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Plug-in hybrid vehicles and the 2035 objective: analysis of the socio-economic and climate impacts of a prolonged authorization of sales in the name of 'technological neutrality'

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IN COLLABORATION WITH

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

IDDRI

EXECUTIVE SUMMARY

Allowing the sale of plug-in hybrids or range-extended electric vehicles beyond 2035? The IMT shows that such a choice would (1) cost users more, particularly the most modest ones driving older used vehicles, (2) lead to significantly higher greenhouse gas emissions, and (3) negatively impact the trade balance and national sovereignty.

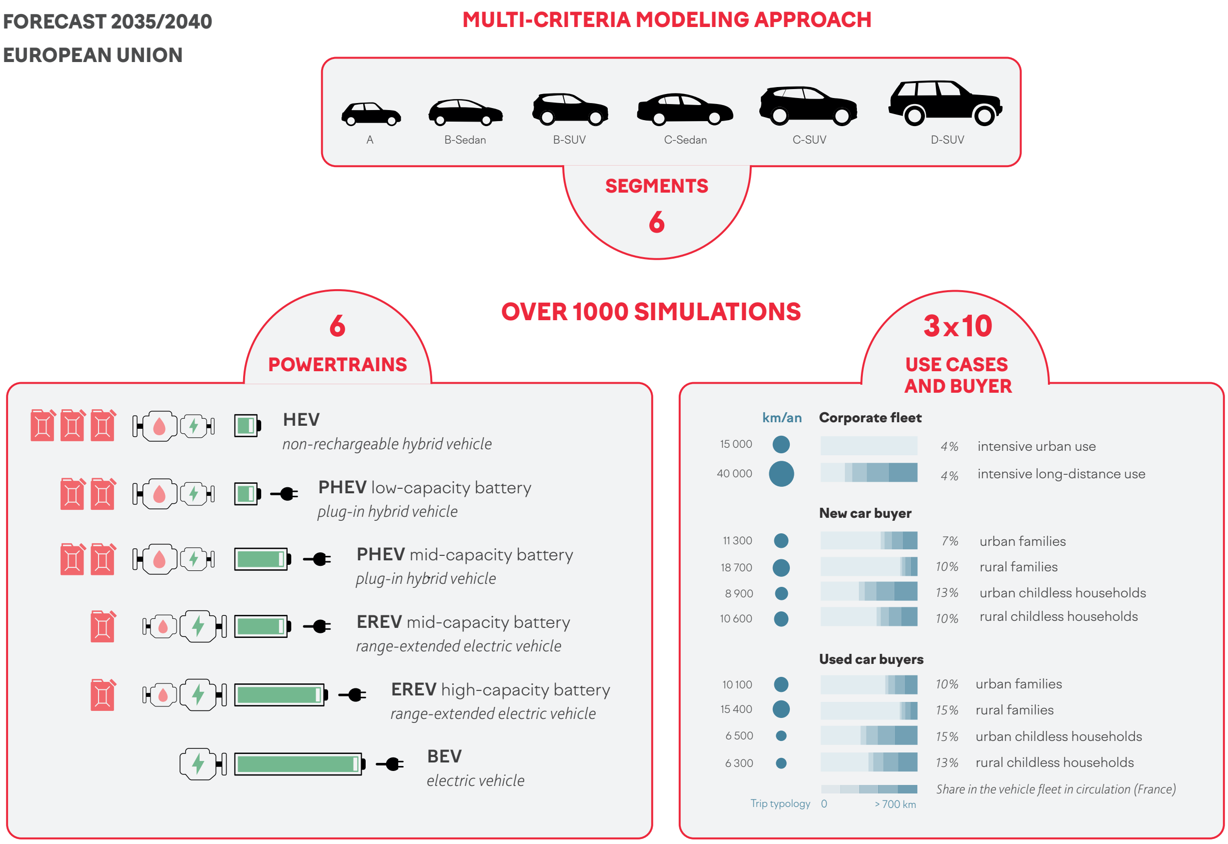
As the European Union debates the revision of its CO_2 standards for new cars, the Institute for Mobility in Transition (IMT-IDDRI) publishes a new study, *"Plug-in hybrid vehicles and the 2035 objective: analysis of the socio-economic and climate impacts of a prolonged authorization of sales in the name of 'technological neutrality'."*

The study examines **how authorizing the sale of plug-in hybrid vehicles after 2035**, instead of maintaining the planned phase-out of internal combustion engines by that date, **would affect households, the climate, and the industry.**

The debate initiated by car manufacturers on the relevance of banning the sale of internal combustion-engine vehicles from 2035 onwards has brought forward the concept of "technological neutrality". More precisely, it has fueled the idea that other pathways could exist —more efficient, more economical, or politically more acceptable—to progress toward decarbonization and achieve the European Union's climate objectives, notably carbon neutrality by 2050.

In particular, the notion that new powertrain technologies could make the transition more acceptable for car users has recently gained traction in the public debate. Two technologies are mainly highlighted: plug-in hybrid electric vehicles (PHEV) equipped with higher-capacity batteries than current models, and range-extended electric vehicles (EREV)—electric vehicles fitted with a small combustion engine used solely as a generator to recharge the battery. Some manufacturers present these powertrains as ones that offer greater flexibility for long-distance travel, by limiting the reliance on costly motorway

FIGURE A. Methodology



charging, and as showing a carbon footprint comparable to that of fully electric vehicles, thanks to a smaller battery and better energy efficiency (due to a potentially lower total vehicle weight). However, **their actual ability to deliver on these promises remains highly uncertain**: such vehicles do not yet exist on the European market, and their performance has not been robustly quantified.

To bring objectivity to these issues, the analysis produced by IMT-IDDRI, in collaboration with C-Ways and ICCT, relies on **more than 1,000 simulations** combining real use cases, vehicle segments, powertrain types, and buyer categories. In addition to the assumptions generally used by car manufacturers—focusing on new car buyers (mainly corporate fleets, accounting for about 50% of sales, and for the biggest part of the rest, households belonging to the top 20% income bracket)—**the study also includes the costs borne by 2nd-hand buyers and 3rd-hand buyers**. This approach better reflects the economic reality of most households, whose driving profiles (daily versus long-distance use), investment capacity, and maintenance needs differ significantly from those of new car buyers.

1. More expensive vehicles for households—especially upon resale

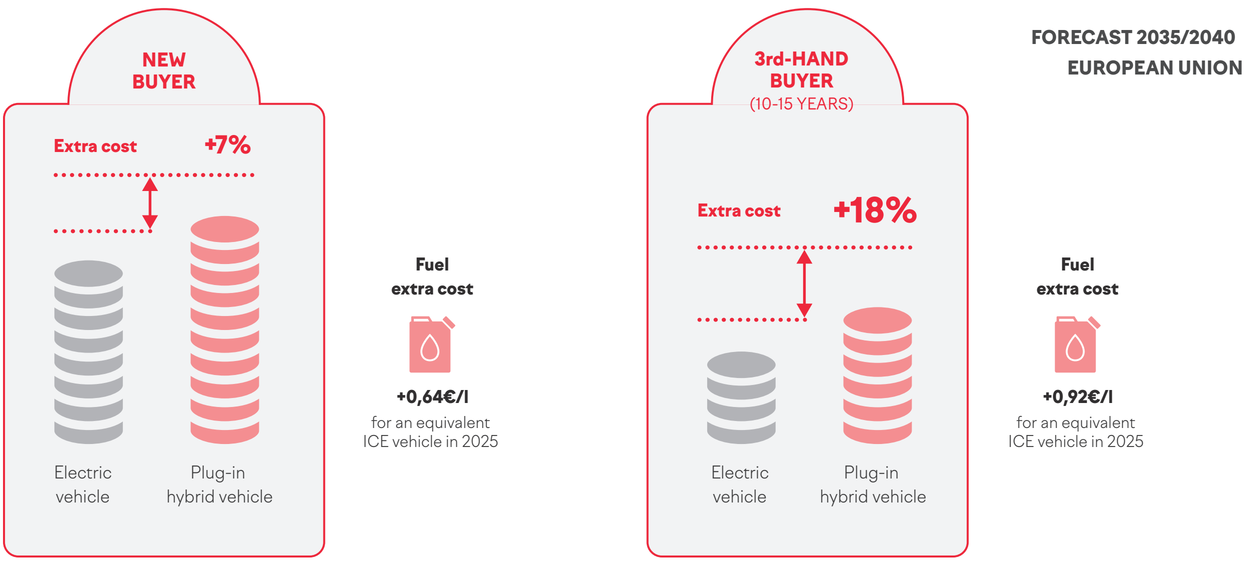
The study shows that for all use cases, **the total cost of ownership (TCO) of PHEV and EREV models would be higher than that of battery electric vehicles (BEV).**

- For a new car buyer (considering the average driving profile of these users), **PHEV mid-capacity battery** models would have a TCO on average **7% higher** than if the same users drove a BEV (fully electric vehicle).
- For 3rd-hand buyers, this cost gap rises to **+18% on average** (ranging from +14% to +29% depending on the case).
- Expressed as an equivalent increase in fuel prices in 2025 for an internal combustion engine (ICE) vehicle, these average TCO gaps correspond to roughly **+€0.64/l** for a new vehicle and **+€0.92/l** for a 3rd hand vehicle.

