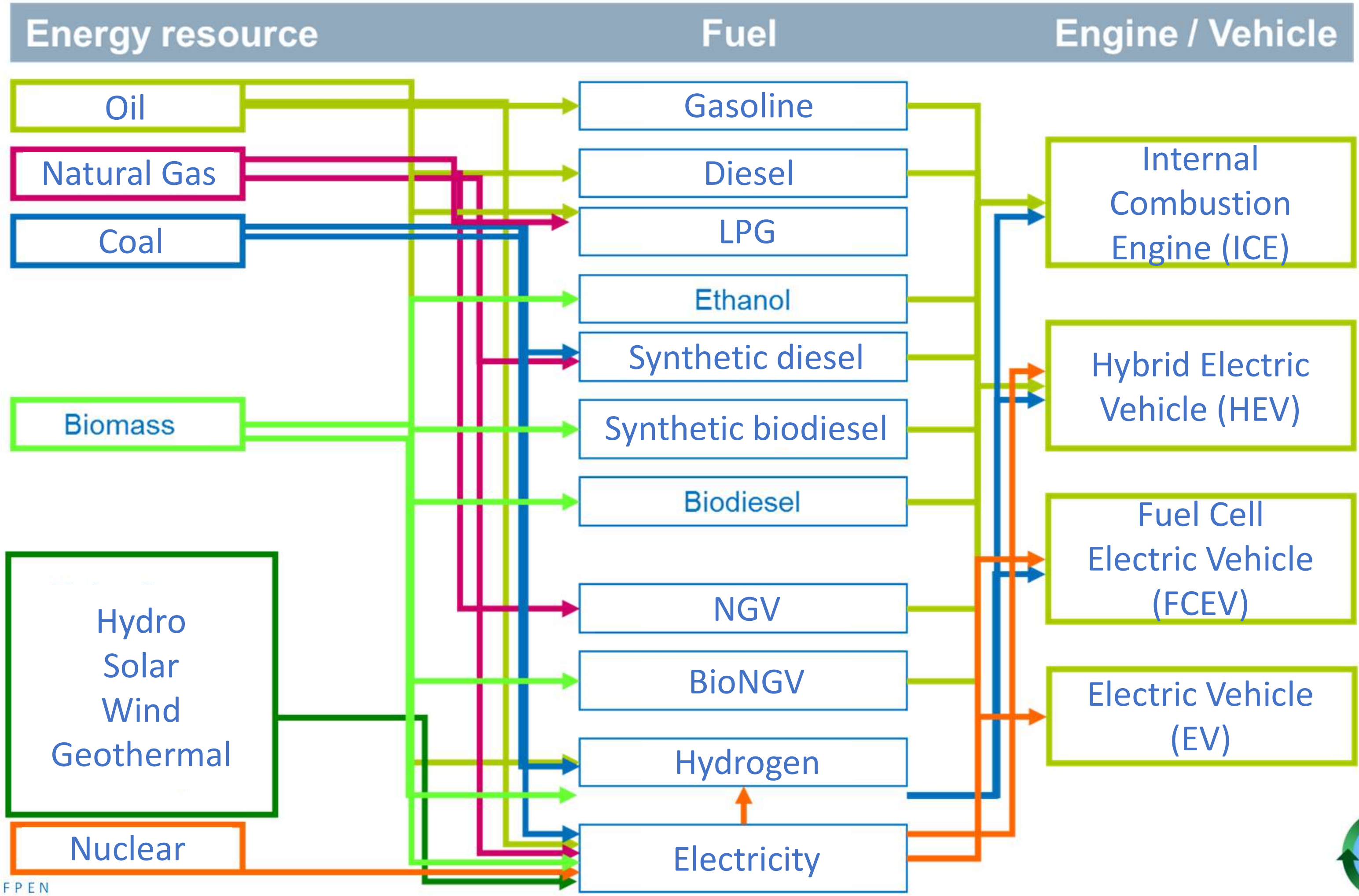
- With the development of the electrification in transport, all the vehicles' life cycle must be considered, combined to the well-to-wheel assessment.

- It is also crucial to assess other environmental impacts than the sole climate change impact trying to avoid environmental impacts' transfers.



