Life-cycle assessment (LCA) of greenhouse gas emissions from passenger cars in real-world conditions

User Guide

Table of contents

1. Purpose and overview of the LCA simulator

As powertrains diversify in their electrification levels – Hybrids (HEV), Plug-in Hybrids (PHEV) and Battery Electric Vehicles (BEV) – along with the fuel production pathways – fossil and renewable routes – the carbon footprint over their life-cycle heavily depends on their use cases (e.g. driving profile) and context of use (e.g. carbon intensity of electricity). This interactive tool allows to design several scenarios combining these parameters and to compare their environmental performance.

The tool design is made of two main panels (Figure 1): on the left hand side, the results panel, where a bar graph representing life-cycle GHG emissions is displayed; on the right hand side, the configuration panel.

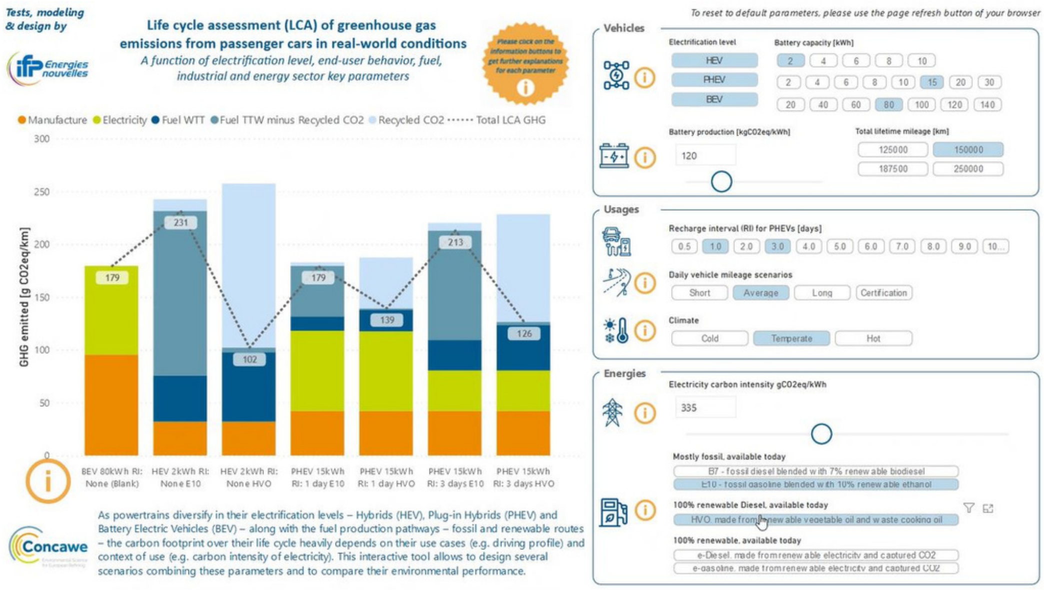

Figure 1: Screenshot of the online vehicle LCA simulator

2. Results panel

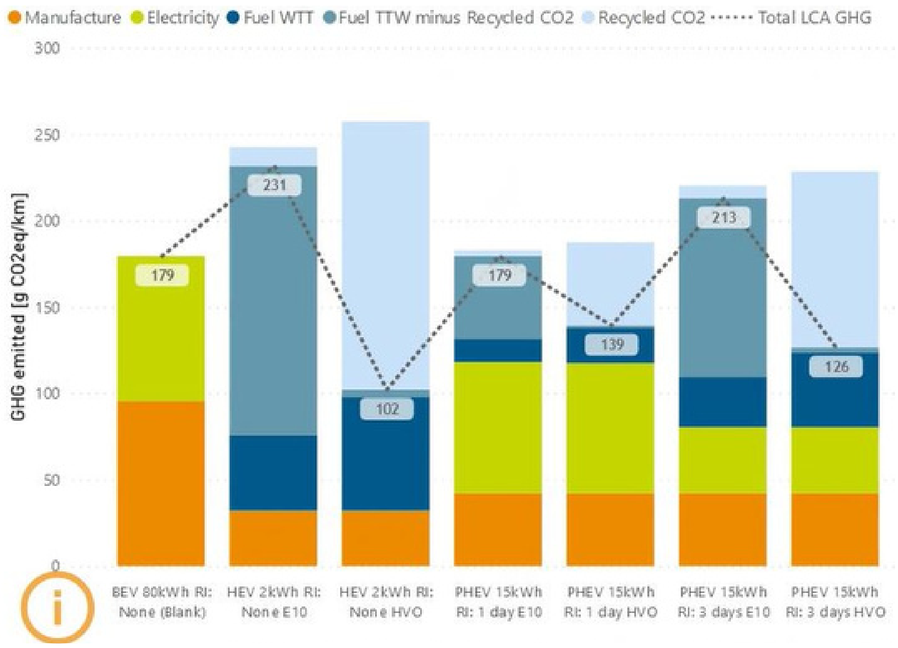

Figure 2: Screenshot of the results panel

The results panel (Figure 2) displays a bar graph, allowing to compare the life-cycle GHG emissions of the selected configurations, which are detailed on the X-axis. A split by origin of the emissions follows the vehicle life-cycle GHG emissions perimeter illustrated in Figure 3:

- GHG emissions related to the manufacture of the vehicle, including the glider and the battery;
- GHG emissions related to the production of the electricity used by the vehicle;
- GHG WtT emissions related to the production of the fuels used by the vehicle;
- GHG TtW emissions related to the combustion of the fuels used by the vehicle: it includes the non-CO_2 GHG tailpipe emissions (CH4 and N2O emissions, measured during the experimental campaign) and excludes the recycled CO_2, which are by nature transparent from an LCA perspective;
- Recycled CO_2 "emissions" which are in fact neutral from an LCA perspective (even if they can be measured at the tailpipe) and therefore excluded from the LCA scope. Recycled CO_2 relate to the share of CO_2 emissions offset which occurs during the production of the fuel and that results in a closed-loop carbon-cycle: e.g. for biofuels the CO_2 captured by biomass from the air when it grows; or for e-fuels the CO_2 captured from the air via Direct Air Capture.

2. Results panel

Furthermore, the utility factor of PHEVs and HEVs configurations can be read when hovering the mouse pointer over the corresponding bar.