These consolidated average values cover all vehicle segments in which PHEV or EREV models are likely to be available—notably B-SUV, C-Sedan, C-SUV, and D-SUV segments—as well as all user profiles, weighted according to their representativeness in the vehicle fleet. It is worth noting that the TCO advantage of BEVs is systematic, regardless of the segment/powertrain/user configuration considered. Detailed results for specific cases are presented in the main body of the report.

FIGURE B. Average cost gap between a new plug-in hybrid vehicle model and an electric vehicle

Average total cost of vehicles: purchase, fuel/electricity, charging infrastructure, maintenance, insurance, and parking.



The observed TCO differences between powertrains are mainly explained by two key components: fuel costs and maintenance costs. These same factors also explain why the economic advantage of BEVs increases as they change ownership on the used-car market. Indeed, these costs are lower in absolute value and tend to remain stable (energy prices) or increase (maintenance costs) over the vehicle's lifetime. Their relative weight in the TCO therefore becomes dominant for 3rd hand buyers, reinforcing the comparative advantage of BEVs. To a lesser extent, PHEV and EREV models are also penalized by production costs close to those of BEVs, due to their dual (electric and combustion) powertrains.

The calculations take into account the projected situation in the European Union by 2035–2040, assuming a significant increase in electric-only range for PHEVs compared with currently marketed models. EREV high-capacity battery models, similar to those already available on the Chinese market (with a real electric-only range above 150 km and electric power roughly three times higher than that of the combustion engine), would show a TCO gap with BEVs, comparable to or slightly higher than that of the PHEVs considered.

To illustrate these cost gaps concretely for households—especially those who will eventually purchase these vehicles on the second-hand market (PHEVs or EREVs initially bought new and resold by companies or high-income households)—the TCO differences were expressed as an equivalent increase in fuel prices (€/l) that an ICE driver in 2025 would have to face to reach a comparable usage cost. This approach puts the observed differences in perspective with the exceptional inflation period of 2022, when average pump prices in the European Union rose at most by +€0.40/l. The results show that, depending on the use case, the TCO differences would correspond to equivalent increases ranging **from one to four times** the levels reached in 2022.

These results are based on **prudent and realistic assumptions**: removal of public purchase subsidies for electric vehicles, maintenance of relatively high battery costs to balance potential consequences of a localized production scenario within the EU, and alignment of car manufacturers' margins across powertrains. Thus, even under this conservative scenario, battery electric vehicles retain a significant competitive advantage over hybrids powertrains by 2035.

2. A losing bet for the climate

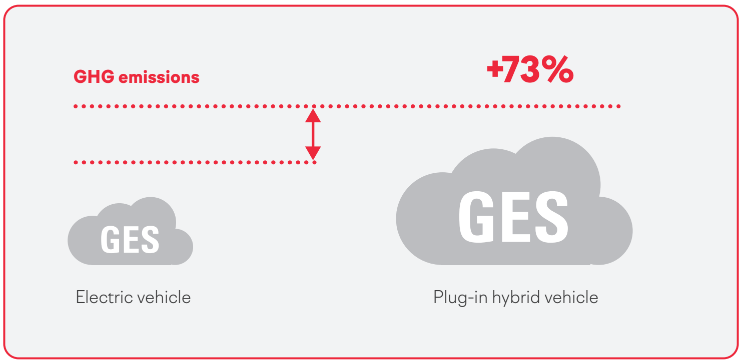
The results are equally clear from a climate standpoint: **across all use cases studied**, complete life-cycle greenhouse gas (GHG) emissions from PHEV and EREV models would remain significantly higher than those of BEVs.

- On average, **PHEV mid-capacity battery** models would emit **+73% more GHGs** than comparable BEVs (with differences ranging from +36% to +111%, depending on segment and use case).
- **EREV high-capacity battery** models would emit slightly less than PHEV, **+61% more GHGs** than comparable BEVs on average, but they still remain above BEVs for every use case.

The advantage of BEVs stems from their much lower use-phase GHG emissions, which largely offset the slightly higher emissions linked to battery manufacturing. Even though PHEV and EREV models have smaller batteries, requiring fewer critical materials and

FIGURE C. Additional life-cycle emissions per kilometre for a new-generation hybrid vehicle compared with an electric vehicle

Life-cycle greenhouse gas emissions: vehicle manufacturing, fuel and electricity production and use.



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EUROPEAN UNION

generating a lower carbon footprint during production—and may even show slightly better energy efficiency in electric mode due to their reduced battery weight—they do not achieve a comparable level of life-cycle decarbonization to that of equivalent BEVs.

Their higher total TCO (and, in some cases, higher purchase cost) compared with ICE and BEV models also suggests that **they are unlikely to play a major role in accelerating the fleet renewal.**

In this context, supporting such vehicles—for example by delaying the tightening of the utility factor (UF) used for PHEV homologation (which allows them to report emission or consumption data far from real-world usage, as noted by the European Commission), or by authorizing their sale beyond 2035, even if restricted to EREV) would not constitute an effective lever to accelerate or secure the transport sector's decarbonization trajectory. On the contrary, it could significantly slow down the expected progress.

The study also shows that, **despite their higher real-world range** (2 to 3 times that of a current BEV), PHEV and EREV models **do not meet a major need**: BEVs in the B-SUV segment and above already cover **three-quarters of long-distance trips with at most a single fast charge**, and this performance will continue to improve as battery range steadily increases.

The study also includes several sensitivity analyses, assessing variations in total cost of ownership and GHG emissions based on different parameters: price and carbon intensity of electricity, gasoline price, battery material costs, and more. It notably examines the impact of restricting the use of PHEV combustion engines in urban areas to encourage or mandate electric operation. In this scenario, the GHG emission gaps between PHEVs and EVs do not change significantly.

BOX 1. BIOFUELS: PARTIAL EMISSIONS REDUCTION, BUT AT THE EXPENSE OF SIGNIFICANTLY HIGHER USAGE COSTS FOR USERS OR MEMBER STATE BUDGETS

The study also modeled a scenario in which PHEVs are fueled **100% with biofuels** priced at their production cost (i.e., not subsidized or tax-reduced as is currently the case). This assumes that by 2035–2040, available agrofuels will be **primarily allocated to maritime or aviation sectors**, which need them and can afford higher prices than road users. In this context, it is difficult to imagine that across Europe, member states would have the intention and the capacity to subsidize these fuels for private vehicles.

Result:

The life-cycle greenhouse gas emissions gap between **PHEV mid-capacity battery** models and BEVs would be reduced, but **not eliminated** (still **+23% on average**).

However, the **total cost of ownership would increase significantly**, due to the higher production cost:

- **+14%** for the average TCO gap between rechargeable ICE vehicles and BEVs for a new car buyer (equivalent to an increase of approximately **+€1.22/l** if expressed as a 2025 ICE fuel price increase);
- **+29%** for a 3rd-hand buyer, equivalent to an increase of approximately **+€1.49/l** in 2025 for an ICE user.

In other words, even in the most optimistic scenario, **biofuels would not be sufficient to make hybrids competitive**, either ecologically or economically.

BOX 2. FOR THE TRADE BALANCE AND THE EUROPEAN ECONOMY, AN INCREASED RISK OF DEPENDENCE ON IMPORTS

PHEV and EREV models, by combining batteries and combustion engines, would continue to sustain dependence on imports of fossil energy and non-European components.

— Considering only flows related to battery materials and oil, the use of **a PHEV mid-capacity battery generates a trade deficit roughly twice as high as that of a BEV**.

— Furthermore, maintaining a significant share of combustion-engine vehicles could delay the development of a European battery industry and weaken manufacturers' expertise in fully electric powertrains. Finally, the range-extended vehicles considered in the study currently correspond to models produced almost exclusively by Chinese car manufacturers for their domestic market, where they already hold a significant technological lead.

3. IMT Recommendations

Maintaining the authorization to sell hybrids beyond 2035 would **slow Europe's technological, energy, and strategic autonomy**, without providing tangible benefits for users or the climate.

In light of these results, IMT recommends:

— **Maintaining the ban on the sale of partially combustion-powered vehicles after 2035**, while complementing usage-based emission standards with regulations, labels, or eco-scores that **prioritize vehicles that are more efficient, repairable, compatible with a circular materials economy, and produced in a way that is more respectful of resources and the climate**;

— **Accelerating support for the production and demand of small "Made in Europe" electric vehicles**, through instruments such as social leasing, corporate fleet tax measures, and public procurement frameworks;

— **Strengthening European industrial policy** by ensuring regulatory stability and encouraging investment in the battery sector, charging infrastructure, and related skills.

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Table of figures

CONTEXT

The European Strategic Dialogue on the Automotive Industry, launched in February 2025 by the European Commission, began ahead of the initiation of the review clause process for Regulation (EU) 2019/631 on CO_2emission performance standards for new passenger cars and light commercial vehicles. Both the Strategic Dialogue and the Review Clause aim to assess the measures guiding the sector toward carbon neutrality while taking into account industrial and economic constraints.[1]

Since the gradual adoption of European CO_2 emission standards, the European Union has set a stepwise reduction trajectory: -15% in 2025, -55% in 2030, and -100% in 2035 compared to 2021 levels for new passenger cars. This trajectory reflects a now-structuring policy direction: the gradual phase-out of internal combustion engines and the large-scale electrification of the vehicle fleet. As European Commission President Ursula von der Leyen has emphasized, the question is no longer *whether* this electrification will take place, but *how* Europe will adapt to it.