Source: inspired from Ternel et al., 2021

WHY BIOMASS IN TRANSPORTATION SECTOR?
VARIABILITY AND COMPETITIVENESS OF TECHNOLOGY



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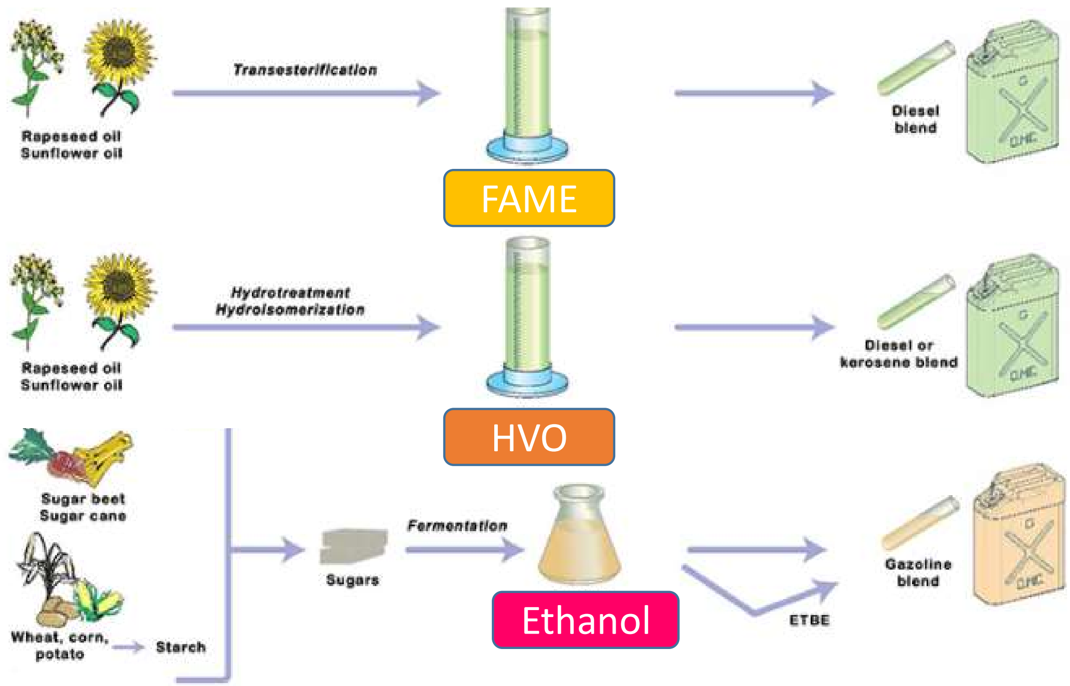
DIFFERENT CLASSIFICATION OF BIOFUELS (1/2)



Conventional biofuels

- Mature technologies
- 79.6 Mtoe in 2017, i.e. nearly 4% of the energy consumption of road transport worldwide
- Main production areas: USA, Brazil, EU28, China