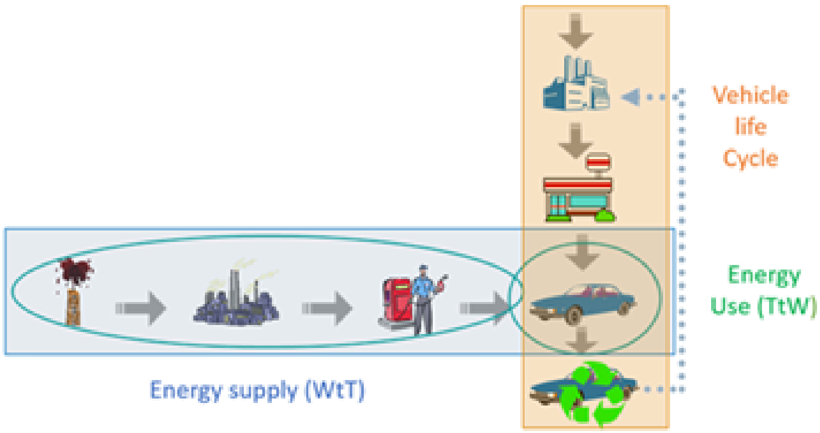

Figure 3: Vehicle life-cycle GHG emissions perimeter

3. Configuration panel

3.1 Vehicles section

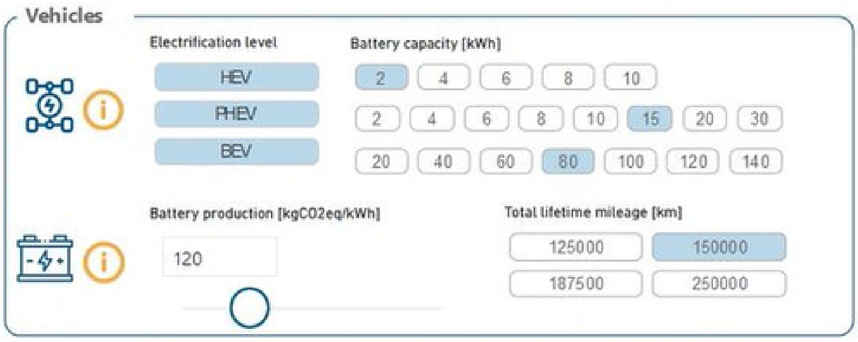

Figure 4: Screenshot of the vehicles section

The vehicles section (Figure 4) allows to set the configuration of different electrified vehicles: HEVs, PHEVs and BEVs:

- The PHEV simulations are supported by the models described in the Concawe report 10/22;
- The HEV configuration is simulated as a lighter PHEV (120 kg less, accounting for a smaller battery and no recharging system) running in Charge Sustaining mode (CS) only;
- The BEV configuration derives from the PHEV one with:
  - 2300kg curb mass in 80kWh setting (200 kg more than the tested PHEV);
  - 20% reduced rolling and drag coefficients (reflecting improved vehicle aerodynamics and optimized tires);
  - a 250kW Permanent Magnet Synchronous Machine (PMSM);
  - and a heat pump having a Coefficient of Performance (COP) of 3 for cabin heating instead of a resistor.

For each of these vehicles, the battery capacity can be parametrized, between 2 and 10 kWh for the HEVs, between 2 and 30 kWh for the PHEVs, and between 20 and 140 kWh for the BEVs.

A slider allows to adjust the CO_2 emissions related to the production of the battery (expressed in kg of CO_2/kWh of battery). An information panel (Figure 5) provides guidance on the range of values which can be found for the production of Li-ion batteries in the literature according to [Lutsey et al., 2018; Aichberger et al., 2020]. By default, the value is set at the median value of 50 publications on the issue, 120 kg of CO_2/kWh of battery, and can be modified to any lower or higher value by the user of the simulator.

3. Configuration panel

3.1 Vehicles section

Finally, the total lifetime mileage of the vehicles can be adjusted, between 125000 km and 250000 km. As the life-cycle emissions are expressed in g CO_2,eq/km, the emissions related to the manufacture "decrease" when the lifetime of the vehicles increases, with the underlying assumption that no further manufacture emissions will occur during the lifetime of the vehicle (e.g. the original battery is used during the whole vehicle lifetime and there is no battery replacement at the vehicle midlife).