This transition is already underway in other major world regions: China and Asia more broadly (including countries such as Vietnam and Indonesia) have built ambitious and coherent industrial strategies centered on electric vehicles—from battery production to the rise of national champions and the organization of entire value chains. From both a technical and economic standpoint, the electric vehicle has emerged as the most mature, energy-efficient, and medium-term competitive solution.

As of 2025, European manufacturers are generally on track to meet their CO_2 emission reduction targets.[2] The share of electric vehicles among new car registrations is increasing rapidly (+17% in the first half of 2025 compared with +13% in 2024[3]), driven by the continued decline in battery costs and vehicle prices, as well as by the rise of more affordable models. The current trajectory shows that, from both a technical and economic standpoint, manufacturers are now capable of meeting the 2025 and 2030 targets—a positive and encouraging dynamic for the European industry. However, significant disparities remain between countries. While markets such as Germany, France, and the Nordic countries are seeing strong and growing EV sales, others in Eastern and Southern Europe are lagging behind, held back by limited charging infrastructure and less supportive public policies.

At the same time, since 2024, opposition to climate policies has gained strength, citing arguments about their alleged ineffectiveness, their economic or industrial cost, and their impact on lifestyles.[4,5] The electrification mandate and the associated penalties are often portrayed as the main source of the automotive sector's economic difficulties, whereas these challenges actually stem from multiple causes: three-quarters of the recent increase in new car purchase costs result from factors other than electrification.[6]

In this context, some European manufacturers are calling for the possibility to develop and market hybrid electric-combustion vehicles after 2035[7]. These discussions are driving requests to the European Union for measures supporting these powertrains, such as adjustments to the utility factor for PHEVs or various regulatory bonuses. The main argument put forward is that of "technological neutrality": rather than enforcing an outright ban on the sale of internal combustion vehicles or on non-zero-emission vehicles in use, the European Union could allow the marketing of other supposedly low-carbon vehicles—including plug-in hybrids and vehicles running on biofuels or e-fuels—which are considered more socially acceptable and potentially capable of maintaining industrial competitiveness while contributing to decarbonization.

However, the actual feasibility of these options—both from a technical standpoint and in terms of their real environmental impact, customer attractiveness, and industrial consequences—remains unproven and has been the subject of far too limited analysis.

Behind the seemingly reasonable idea of technological neutrality lie three major issues.

First, it is uncertain whether internal combustion vehicles running on biofuels or e-fuels can achieve greenhouse gas reductions comparable to those of electric vehicles. Some production processes for these fuels can generate life-cycle emissions similar to, or even higher than, those of fossil fuels. Moreover, their limited availability—particularly considering Europe's production potential—could force users of internal combustion vehicles to supplement their consumption with fossil fuels, thereby reducing overall emission gains.[8]

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1 European Parliament. CO_2 emissions: flexibility measures for car manufacturers, May 2025. [available online]

2 International Council on Clean Transportation (ICCT). *The EV Transition Check: Progress and Challenges in the European Electric Vehicle Market,* septembre 2025. [available online]

3 International Council on Clean Transportation (ICCT). European Market Monitor: Cars and vans (June 2025), juillet 2025. [available online]

4 Institut Mobilités en Transition (IMT) & IDDRI. A "social contract" approach to political issues in mobility transition, June 2025 [available online]

5 Construire l'écologie. Greenblaming: the making of the ecological scarecrow, 2024. [available online]

6 Institut Mobilités en Transition (IMT) & C-Ways.The truth and myths about the causes of vehicle price increases between 2020 and 2024, May 2025. [available online]

7 Verband der Automobilindustrie (VDA). 10-point plan for climate-neutral mobility, juin 2025. [available online].

8 Secrétariat général à la planification écologique (SGPE). Biomass closure: issues and orientations, November 2024 [available online]

Second, such a move would send a signal of technological diversity and competition without a clear direction or defined industrial priorities. This kind of regulatory loosening would risk dispersing Europe's investment capacity across multiple technological options, increasing risks for manufacturers and suppliers, or leading to a wait-and-see attitude toward industrial transformation. The European industry's already evident lag behind China—the world's leading market in both sales and production—in the electric vehicle value chain, in terms of innovation and competitiveness, would likely deepen. Moreover, China also produces plug-in hybrids and range extenders that are far more price-competitive than those currently manufactured in Europe, and these are not subject to the same import tariffs as Chinese electric vehicles.

Third, some manufacturers highlight the potential development of new powertrains, particularly plug-in hybrid vehicles (PHEVs) equipped with larger batteries than current models, as well as range-extended electric vehicles (EREVs)—electric vehicles fitted with a small combustion engine used solely as a generator to extend range, a technology currently commercialized only by a few Chinese manufacturers. According to them, such vehicles could appeal more to drivers by offering greater flexibility on long journeys (by reducing reliance on costly motorway charging) and could achieve a carbon footprint comparable to that of battery electric vehicles, thanks to smaller batteries and better energy efficiency. However, the actual ability of these vehicles—which, at this stage, do not exist on the European market—to deliver on these promises has not yet been precisely quantified.

Thus, while *technological neutrality*—often promoted under the guise of "common sense," and frequently accompanied in practice by calls to relax regulatory constraints related to electrification—may seem attractive on paper, it raises critical questions about its real effectiveness in achieving decarbonization goals and its impact on Europe's industrial momentum. A credible assessment requires rigorous economic and environmental analyses—analyses which, to date, have not been conducted by those advocating this approach.

In this context, the present study aims to provide an objective and dispassionate contribution to the debate on the role of hybrid and electric powertrains after 2035, by assessing their potential contribution to:

- **Decarbonization**, through the evaluation of greenhouse gas emissions over each vehicle's entire life cycle;
- **Household and user budgets**, by estimating their total cost of ownership (TCO);
- **Other potential benefits**, including user convenience, industrial competitiveness, and impacts on the European trade balance.

To this end, all combustion, hybrid, and electric powertrains likely to be available after 2035 have been considered, including advanced technical configurations promoted by some manufacturers but still theoretical.

Addressing this issue also requires going beyond the manufacturer's perspective, focused on vehicle supply, to include the satisfaction of buyers and users. These are not limited to **new car buyers**—primarily companies and high-income households,[9]—who represent only a minority of the population—but also **2nd hand buyers** and **3rd hand buyers**, whose driving patterns, purchasing behavior, and maintenance needs are different. Certain measures designed to support new vehicles may have little impact on, or even disadvantage, used-car buyers, leading to a two-speed decarbonization process.

The economic and climate relevance of vehicles must therefore be assessed over their **entire lifetime**, taking into account their transition to the used-car market and successive ownerships—a dimension often overlooked in debates and impact assessments.

9 For example, for France: Observatoire des inégalités. Automobiles and standard of living: who buys what?, May 2024. [available online]. In France, 87% of passenger vehicle transactions in 2022 took place on the second-hand market.. Statistiques publiques de l'énergie, des transports, du logement et de l'environnement (SDES). Car purchases in 2022: fewer combustion powertrains and newer vehicles for higher-income households, March 2024. [available online].

METHODOLOGY

The objective of this study is to estimate and simulate (1) greenhouse gas emissions over the entire vehicle life cycle, (2) the total cost of ownership (TCO), and (3) several other performance and resilience indicators, for the different powertrains available for passenger cars within the European Union in the 2035-2040 timeframe.

Figure 1 details the various parameters considered in the simulation.

Assumptions regarding use cases

Given that these indicators vary significantly depending on the use case, ten representative use cases were defined, covering the full range of situations encountered among owners of at least one passenger car. These use cases are differentiated according to:
- Income level (high-income: the top 30% of households / low-income: the remaining 70%),
- Place of residence (urban / rural),
- Number of people to transport (with or without children).

The ten selected use cases are as follows:
- 1. Corporate fleet for intensive urban use;
- 2. Corporate fleet for intensive long-distance use;
- 3. High-income urban families;
- 4. High-income rural families;
- 5. High-income urban childless households;
- 6. High-income rural childless households;
- 7. Low-income urban families;
- 8. Low-income rural families;
- 9. Low-income urban childless households;
- 10. Low-income rural childless households.

The corporate fleet for intensive urban use and the corporate fleet for intensive long-distance use represent two contrasting professional driving patterns, reflecting the fact that corporate fleets often consist partly of lighter passenger vehicles for short distances and partly of heavier passenger vehicles for longer trips.