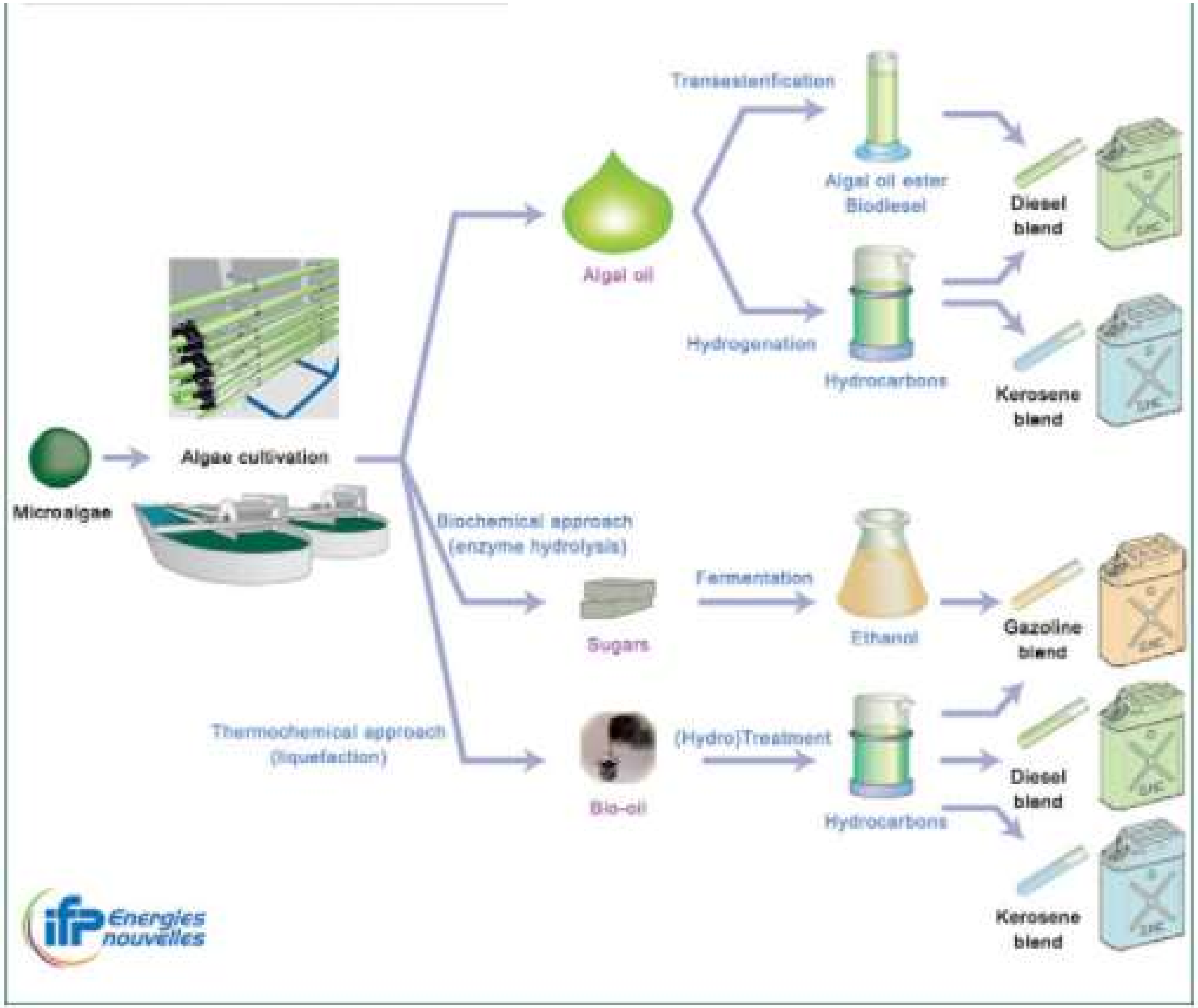
Lignocellulosic biofuels

- New technologies for a different type of resource
- Technological maturity expected by 2020
- Industrial maturity expected by 2025

DIFFERENT CLASSIFICATION OF BIOFUELS (2/2)

NEW ENERGIES

- **Other biofuels**
  - The same conversion processes as for conventional biofuels (mature technologies), but from new resources
    - Industrial oily lipid by-products
    - Co-products of the sugar and starch industries
  - Microbial biofuels via microorganisms producing sugars or lipids
  - Lipidic algae