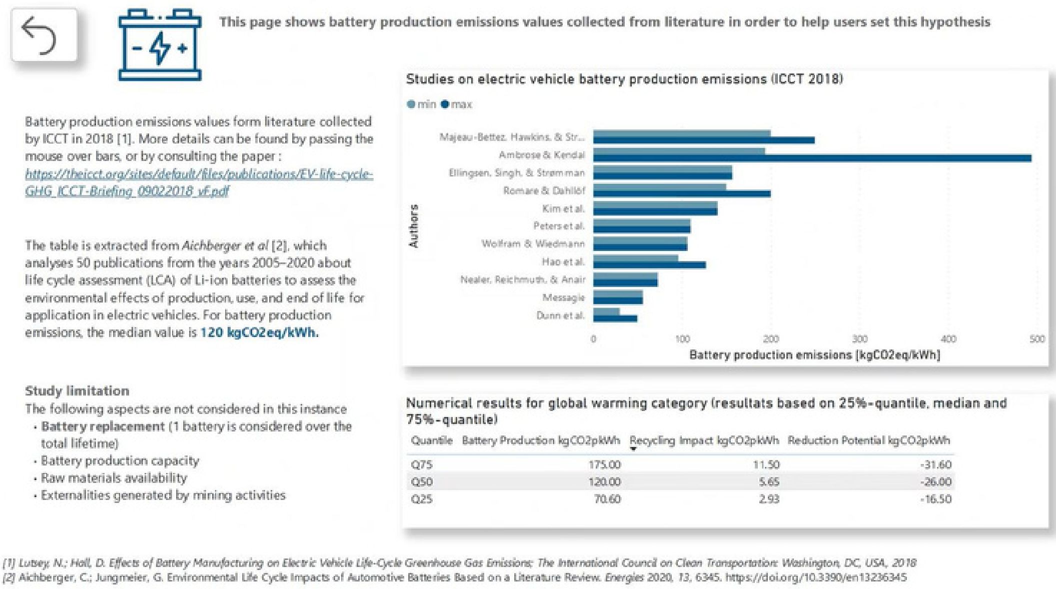

Figure 5: Screenshot of the battery information panel

3. Configuration panel

3.2 Usage section

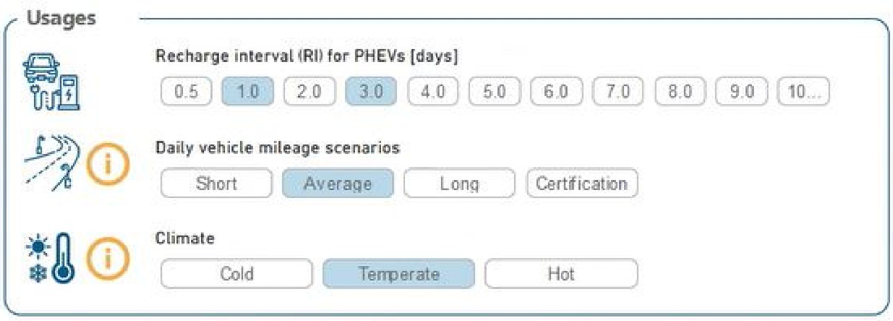

Figure 6: Screenshot of the usage section

The usage section (Figure 6) allows to configure the recharge frequency of PHEVs, between twice a day and every 10 days. Furthermore, the daily vehicle mileage can be selected: today, only the two options presented in this article are available (Figure 7), but it is planned to elaborate further options in the next versions of the tool. Finally, the climate conditions can be set to either "Cold", "Temperate" and "Hot", following the distribution curves presented in this article (Figure 8).

Following the configuration of this section and of the previous one, the online simulator calculates the energy performance of the vehicles exactly as presented in this article.