For each of these use cases, three main parameters were defined:
- Type of purchase: new or used. High-income households and corporate fleets are considered to purchase mainly new vehicles, while low-income households tend to buy used ones (2nd hand buyers or 3rd hand buyers);

FIGURE 1. Multi-criteria modeling approach

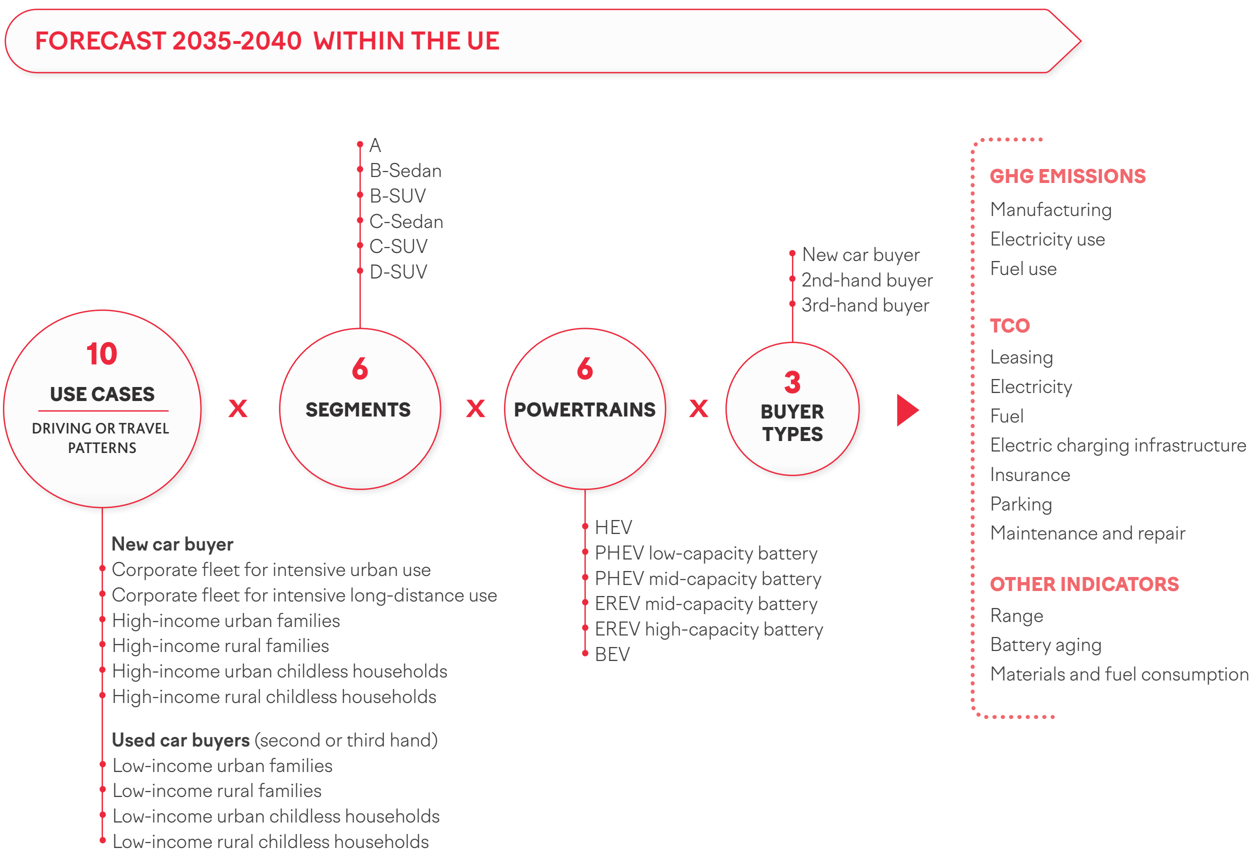
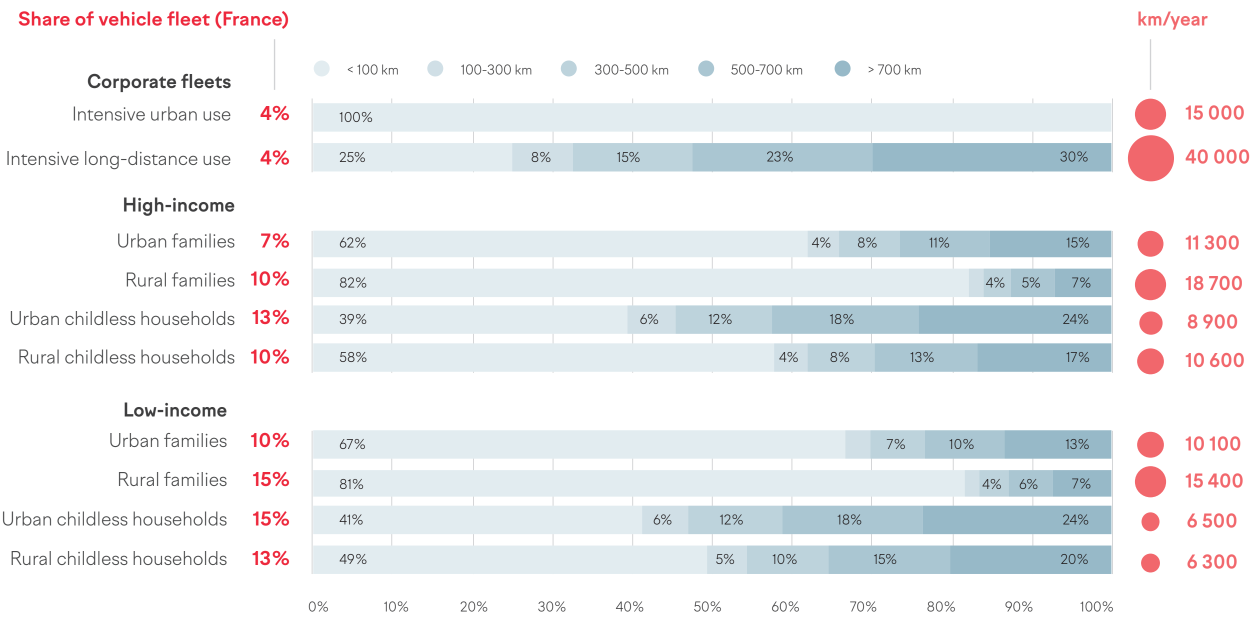


FIGURE 2. Breakdown of driving patterns by annual distance category



Travel profiles from French statistics and surveys, assumed representative enough to define EU user clusters.

— Annual mileage: depending on the place of residence and income level;
— Breakdown of annual mileage: share of short and long trips, including the distribution of trips across different distance categories to account for charging needs and the share of electric versus combustion driving for dual-energy vehicles.

In the absence of EU-wide data, these mobility profiles were derived from a statistical analysis of French survey data.[10] They are assumed to be sufficiently representative to define user groups at the European level. These use cases are intended to cover the vast majority of driving situations within the EU while remaining distinct enough from one another to illustrate contrasting patterns.

Considering that after 2035 only electric vehicles will remain available in the A and B-sedan segments (see next section), the following analysis focuses exclusively on the characteristics of B-SUV segment vehicles and above. It was therefore necessary to identify the specific travel patterns associated with these vehicles. These segments constitute the majority of households' primary cars and, as such, account for most long-distance trips made by car. When weighting the results by the representativeness of each use case within the fleet, we find that high-income households using these vehicles make on average 63% of their trips over short distances, compared with 67% for low-income households. By comparison, this share would rise to an average of 79% if all trips were considered, regardless of segment.

Figure 2 details the distances driven, the types of trips, and the representativeness of each use case considered. *Note: High-income urban families drive an average of 11,300 km per year, 62% of which consists of trips shorter than 100 km. They represent 7% of the passenger car fleet in circulation.*

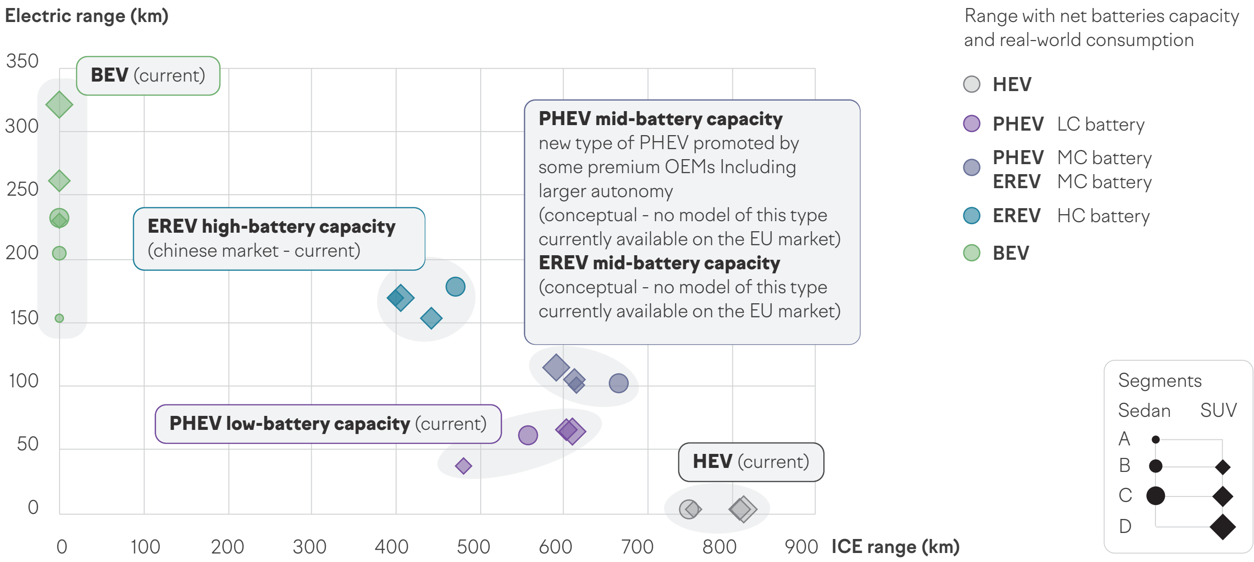
Assumptions regarding technical performance

To cover all powertrains expected to be available for purchase in 2035-2040, six vehicle segments were considered: A; B-Sedan; B-SUV; C-Sedan; C-SUV; D-SUV.