LCA OF BIOFUELS
SCOPE DEFINITION

NEW ENERGIES

The main steps defining the boundaries of the LCA of a biofuel chain

Cultivation & harvesting of biomass

→ **Conversion 1**

→ **Conversion 2**

→ **Distribution**

→ **Biofuel use**

1 km

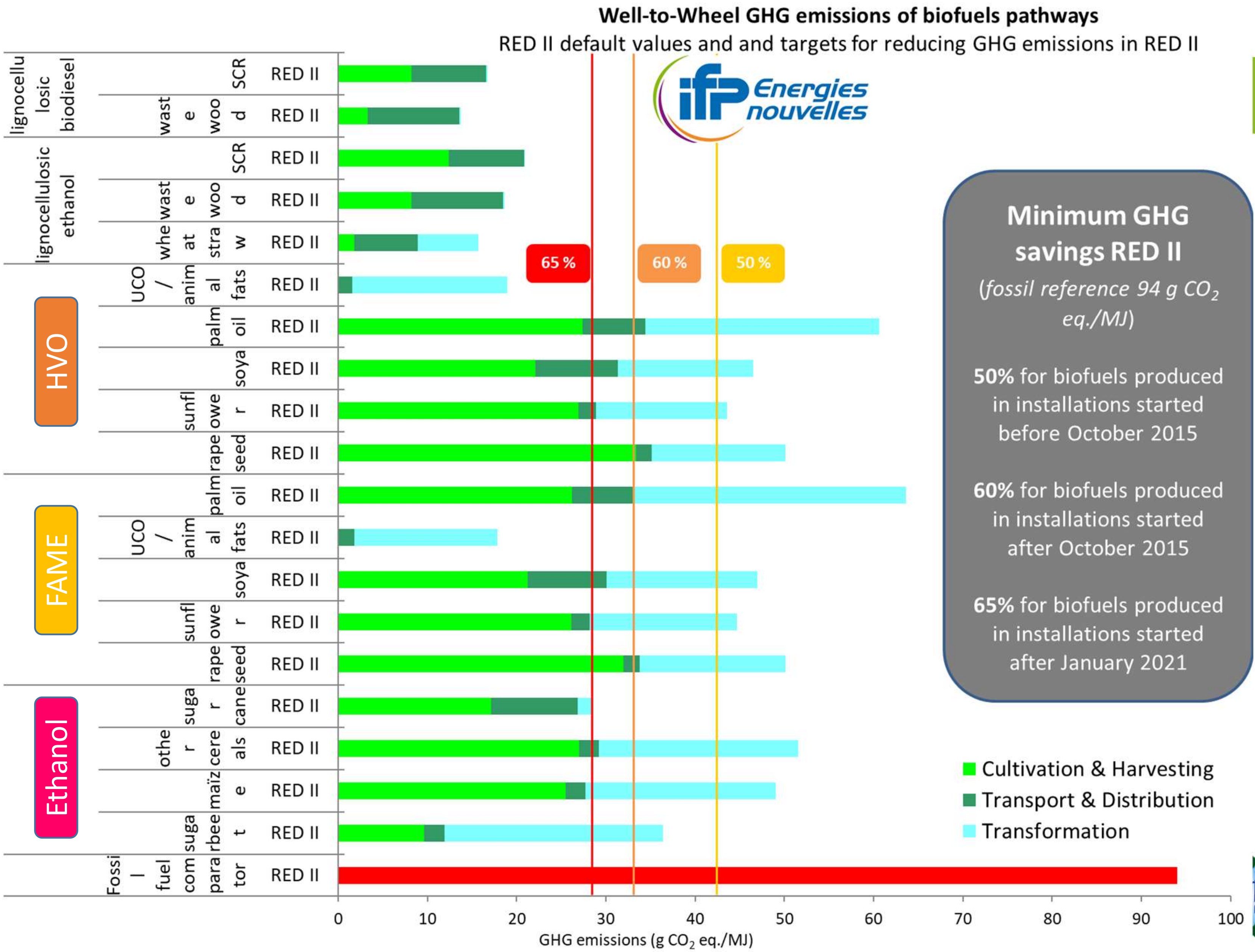
Intermediate transport stages of biomass, intermediate products and final fuel (road and/or rail and/or river or even sea for biomass imports)

