Final Report extract

Project Name:

Bioéthanol – E85 C-Segment Passenger Car Life Cycle Assessment

Author: Fimes Ludovic, van Sloun Andreas, Schroeder Benedikt

Date: 2026-04-09

1. Introduction

Transportation remains heavily dependent on petroleum and is the second-largest contributor to global GHG emissions after electricity generation.

In Europe, increasingly stringent regulations - such as the "Fit for 55" package and the potential ban on internal combustion engines by 2035 - are accelerating the shift toward low-carbon mobility solutions.

While electrification is a major pathway, alternative fuels like bioethanol (E85) could significantly reduce emissions when assessed over the full life cycle, especially for hybrid vehicles.

The study commissioned by Bioéthanol aimed to evaluate the environmental benefits of using Superethanol-E85 in a C-segment light vehicle across different time horizons (2025 & 2035).

The analysis focuses exclusively on GHG emissions (in CO_2eq/km) and considers both vehicle & fuel impacts through a comprehensive life-cycle assessment

2. Executive Summary

2.1. Key Findings – 2025

In Europe, E85-fueled PHEVs are already more competitive than BEVs with regards to lifecycle GWP. E85 PHEVs maximize CO2 reduction benefits from both renewable fuel use and electrified driving.

For the 2025 LCA assessment, FEV considered the following boundary conditions:

- Battery production based in China, aligned with its current position as world's largest battery production capacity.

- 77 kWh (NMC) battery capacity selected to reflect current state of the art capacities (e.g., VW ID.4).
- Simulation reflects a UF of 50%, aligned with latest ICCT study
- E85 enables higher thermodynamic efficiency in a FlexFuel engine through enhanced knock resistance, stronger charge cooling and more calibration flexibility. An E85-optimized engine map can lead to ~4% engine efficiency increase. However, the lower calorific value of E85 compared to E10 results in an overall fuel consumption increase of ~26%.
- For France, a reduction of 73% GHG (source : Carbure 2024) compared to fossil fuel was considered, corresponding to 25.4 gCO_2/MJ; For Germany/Europe, a reduction of 77% GHG (source : EEA 2025) compared to fossil fuel was considered, corresponding to 21.6 gCO_2/MJ

In 2025, the relevance of BEVs is directly influenced by the carbon intensity of electricity production:

- In Germany, where coal and natural gas still play a major role in the electricity mix, BEVs show a higher GWP than E85-fueled vehicles (ICEVs, HEVs, and PHEVs).
- In France, however, where electricity is largely generated from nuclear power, BEVs show the lowest GWP; Nevertheless, E85 PHEV powertrains remain highly competitive due to their efficient use of low-GWP electricity and fuel.
- Europe's average electricity carbon intensity acts as a baseline scenario; In this scenario, E85 PHEVs already emerge as the most competitive option for life cycle GWP, offering a strong balance between electrified driving benefits and battery size CO2 impact; BEVs still outperform ICEVs and HEVs' GWP.

The sensitivity analysis shows that in the EU and Germany, E85 PHEV competitiveness remains robust even at higher lifetime mileage (240k km); In France, E85 PHEVs could close the gap to BEVs only at very low lifetime mileage, as BEVs are barely impacted by the mileage change, since battery and manufacturing dominate their GWP.

2.2. Key Findings – 2035

By 2035, the E85-fueled PHEV delivers the lowest GWP in almost all markets and stands out as the most competitive solution. Battery production (particularly with NMC chemistry) remains the main challenge for BEV competitiveness.

For the 2035 LCA assessment, FEV considered the following boundary conditions:

- Battery production shared between China (50%) and Europe, reflecting the European activities to increase the local battery production footprint.
- 90 kWh (NMC) battery capacity considered to reflect future cell density improvements; bigger PHEV battery considered, aligned with future market expectations (higher EV-range requirements).
- With the larger battery, our simulation yields a utility factor of 59%, consistent with the expected future shift in user behavior driven by the increased electric range.
- Technology improvements related to vehicle aerodynamics, RR, body weight, ICE efficiency and EV efficiency considered: BEV improvements lead to ~14% consumption reduction.
- To reflect expected improvement with regards to GHG emissions in Bioethanol production, higher GHG reduction were considered for both France & Germany/Europe: For France, a reduction of 77% GHG compared to fossil fuel was considered, corresponding to 21.6 gCO_2/MJ; For Germany/Europe, a reduction of 85% GHG compared to fossil fuel was considered, corresponding to 14.1 gCO_2/MJ
- Additionally, by 2035, the share of E10 in E85 is expected to be replaced by renewable gasoline, such as bionaphtha, with a GHG reduction of 85% (14.1 gCO_2/MJ)