These segments were combined with six different powertrains:

10 Notably, the *Enquête Mobilité des Personnes* (French Ministry for the Ecological Transition and Territorial Cohesion, *Detailed results of the 2019 Personal Mobility Survey*, December 2021, [available online]). Since the survey does not document vehicle segments, it had to be supplemented in order to identify the travel patterns specific to B-SUV segment vehicles and above. To do so, a second database produced by C-Ways, which includes information on road mobility practices as well as vehicle segments, was used. The linkage between the two sources was carried out on the basis of a set of common and relevant variables (short-distance mobility of the primary vehicle, long-distance mobility of the primary vehicle, income level, type of urban area, and household size and composition).

FIGURE 3. **Electric and ICE range assumptions**



LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

— Hybrid Electric Vehicles (HEV);
— Plug-in Hybrid Electric Vehicles (PHEV) low-capacity battery, corresponding to vehicles currently available on the European market;
— Plug-in Hybrid Electric Vehicles (PHEV) mid-capacity battery, a new type of plug-in hybrid promoted by some premium manufacturers, offering increased electric range (concept);
— Range-Extended Electric Vehicles (EREV) mid-capacity battery, a new type of plug-in hybrid promoted by some premium manufacturers, offering increased electric range (concept);
— Range-Extended Electric Vehicles (EREV) high-capacity battery, currently available only on the Chinese market;
— Battery Electric Vehicles (BEV).

The PHEV mid-capacity battery and EREV configurations are still largely conceptual, as promoted by manufacturers. Technical specifications for these vehicles were established based on insights from the automotive industry and existing models already available on the Chinese market.

For A and B-Sedan segments, only BEV characteristics were defined, as these segments are not expected to offer PHEV or EREV powertrains by 2035 due to their limited size, which makes it difficult to combine combustion and electric systems efficiently.

Fully internal combustion vehicles (ICE) were not included, given their progressive replacement by HEVs, which are becoming the new standard for vehicles primarily powered by combustion engines.[11] All vehicles equipped with an internal combustion engine were assumed to use a gasoline powertrain.

Figure 3 shows the comparative electric and/or combustion range resulting from the assumptions used in the study for each vehicle type. *Note: B-SUV PHEVs equipped with a low-capacity battery have a real-world electric range of 36 km and a combustion range of 481 km.*

For each segment × powertrain combination, the following parameters were defined:
— The actual capacity of the electric battery and fuel tank;
— The real-world energy consumption per kilometer (for both combustion and electric powertrains);
— The power output of the electric and/or combustion engines;
— The share of use between combustion and electric operation, distinguishing between short and long trips.

11 Geffray, L.-P., Benoit, M., "Hybrid powertrains are the new automotive standard: a redeployment of public policies towards electric vehicles is needed", Institut Mobilités en Transition, December 2024. [available online]

These technical parameters are based on:

- For HEV, PHEV, and EREV, the performance of vehicles sold between 2023 and 2025 within the European Union.[12]
- The EREV mid-capacity battery, which currently exists only as a concept, was assumed to have technical characteristics identical to those of the PHEV mid-capacity battery.
- The performance of the PHEV/EREV configurations considered in this study covers the full range between the PHEVs currently sold in the EU and the EREVs sold in China (as the EREVs currently circulating within the EU are essentially produced by Chinese manufacturers). Notably, EREVs with high-capacity batteries exhibit better energy efficiency in electric mode than BEVs, due to their lower overall weight;
- For BEVs, assumptions were based on the performance of vehicles sold or announced in 2025.

Regarding battery capacity, it was assumed that the *usable* capacity corresponds to 82% of the nominal (rated) capacity, reflecting user behavior that limits full charge and discharge cycles to preserve battery performance.

Regarding vehicle energy efficiency, a +15% gap was applied between homologated and real-world efficiency values.

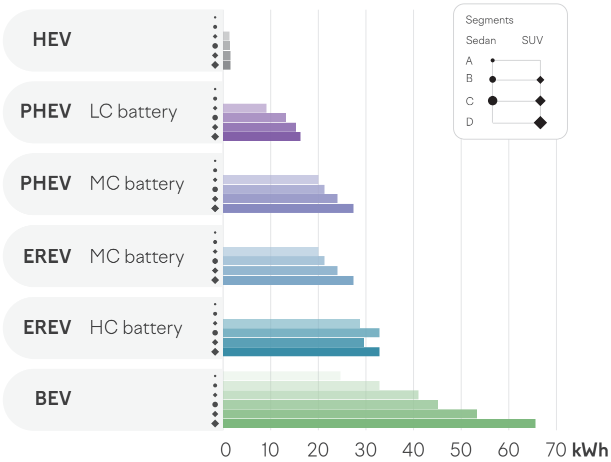
Figures 4.a, 4.b, 4.c, 5.a, 5.b, 5.c, and **6** detail the technical assumptions considered for each vehicle type and compare them with the 2024 sales averages in the EU and China. *Note: A-segment battery electric vehicles (BEVs) have a net battery capacity of 25 kWh, corresponding to 82% of the nominal capacity, to reflect real-world usage conditions.*

The projection of vehicle performance for the 2035-2040 period is therefore based, conservatively, on the actual technical performance of today's vehicles. These assumptions are generally less favorable to electric powertrains than to combustion ones, since significant technological progress is expected by 2035-2040 in areas such as battery energy density, mass, and chemistry, as well as overall vehicle efficiency—whereas the potential for improvement in combustion engines is limited, given their already mature technology.

As a result, the study's findings do not rely on optimistic assumptions about strong future gains in electric vehicle performance—such improvements would, in fact, further strengthen their results.

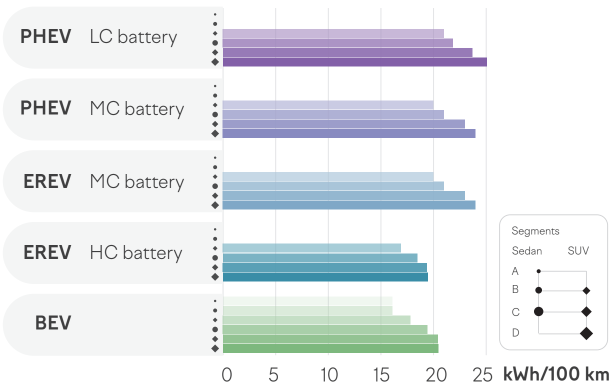
12 Manufacturers' websites, expert consultations, C-Ways modeling, ICCT based on ADAC European sales data for the 2023–2025 period. Due to the limited number of available models, the average energy efficiency of low-capacity battery B-SUV PHEVs was inconsistent. It was therefore reassessed to ensure performance consistency across segments.

FIGURE 4.a Net battery capacity



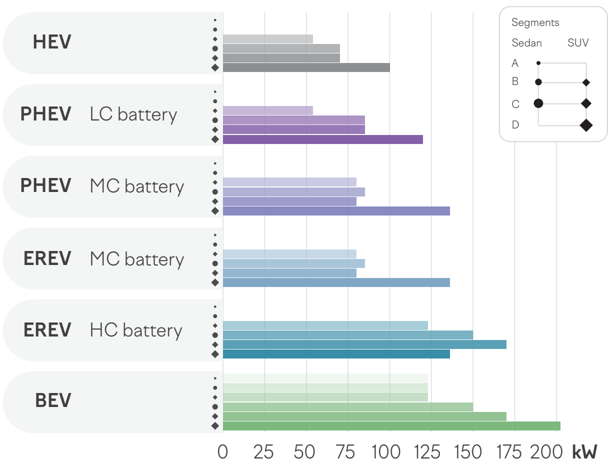
82% of the gross capacity is used as the net battery capacity in the simulations. The difference prevents overcharge/deep discharge, thus preserving battery life and performance.

FIGURE 4.b Real-world electrical consumption



Real-world consumption considered equal to 115% of homologation values.

FIGURE 4.c Electric motor power



LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

FIGURE 5.a Tank capacity

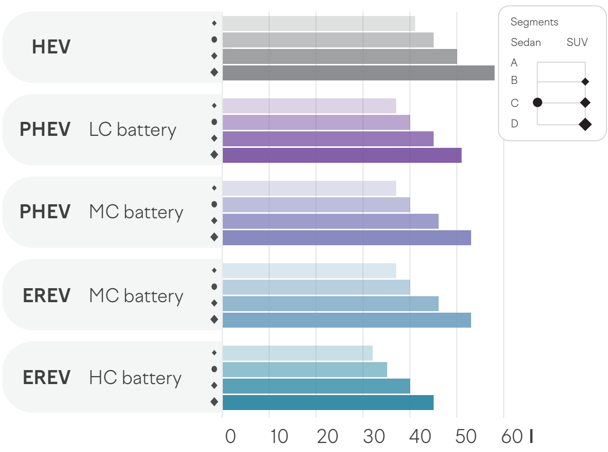
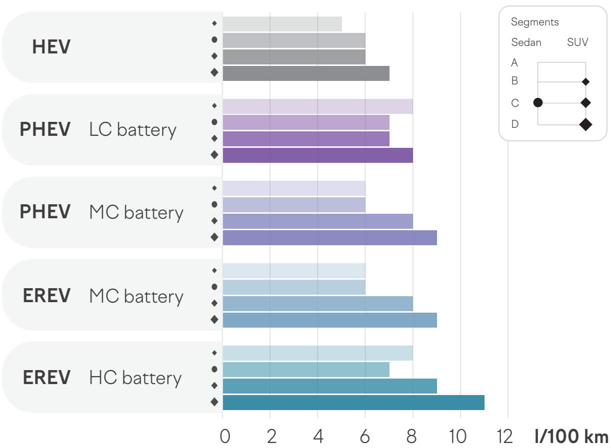
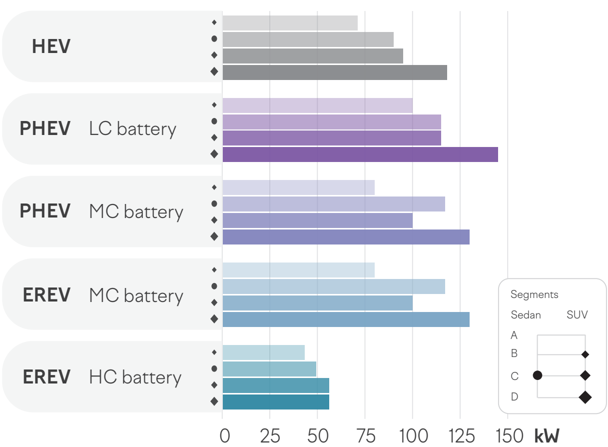