and/or

and/or

and/or

NEW ENERGIES

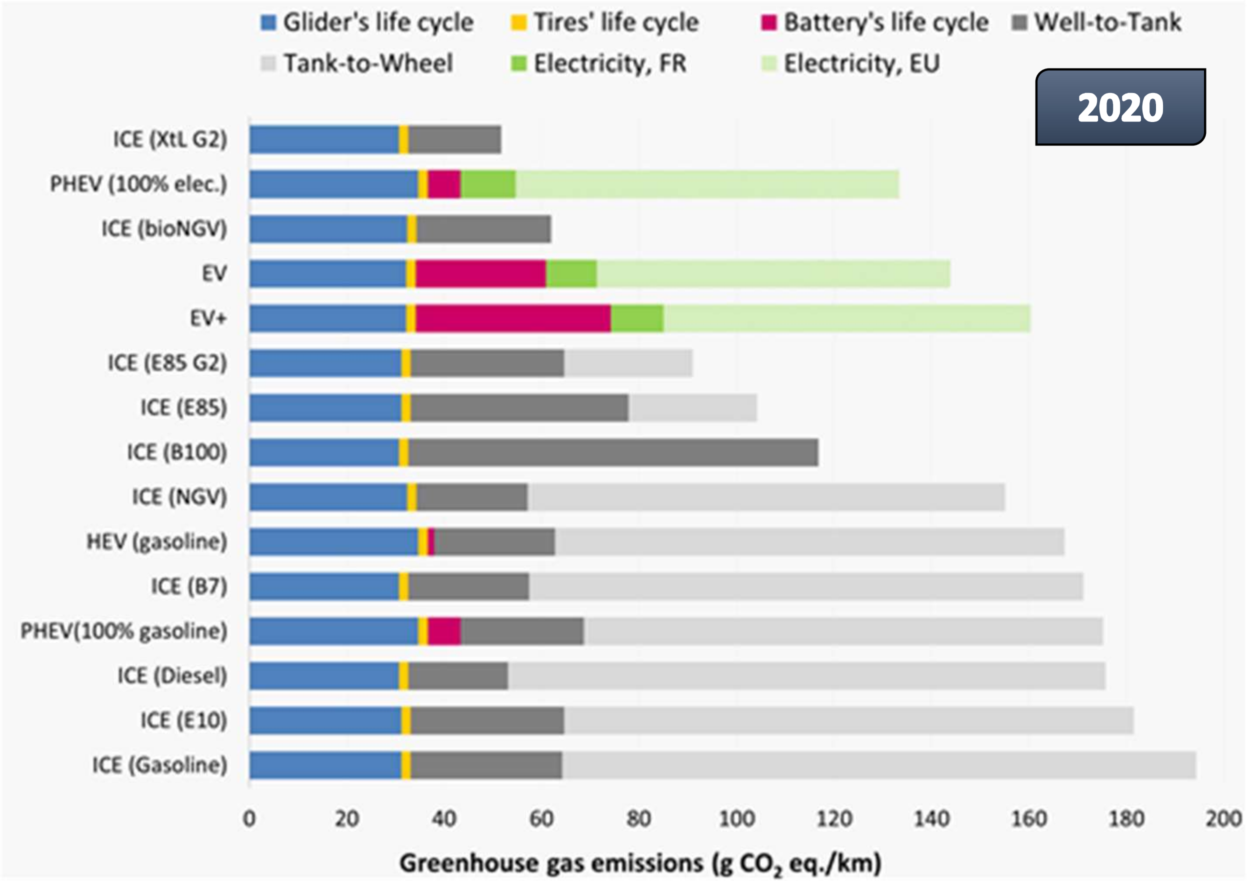


ENVIRONMENTAL IMPACT ASSESSMENT OF SEVERAL POWERTRAINS PROPELLED WITH SEVERAL ENERGY PATHWAYS

CLIMATE CHANGE IMPACT INDICATOR

Potential global warming impacts for a C-segment passenger vehicle in 2020, WLTC cycle

- Significant contribution of **battery life cycle** to total vehicle life cycle GHG impacts
  - 4% for an HEV
  - 16% for a PHEV
  - From 45% to 55% for an EV
- High sensitivity to the **charging electricity mix** for electrified vehicle
- Resource mix used by the average biofuel mix pumped in France in 2017 (DGEC)
- Default REDII average values for biofuels: GHG emissions and LHV
- **Glider's life cycle** roughly equivalent among powertrains
- ICE: high impact of WTW stage, especially TTW for fossil fuel ≠ from biofuels where **WTT** has greater impacts



Sources: Bouter, A., Hache, E., Ternel, C., Beauchet, S., ***2020***, Int. Journal of Life Cycle Assess.
Ternel, C.; Bouter, A.; Melgar, J., **2021,** Transportation Research Part D.