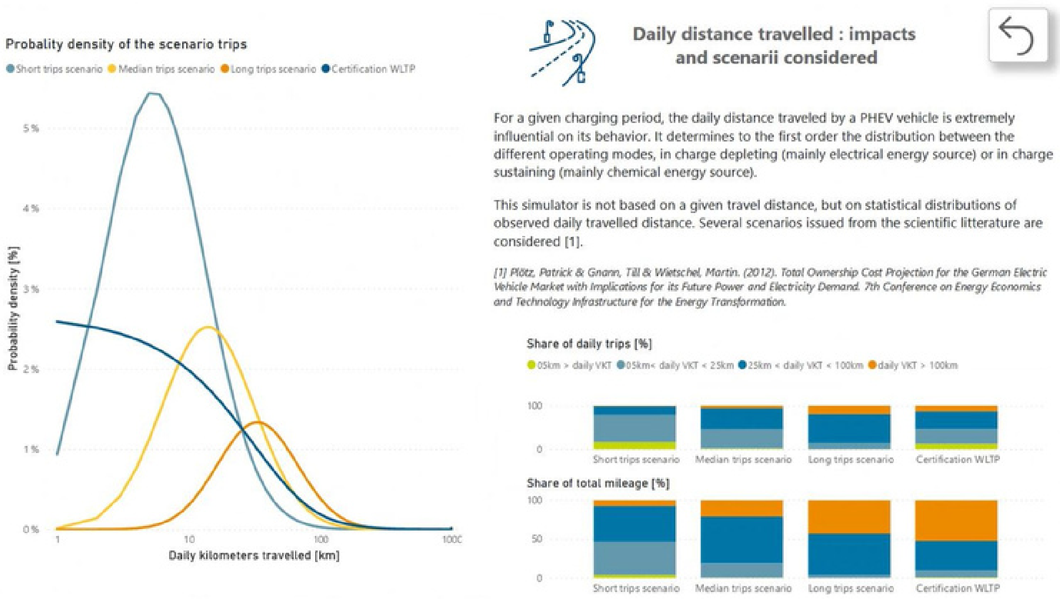

Figure 7: Screenshot of the daily vehicle mileage information panel

3. Configuration panel

3.2 Usage section

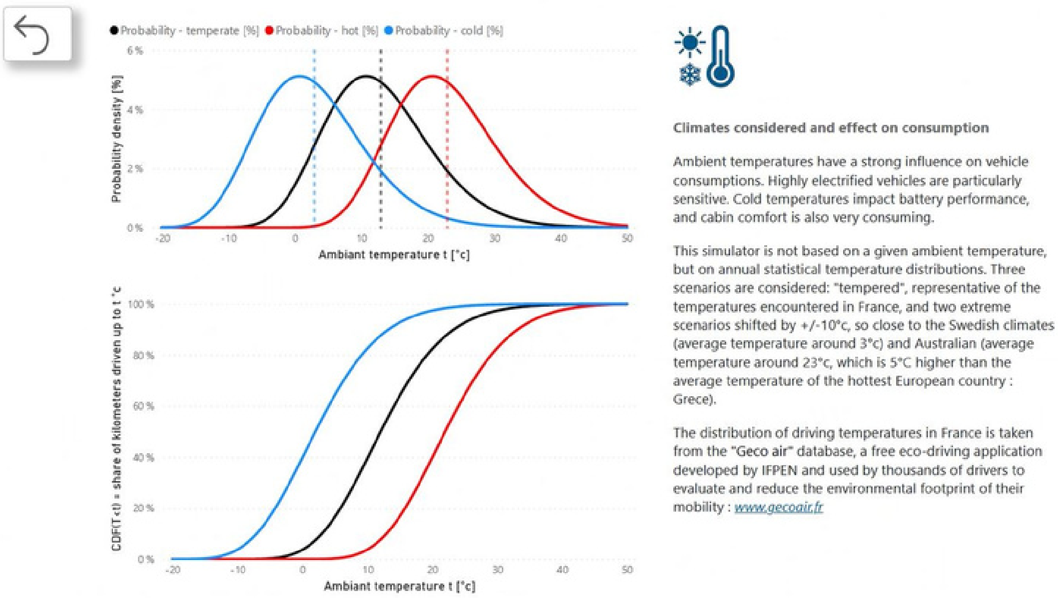

Figure 8: Screenshot of the climate information panel

3. Configuration panel

3.3 Energies section

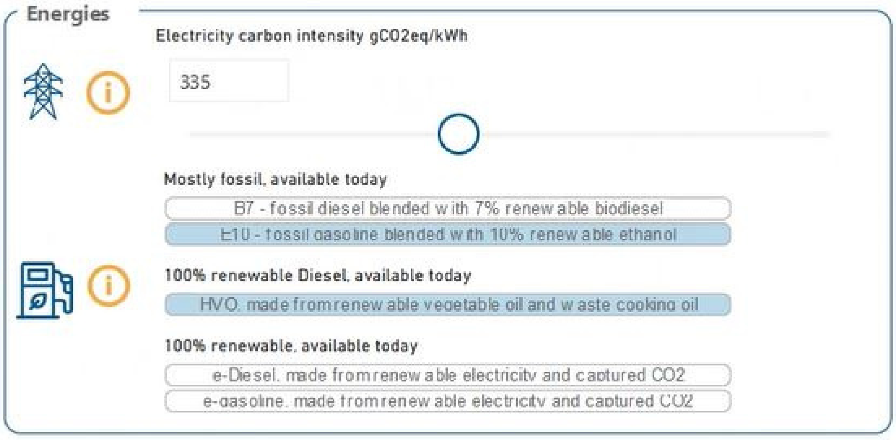

Figure 9: Screenshot of the energies section

The energies section (Figure 9) allows to configure the electricity carbon intensity. An information panel provides guidance to the user for the range of values to set (Figure 10). The data presented here is extracted from a recent (2022) paper by the European Commission's Joint Research Center (JRC) [Scarlat et al., 2022]. It provides data from 2019 on GHG intensity of used electricity in Europe (with a split per each European country).