FIGURE 5.b Real-world ICE consumption



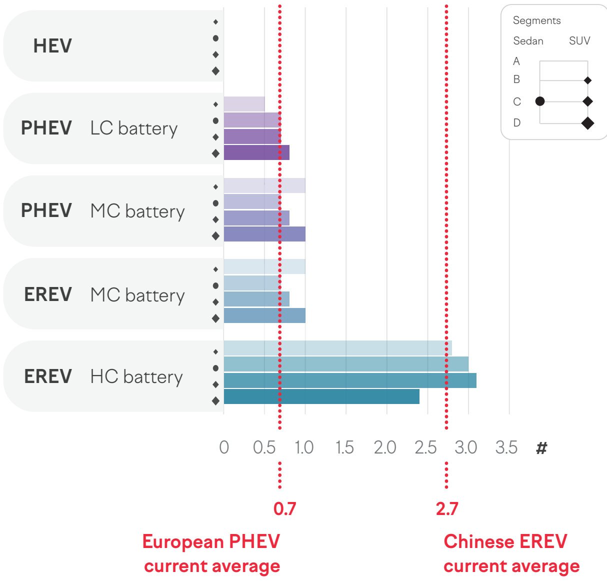
Real-world consumption considered equal to 115% of homologation values.

FIGURE 5.c ICE power



LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

FIGURE 6. Ratio electric power motor/ICE power motor



LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

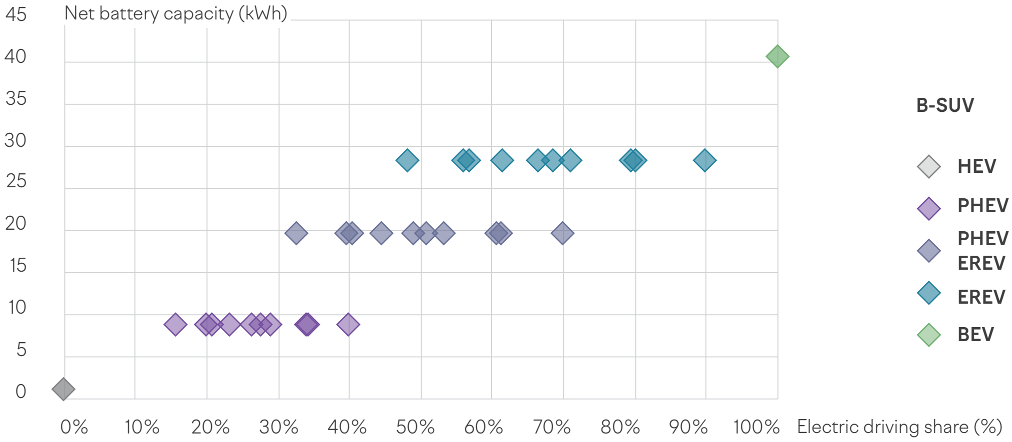
Finally, to account for the fact that PHEVs and EREVs are not recharged before every trip, different charging behaviors were considered depending on trip type. For short trips, under realistic conditions:

- PHEV low-capacity battery vehicles are assumed to be charged before 40% of trips;
- PHEV mid-capacity battery and EREV mid-capacity battery vehicles are charged before 70% of trips;
- EREV high-capacity battery vehicles are charged before 90% of trips.

For all long trips, the battery is assumed to be fully charged before departure.

FIGURE 7. Electric driving share considering actual battery range and travel pattern – B-SUV

Each point corresponds to a different use case



LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

Figure 7 illustrates the share of trips covered by a B-SUV depending on its powertrain and use case (each use case is represented by a data point for each powertrain), as well as the share of driving done in electric mode. *Note: For a B-SUV PHEV low-capacity battery, 15% to 40% of kilometers are driven in electric mode, depending on the use case.*

Assumptions regarding greenhouse gas emissions

The life-cycle GHG emissions of vehicles estimated in this study include:

— The manufacturing phase, and
— The use phase (fuel and electricity).

Emissions related to recycling and maintenance were not included, due to the lack of projected data for the 2035-2040 period and their relatively minor contribution to total life-cycle emissions.

To estimate the life-cycle emissions of each use case × segment × powertrain combination, assumptions were established concerning:

— Emissions from fuel consumption (including upstream emissions), with or without the integration of biofuels;
— Emissions from electricity generation (including upstream emissions);
— Emissions from vehicle manufacturing;
— Emissions from battery manufacturing.

Vehicle manufacturing excluding batteries. GHG emissions from vehicle manufacturing (excluding the battery) were estimated to range from 4 tCO_2e for an A-segment vehicle to 8 tCO_2e for a D-segment vehicle. This reflects a 15% reduction in manufacturing-related GHG emissions (excluding batteries) compared with the production emissions of equivalent vehicles currently on the market.[13]

Battery manufacturing. GHG emissions related to battery manufacturing were estimated at 48 kgCO_2 per kWh of nominal capacity, corresponding to the projected average emissions of an NMC battery produced within the EU by 2035. This represents a 20% reduction compared with the current emissions of EU-produced NMC batteries, mainly due to the expected decrease in the carbon intensity of the EU electricity mix over the next decade.[14]

Fossil fuel. GHG emissions related to fuel consumption were estimated for each segment × powertrain combination based on the certified emissions of vehicles currently sold within the EU, including an estimate of upstream emissions (notably refining).[15]

13 Negri, M., & Bieker, G. (2025). Life-cycle greenhouse gas emissions from passenger cars in the European Union: A 2025 update and key factors to consider (ID-392). International Council on Clean Transportation. [available online] ; BIEKER, G. (2021). A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars (rev. 2). International Council on Clean Transportation. [available online]

14 Negri, M., & Bieker, G. (2025). *Life-cycle greenhouse gas emissions from passenger cars in the European Union: A 2025 update and key factors to consider* (ID-392). International Council on Clean Transportation. [available online] ; Bieker, G. (2021). *A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars (rev. 2)*. International Council on Clean Transportation. [available online]

15 Manufacturers' websites, expert consultations, C-Ways and ICCT expertise, European ADAC sales data for the 2023–2025 period.

Biofuel.GHG emissions related to biofuel consumption were estimated to be 51% lower than those of gasoline, considering only the fuel life cycle (excluding vehicle manufacturing and end-of-life). This estimate is based on work conducted by ADEME on bio-gasoline emissions, incorporating a moderate land-use change assumption.[16]. This assumption takes into account the fact that a significant share of the bio-gasoline consumed in France is imported, which generates land-use change-related emissions outside the national territory.[17] This imported share would likely increase significantly if a large number of vehicles running entirely on biofuels were allowed to circulate.

Electricity. GHG emissions related to electricity consumption were set at 100 gCO_2e per kWh, corresponding to the projected average carbon intensity of the European Union's electricity mix over the 2025-2035 period[18].

Figures 8.a, 8.b, and **8.c** present the assumptions regarding GHG emissions for the vehicles considered in the study. *Note: B-SUV HEVs generate GHG emissions related to gasoline combustion and refining amounting to 103 gCO_2eq/km.*

Assumptions regarding Total Cost of Ownership (TCO)

To estimate the total cost of ownership (TCO) for each use case × segment × powertrain combination, the following assumptions were applied:

Vehicle manufacturing cost excluding batteries. The manufacturing cost of each vehicle (excluding the battery) was defined for each segment. It corresponds to the average cost of vehicles sold within the EU, reduced by €3,000 to reflect the efficiency gains in production projected by 2030-2040.[19]

Battery manufacturing cost. Battery costs range from €300/kWh (for HEVs) to €80/kWh (for BEVs) to reflect the fixed share of battery-related costs. This

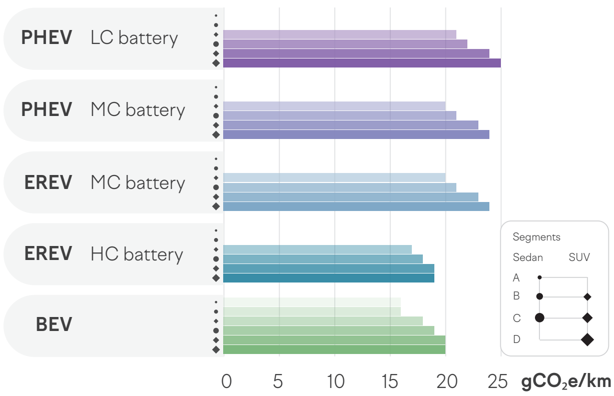
16 ADEME. Life cycle analyses applied to first-generation biofuels consumed in France, April 2018. [available online]