ENVIRONMENTAL IMPACT ASSESSMENT OF SEVERAL POWERTRAINS PROPELLED WITH SEVERAL ENERGY PATHWAYS

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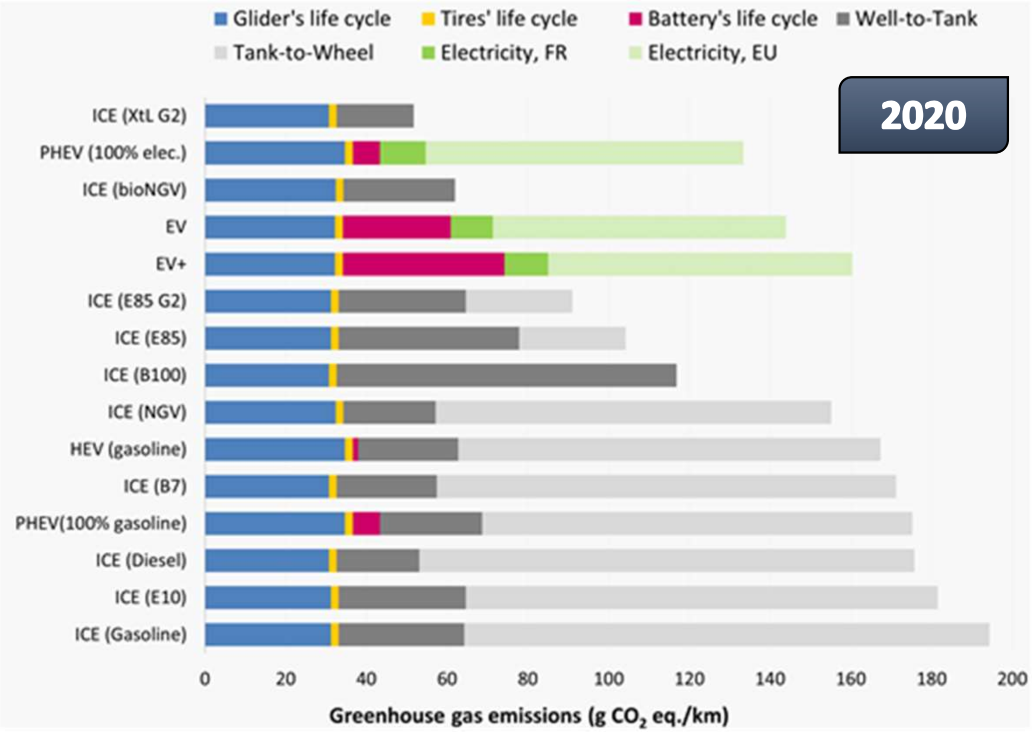
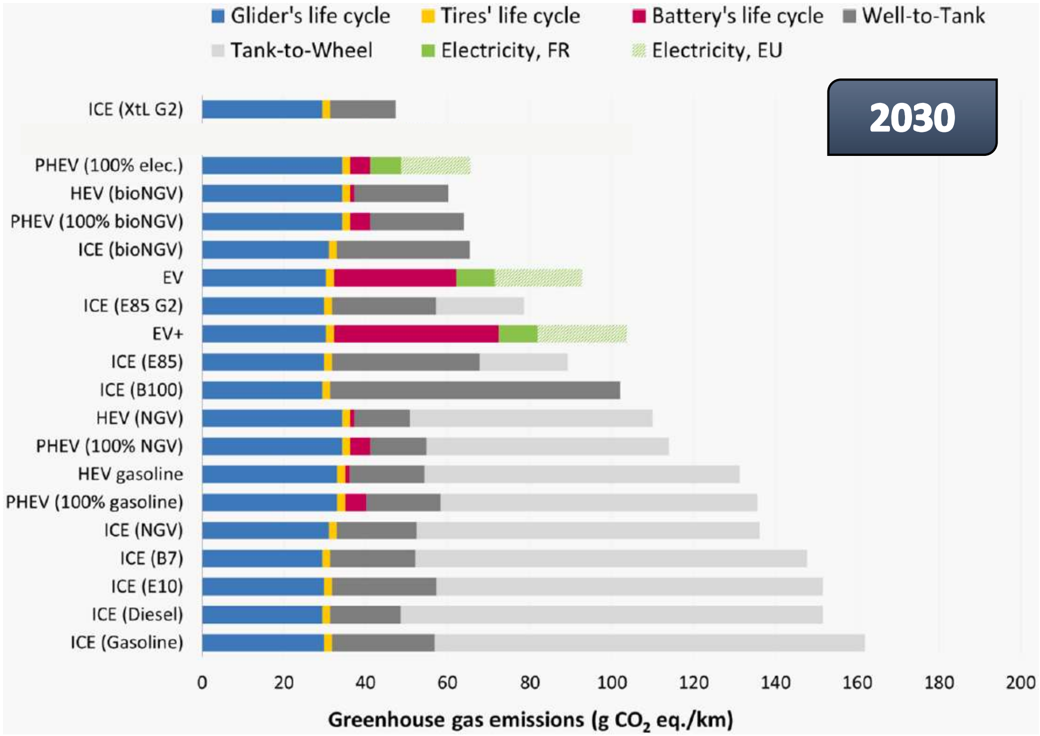
SUSTAINABLE MOBILITY





- A forecast comparative analysis of GHG emissions is presented here.
- Updated vehicle weigth, battery technologie and CO_2 electricity content are considered for 2030
- ICE, HEV or PHEV engines powered with advanced biofuels complement the full electrified powertrains