The estimated used electricity carbon intensity value for the European Union in 2019 was 334 g CO_2,eq/kWh, down from approximately 650 g CO_2,eq/kWh in 1990 and is expected to further decrease in the coming decades. By default, the electricity GHG intensity is set at 334 g CO_2,eq/kWh in the simulator accordingly, but this value can be modified to any lower or higher value by the user.

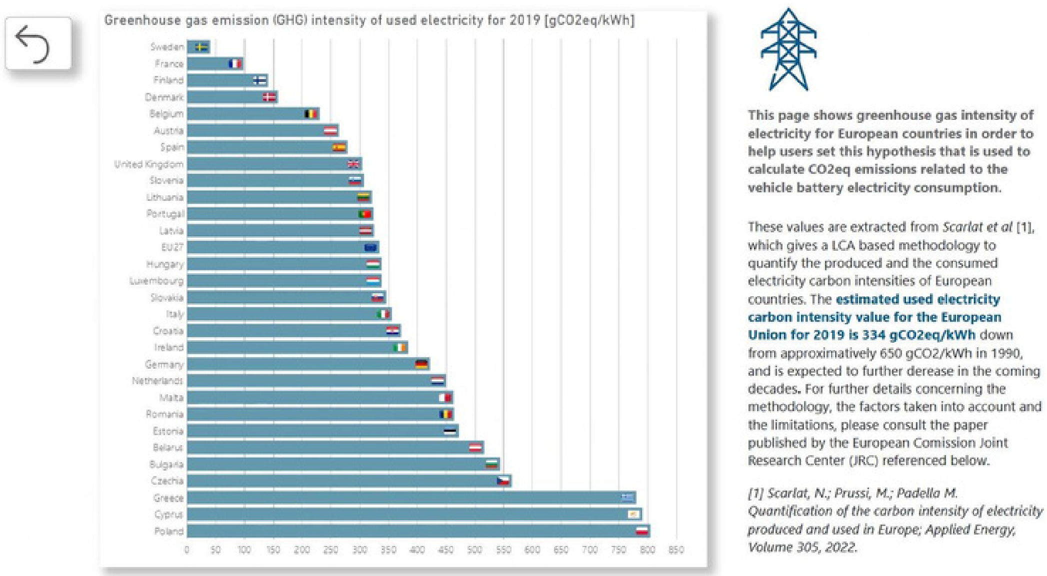

Figure 10: Screenshot of the electricity carbon intensity information panel

3. Configuration panel

3.3 Energies section

Finally, several fuel options can be configured, either for the gasoline or the Diesel ICE. An information panel (Figure 11) provides information about the fuels production pathways and their WtT, TtW, WtW emissions and recycled CO_2, mostly extracted from the JEC WTT v5 report [JEC, 2020]. More details about the fuels production pathways can be obtained by hovering the mouse pointer over a given bar. Some of the fuel options are already commercially available in Europe (e.g. B7, B10, E10 and HVO), some others are technically accessible but not yet specified (e.g. E20) and some others are not yet available at industrial scale (e.g. e-Methanol-to-Gasoline, e-Diesel via Fischer-Tropsch, BtL via Fischer-Tropsch and Carbon Capture and Storage).

It is notable that the range of WtW emissions between the different fuels production pathways is large, mainly depending on the renewable content of the fuel. One pathway can even provide negative WtW emissions (BtL via Fischer-Tropsch and Carbon Capture and Storage): as surprising as it may seem, this is technically correct as this pathway allows the CO_2 captured by the biomass when it grows to be sequestrated underground.