17 Geffray, L.-P., Aubert, P.-M., Frouin, Y., First-generation biofuels in road transport: better understanding current dynamics and future challenges. Institut Mobilités en Transition (IMT), November 2023. [available online]

18 C-Ways via IEA. For comparison, these emissions are far higher than those of the current French electricity mix, estimated at 30.2 gCO_2eq/kWh in 2024 by RTE. The GHG emission estimates considered here therefore represent a European average, higher than for a vehicle used in France. Réseau de Transport d'Électricité (RTE). Electric balance 2024 – Summary, April 2025. [available online]

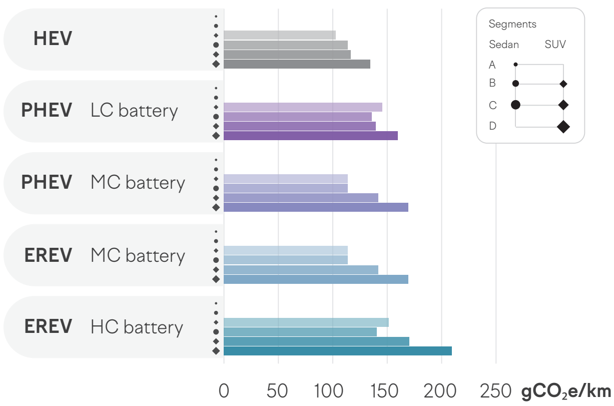
19 Manufacturers' websites, expert consultations, C-Ways modeling.

FIGURE 8.a GHG emissions from electricity consumption (LCA)



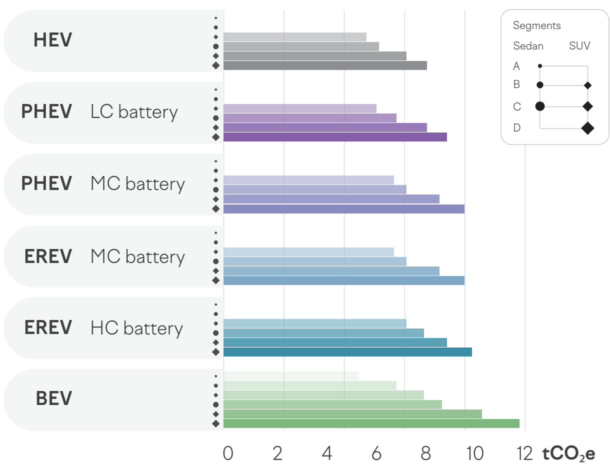
European electricity mix 2035-2040 (LCA) : 100 gCO2eq/kWh.

FIGURE 8.b GHG emissions from ICE (LCA)



Direct emissions + refining.

FIGURE 8.c GHG emissions from manufacturing (LCA)



Battery manufacturing emissions -20% vs current NMC Europe-produced. Vehicule manufacturing (excl. batteries) -15% vs current average (conservative / study purpose).

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

price corresponds to the projected cost of an NMC battery produced within the EU by 2030-2040. For BEVs, this represents a 27% decrease in battery costs compared with current levels, reflecting the efficiency gains expected from European gigafactories over that period[20]. This price remains higher than the projected cost of LFP batteries produced in China over the same period, estimated at around €60/kWh. This assumption should therefore be considered conservative within the framework of this study and in light of its objective to provide an unbiased assessment (the conservative nature reflecting the intent not to favor BEVs by default over other powertrains in TCO comparisons).

Manufacturing cost of electric and combustion engines. The cost of electric motors was set at €18/kW, compared with €20/kW for combustion engines, based on the current cost levels of these powertrains.[21]

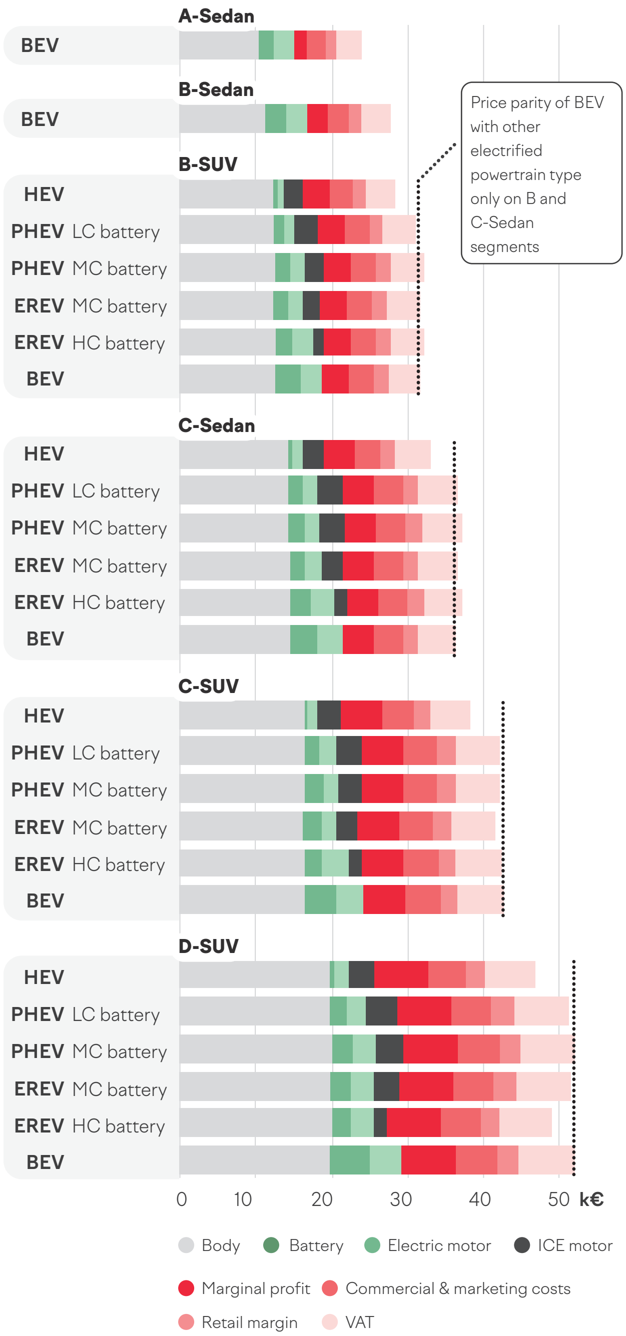
Manufacturer margins. Unit margins by vehicle segment are assumed to remain similar to current levels but identical across all powertrains (which differs from current manufacturer strategies, where margins are generally higher for combustion vehicles than for electric ones). They range from €1,500 per A-segment vehicle to €7,000 per D-SUV.[22]

Public subsidies. No public subsidies are included in the analysis, assuming that purchase incentives for electric vehicles will be phased out as their market share continues to grow.

Dealer margins, discount anticipation, and rebates. To the production costs, the following were added: a distribution network margin of 8%, a discount anticipation of 15%, aVAT rate of 20%, and a purchase rebate of -5% for private buyers and -15% for corporate fleets, reflecting the margins and discounts currently observed on the market.[23]

Figure 9 details the vehicle sale prices, excluding rebates, for all vehicles considered in the study. *Note: The production cost of an A-segment BEV, excluding the battery, is estimated at €10,500 per vehicle.*

FIGURE 9. Breakdown of vehicle prices



LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

20 Manufacturers' websites, expert consultations, C-Ways modeling
21 Manufacturers' websites, expert consultations, C-Ways modeling
22 Manufacturers' websites, expert consultations, C-Ways modeling
23 Manufacturers' websites, expert consultations, C-Ways modeling

Purchase price calculation method. These purchase prices are integrated into the TCO calculation assuming acquisition through leasing or financing,[24] with repayments spread evenly over five years for each buyer. The repayment amount depends on:

— The vehicle's value over time (related to its age) and its powertrain. To capture this, a residual value function with a multi-phase exponential decay form was defined, based on findings from the literature[25] and recent reports[26] to reflect current trends in vehicle residual value evolution depending on powertrain type, distinguishing between internal combustion and electric vehicles;

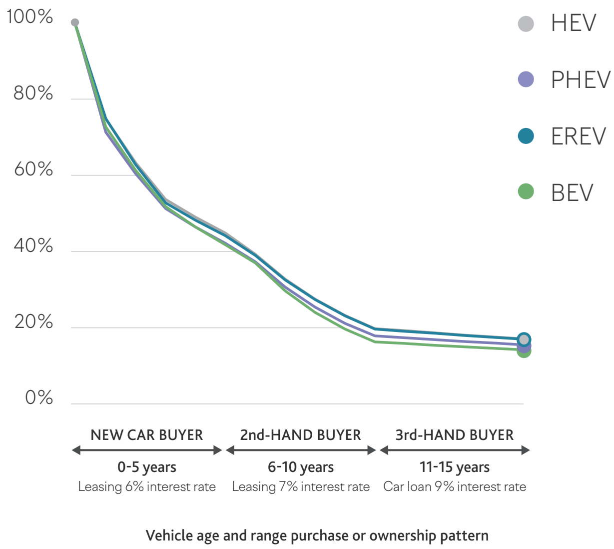
— The loan interest rate varies according to the type of buyer: 6% for new car buyers, 7% for 2nd hand buyers, and 9% for 3rd hand buyers.[27] The increase in the interest rate reflects the fact that used-car buyers generally have lower incomes than new car buyers and are therefore considered less creditworthy.