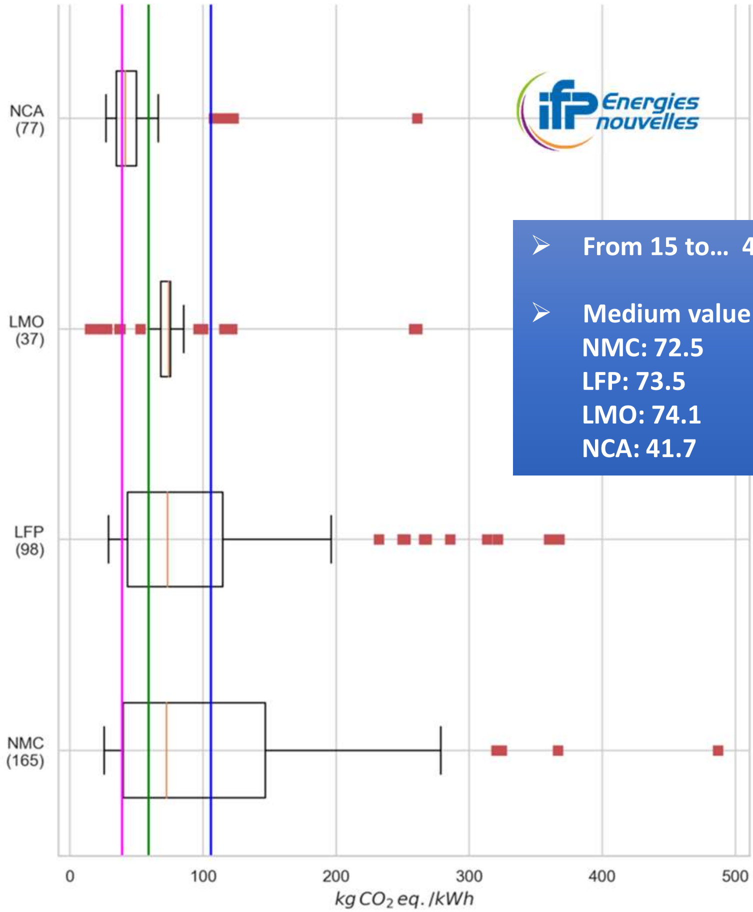
THE GROWING MARKET OF ELECTRIFIED VEHICLES

- Context
  - Growing electrification of the vehicle fleet supported by the countries
- Market response

  - Diversified offer of battery technologies: Li-ion, NiMH, all-solid, etc.
  - Increased performance of existing technologies
  - Future production in EU

- **Question: if electric vehicles do not emit exhaust emissions, what about the environmental impact of battery production?**
- Answer: not so simple...
  - Many studies exist BUT the range of values is very disparate
  - Often little transparency on the assumptions and data available
  - Few studies on the end of life of batteries
  - Regulatory obligation on the end of life of batteries in quantity but not in quality
  - Which environmental impact indicator(s)?

Battery Production Emissions

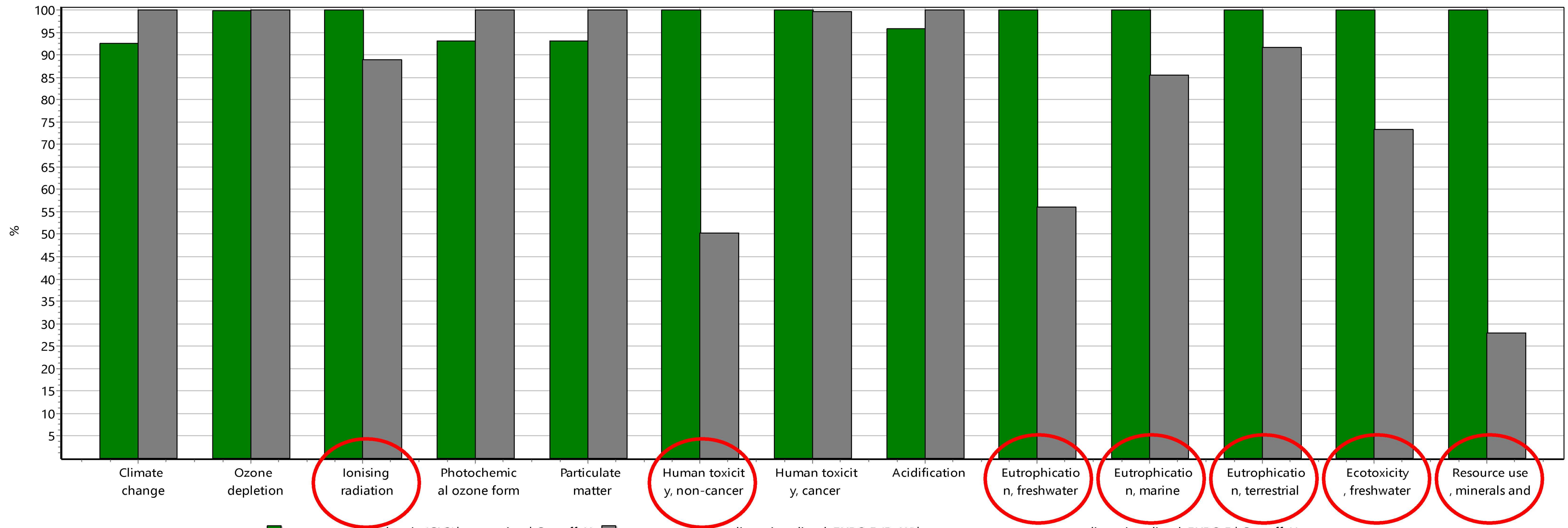


- **From 15 to… 487 $kgCO_{2eq}$/kWh !**
- **Medium value ($kgCO_{2eq}$/kWh):**
  NMC: 72.5
  LFP: 73.5
  LMO: 74.1
  NCA: 41.7