Although this process is not expected to become mainstream, it is nevertheless necessary to offset the remaining GHG emissions in a fully climate-neutral economy [IPCC, 2018].

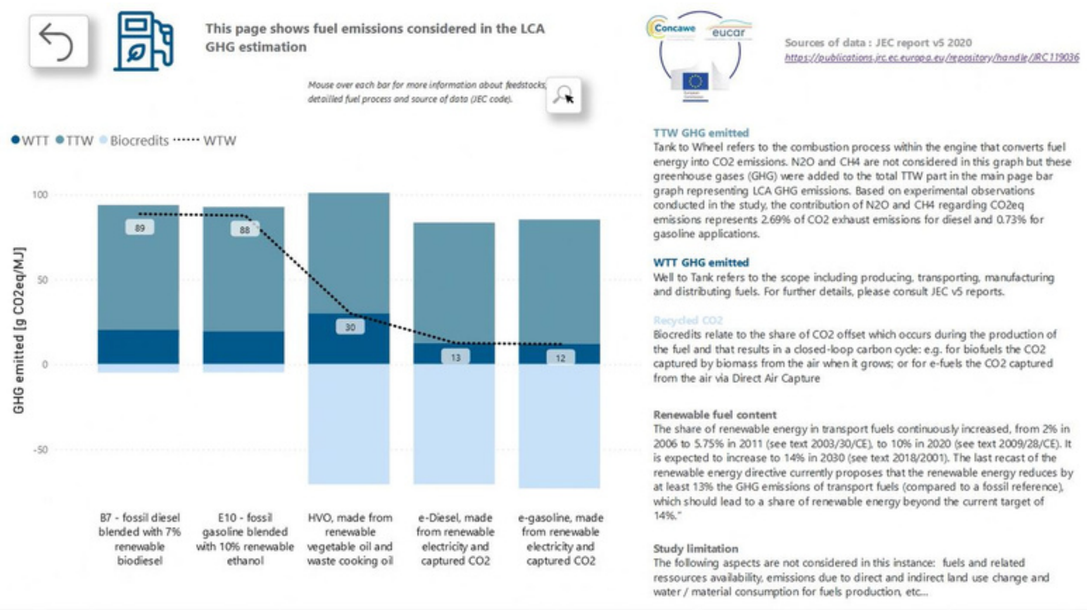

Figure 11: Screenshot of the fuel information panel

Glossary

BEVs:	Battery Electric Vehicles
CD:	Charge Depleting
CH_4:	Methane
CO_2(eq):	Carbon Dioxide (equivalent)
COP:	Coefficient of Performance
CS:	Charge Sustaining
GHG:	Green House Gas(es)
HEV:	Hybrid Electric Vehicles
LCA:	Life Cycle Assessment
N_2O:	Nitrous Oxide
PHEV:	Plug-in Hybrid Vehicle
PMSM:	Permanent Magnet Synchronous Machine
TtW:	Tank-To-Wheels
WtT:	Well-To-Tank
WtW:	Well-To-Wheels

References

1. Lutsey et al., 2018. Lutsey, N.; Hall, D. Effects of Battery Manufacturing on Electric Vehicle Life-Cycle Greenhouse Gas Emissions; The International Council on Clean Transportation; Washington, DC, USA, 2018
2. Aichberger et al., 2020. Aichberger, C; Jungmeier, G. Environmental Life Cycle Impacts of Automotive Batteries on a Literature Review. Energies 2020, 13, 6345. https://doi.org/10.3390/en13236345
3. Scarlat et al., 2022. Scarlat, N.; Prussi, M.; Padella M. Quantification of the carbon intensity of electricity produced and used in Europe; Applied Energy, Volume 305, 2022. https://doi.org/10.1016/j.apenergy.2021.117901
4. JEC, 2020. Prussi, M., Yugo, M., De Prada, L., Padella, M., Edwards, R. and Lonza, L., JEC Well-to-Tank report v5, EUR 30269 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19926-7, doi:10.2760/959137, JRC119036.
5. IPCC, 2018. Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press

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