By 2035, the E85-fueled PHEV delivers the lowest GWP in all markets:

- Cleaner bioethanol production and renewable fuel uptake further strengthen the relevance of ICE-centric powertrains (ICEV, HEV, PHEV)
- In addition to BEVs, improvement in the country-specific electricity mix can also be captured by PHEVs.
- France's low-carbon electricity mix strengthens BEV competitiveness relative to E85-fueled ICEV and HEV powertrains; however, the higher carbon intensity of the EU-average & German electricity mix prevents BEVs from reaching GWP parity with E85-fueled powertrains.
- Overall, battery production - particularly with NMC chemistry - remains the main challenge for BEV competitiveness from a GWP perspective.

In EU & Germany, even at higher lifetime mileage (240 k km), BEVs do not reach the competitiveness levels of ICEV, HEV, and PHEV powertrains. In France, by contrast, the low-carbon electricity mix could make BEVs more favorable beyond 260 k km.

2.3. Additional remarks

FEV aimed to ensure a fair comparison between ICE-centric and BEV powertrains by accounting for expected future improvements. However, some OEM strategies could further strengthen the relevance of BEVs.

2.3.1. Stronger OEM focus on BEV platforms

Today, many OEMs already use dedicated electric platforms for their BEVs.

As a result, some may concentrate their investment and development efforts on BEV-specific platform upgrades, enabling greater improvements in aerodynamics, packaging, and overall efficiency than on conventional ICE-derived platforms.

Towards 2035, such strategy could limit the relevance of ICE-centric vehicles, including hybrids as most are based on conventional platforms.

2.3.2. Adoption of LFP batteries for C-segment applications:

In the short to mid-term, FEV also sees the relevance of LFP increasing in Europe, driven by increasing cost-efficiencies and performance enhancements of LFP chemistries.

- First OEMs have already started adopting LFP chemistries, particularly for lower entry prices vehicles.

- With EVs becoming increasingly mainstreams, OEMs are expected to leverage a more balanced cell chemistry approach to cover both budget-focused and premium segments.

- As LFP batteries have a lower production-related GWP footprint (~30% lower than NMC for the same battery mass, ecoinvent 2025), their use could significantly improve BEV relevance over the full life cycle.

- Today, cell-to-pack technologies implemented in some existing vehicles already help narrow the gravimetric energy density gap between NMC and LFP chemistries.

2.3.3. E85-based REEV: Why does it make sense?

From a customer perspective, range-extender electric vehicles offer many of the core benefits of BEVs while addressing key barriers such as range anxiety, charging dependency, and usage flexibility.:

- Green image / low CO_2 emissions
- High efficiency
- BEV-like driving experience (high comfort, smooth driving, responsive, fast acceleration)
- No range anxiety
- No/less dependency on charging infrastructure

- Lower purchasing price than (long-range) BEVs

From an OEM perspective, they allow manufacturers to build on BEV-related investments while reducing portfolio risk in the event of slower BEV market uptake.

Among others, they allow to:

- Address more / additional customers (BEV sceptics)
- Support regulatory compliance (e.g. ZLEV targets)
- Reach higher utilization of existing BEV platforms and powertrain components (e-drive, battery, ICEs)
    - Leverage of latest technological improvements
- Reach higher utilization of existing/planned BEV production lines
- Support transition to full electric

Overall, REEVs are gaining traction among customers who remain hesitant about full BEVs and can offer OEMs a pragmatic way to hedge portfolio risk.

They are currently seeing strong momentum in China, with established OEMs already beginning to respond.

When paired with E85, REEVs could represent a credible transitional solution, capturing much of the use-phase benefit of electrification while avoiding the production burden of a large BEV battery and further reducing residual fuel-related emissions through bioethanol.