Dispersion of LCA GHG emission results for the different types of Li-ion Bat cathodes (32 studies / 377 observations)

BATTERIES' ENVIRONMENTAL IMPACTS
OTHER THAN CLIMATE CHANGE INDICATOR

Comparison between **ICE diesel vehicle** versus **Electric Vehicle**



Method: EF 3.0 Method (adapted) V1.01 / EF 3.0 normalization and weighting set / Characterization
Comparing 1 km '_passenger car, electric {GLO}| processing | Cut-off, U' with 1 km '_passenger car, medium size, diesel, EURO 5 {RoW}| transport, passenger car, medium size, diesel, EURO 5 | Cut-off, U';

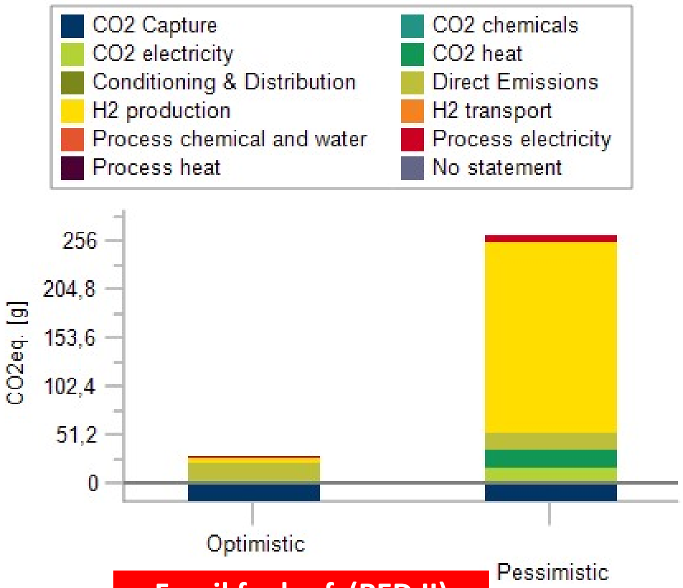
WHAT ABOUT E-FUELS?

Results in $gCO_2eq./MJ$

(based on JEC v5 data, with Ecoinvent data, energetic allocation rather than substitution)

E-diesel

Optimistic	Pessimistic
11,11	244,76



Fossil fuel ref. (RED II)
94 g CO_2 eq. / MJ

Common hypothesis

- CO2 from DAC
- PEM Electrolyser
- No transport of H2

Optimistic scenario

- Wind electricity
- Heat produced with a heat pump

Pessimistic scenario

- European electricity mix
- Heat produced with NG boiler

- E-fuels are very promising from a climate change perspective according to the energy used for their production.
- From a cumulative energy demand perspective, e-fuels are 2 to 3 times more energy consuming than other alternative pathways.

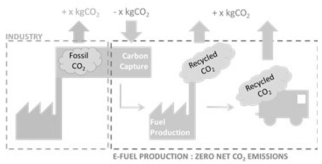
➔ The origin of the energy used to produce e-fuels is crucial for their impacts on climate change indicator

- The production of H_2 stage has a significant role to play about the deployment of e-fuels, especially the origin of the electricity for H_2 production.

TAKE-HOME MESSAGES

PROS

- Biomass
  - Important lever for reducing pollutants in the transportation sector
  - Potentially abundant source of renewable energy
  - Biofuels are easily substitutable for conventional fuels
- Electrified vehicles
  - Zero tailpipe emissions
  - Could be a game changer for GHG reduction according to batteries' weight and energetic sizing
- E-fuels
  - Drop-in
  - Promising solution in terms of GHG reduction



CONS

- Biomass
  - Possible competition of food versus fuel
  - Potential rebounds effects on LUC (direct and indirect)
  - Tailpipe pollutants emissions (other than CO_2)
- Electrified vehicles
  - Consumption of critical raw materials to produce battery
  - Battery's management end of life of batteries could be a game changer between pros and cons
- E-fuels
  - Production: energy consuming
  - Balance depending on the energy source

- LCA is
  - A very powerful multi-criteria environmental decision support tool to guide future policies
  - Which is sensitive to hypothesis and requires sensitivity analysis
  - It seems also urgent to considered other environmental indicators than the only climate change impact indicator to have a broader view of the impacts
  - Large-scale scenario should also be assessed
  - **It is the diversity of low-carbon solutions which seems to be the smarter way**

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