New car buyers are thus associated with corporate fleet or high-income household use cases, while used-car buyers correspond to low-income households.[28]

Figure 10 shows the evolution of residual value and the interest rate associated with the purchase of each vehicle type. *Note: After five years, the residual value of electric vehicles corresponds to 42% of their purchase price.*

FIGURE 10. Vehicule residual value over time

% of new purchase price depending on vehicle age



Buyer type	Vehicle age at purchase	Duration	Purchase value as a share of new vehicle price	Leasing/ loan interest rate
New buyer	0 year	5 years	All powertrains: 100%	6%
2nd hand buyer	5 year	5 years	HEV: 45% PHEV: 42% EREV: 44% VE: 42%	7%
3rd hand buyer	10 year	5 years	HEV: 20% PHEV: 18% EREV: 20% VE: 16%	9%

Gasoline price. The gasoline price was set at €1.79/l in the baseline simulations, based on a crude oil price of $80 per barrel, corresponding to the average price observed between September 2021 and September 2025.[29] This assumes distribution costs and taxation levels consistent with the current EU average.[30] Conservatively, this gasoline price does not include any additional cost related to the implementation of ETS2.[31]

24 Leasing offers are expanding and account for half of PHEV purchases made by private buyers in 2024, and 81% for battery electric vehicles (up from 60% in 2023). For professional buyers, these trends are even more pronounced: leasing represents 83% of PHEV purchases in 2024 (compared with 79% in 2023) and 74% for BEVs (up from 64% in 2023). AVERE-France, *Indicator*, June 2025. [available online].

25 Guo, Z. et Zhou, Y. Residual value analysis of plug-in vehicles in the United States. Energy Policy, 2019. [available online]. Sharma, J. et Kumar Mitra, S. Developping a used car pricing model applyin Multivariate Adaptative regression Splines approach. Expert Systems with Applications, 2024. [available online]. Ghibellini, A. et al. A comprehensive approach to residual value analysis in the luxury automotive market. IEEE access, 2025. [available online].

26 BCG, rapport pour Charge France. Why BEVs outperform PHEVs and Renge-Extended EVs for light transport decarbonization by 2035 in Europe, 2025. [available online]. T&E. Used electric cars are hot, leasing deals are not (Brief). 2023. [available online]. AVERE. Used electric vehicle market study, 2025. [available online]

27 In addition to observations on comparison sites such as CheckmonCredit and MeilleursTaux, these rates were set to increase based on two cumulative factors: the age of the vehicle and the decline in buyers' incomes as the vehicle ages.

28 This choice is based on observed purchasing dynamics. In a stylized manner, approximately one quarter of new vehicle purchases are made by households with an income at or below the median, while this share doubles for purchases of vehicles aged 5 to 10 years and reaches 60% for vehicles aged 10 to 15 years. Statistiques publiques de l'énergie, des transports, du logement et de l'environnement (SDES). Car purchases in 2022: fewer combustion powertrains and newer vehicles for higher-income households, March 2024. [available online]. Since 2019, this trend has been strengthening. Institut Mobilités en Transition (IMT) & C-Ways. The truth and myths about the causes of vehicle price increases between 2020 and 2024, May 2025 [available online].

29 INSEE. *Prices of imported raw materials – Brent crude oil (London) – Spot price in US dollars per barrel. Statistical series no. 010002077.* [available online]

30 Toute l'Europe. *Fuel prices in Europe.* [available online]

31 Commission européenne. *Weekly Oil Bulletin EUR 27 No. 2276, prices as of 06/10/2025. Brussels: European Commission, 2025* [available online] and C-Ways modeling.

Bio-gasoline price. The bio-gasoline price was set at €2.8/l, reflecting current cost premiums compared with gasoline in France[32] and assuming tax revenues per liter equivalent to those of gasoline. In the scenario where a significant share of vehicles operates entirely on biofuels, it is assumed that current subsidies would no longer be maintained, and that governments would seek comparable revenue levels to those generated from conventional fossil fuels.

Electricity price. The electricity price for short-distance driving was set at €0.20/kWh, reflecting charging primarily at home or at the workplace. An additional €0.40/kWh surcharge was applied for fast charging, considered only for BEVs when long-distance trips exceed their range[33] (for France, this would correspond to a slightly higher electricity supply cost of €70/MWh, assuming unchanged taxation levels.)

	Reference values used in the simulations	Sensitivity analyses included in the report
Electricity price	€0.20/kWh (€0.60/kWh for fast charging)	Minimum EU 2024 cost: €0.10/kWh (€0.30/kWh for fast charging) Maximum EU 2024 cost: €0.40/kWh (€1.20/kWh for fast charging)
Gasoline price	€1.79/l	+20% increase: €2.15/l
Bio-gasoline price	€2.8/l	

Charging points. The installation cost of a charging point was estimated at €1,000, equivalent to €200 per year over five years, for all powertrains except HEVs. This reflects the current average cost within the European Union.

Maintenance. Maintenance costs were assessed based on current maintenance expenses, differentiated by vehicle powertrain and vehicle age.[34]

Insurance. The insurance cost was considered proportional to the vehicle purchase price and identical across all powertrains, based on current average insurance costs within the EU.[35]

Parking. An annual parking cost was included in the calculations, with no differentiation by powertrain type or vehicle segment.

	Reference values used in the simulations
Charging point installation cost	€200/year (€1,000 over 5 years)—for all vehicles except **HEVs**
Maintenance costs	Fixed inspection fee: €68/year Additional cost for new vehicles: €447/year Additional cost for 2nd hand vehicles: €564/year Additional cost for 3rd hand vehicles: €680/year Variation by powertrain: -10% for BEVs, +10% for HEVs, PHEVs, and EREVs
Insurance	€408 + 0.014538 × purchase price (€/year)

In general, the TCO projection for the 2030-2040 period presented in this study is based on the following rationale:

— The technical performance of vehicles, as well as the costs of gasoline, maintenance, insurance, residual value, charging infrastructure, and marketing, are assumed to remain broadly equivalent to current levels.
— Over time, the following factors are projected: a slight decrease in the average cost of electricity, vehicle production, and battery production; the phase-out of purchase incentives for electric vehicles and biofuels; and a convergence of manufacturer margins between hybrid and electric vehicles.

32 Ministère de la Transition écologique et de la Cohésion des territoires. Energy balance of France for 2023 – 7.16: Significant decrease in biodiesel prices in 2023, April 2025 [available online]

33 C-Ways modeling.

34 Continuous adjustment according to vehicle age. A coefficient is associated with the vehicle's age and determined from a linear regression on raw fleet data from INSEE, 2017 Household Budget Survey, September 2020 [available online]

35 Estimated from the Les Furêts website [available online]

1. ALLOWING THE SALE OF PHEVS/EREVS AFTER 2035 WOULD, IN PRACTICE, BE DETRIMENTAL TO CLIMATE MITIGATION

As part of this study, life-cycle greenhouse gas emissions (excluding end-of-life and maintenance) were estimated for various vehicle types over the 2035-2040 period—the timeframe from which a regulatory relaxation has been proposed to continue allowing the sale of hybrid combustion vehicles.

The analysis was carried out using ten representative use cases reflecting situations observed in France, differentiated by annual number of kilometers covered and the short-/long-distance ratio, across six different vehicle segments and six powertrains.

Each source of emissions was estimated for the European Union over the 2035-2040 period based on conservative assumptions, including: the actual capacity of the battery and fuel tank; the real energy consumption per kilometer; the power output of the electric and/or combustion engines; emissions from the production of electricity or fuel (including upstream emissions); emissions from vehicle and battery manufacturing; and the distribution of driving between combustion and electric modes for PHEVs and EREVs.

1.1. Comparison of greenhouse gas emissions

The forward-looking analysis conducted in this study shows that, by **2035-2040**, **Plug-in Hybrid Electric Vehicles (PHEVs)** and **Range-Extended Electric Vehicles (EREVs)** will systematically exhibit **higher greenhouse gas (GHG) emissions** than **Battery Electric Vehicles (BEVs[36])** across all **use cases** considered.

On average, **PHEVs with mid-capacity batteries** produce **+73% more life-cycle GHG emissions** than BEVs, across all segments and use cases. Depending on the segment and use case, this gap ranges from +36% (for a C-Sedan used in a corporate fleet for intensive urban use) to +111% (for a D-SUV used in a corporate fleet for intensive long-distance use).

On average, **EREVs with high-capacity batteries** generate **+61% more life-cycle GHG emissions** than BEVs, across all segments and use cases. Depending on the segment and use case, this gap varies from +10% (for a C-SUV or D-SUV used in a corporate fleet for intensive urban use) to +114% (for a B-SUV used in a corporate fleet for intensive long-distance use).

As for other powertrains HEVs and PHEVs with low-capacity batteries (similar to most models marketed in 2025) show even higher emissions than other PHEV or EREV types—on average more than twice the emissions of BEVs, all else being equal.

EREVs with mid-capacity batteries have similar emissions to PHEVs with mid-capacity batteries.

The differences in greenhouse gas emissions between PHEVs/EREVs and BEVs vary significantly depending on the use case.

The smallest gaps are observed in use cases dominated by short trips. In these situations, the combustion engines of PHEVs and EREVs are rarely used, with propulsion relying mainly on electric energy. The near absence of long journeys—during which the combustion engine would normally take over—helps limit emissions. However, since batteries are not systematically recharged before every trip, part of the driving still relies on the combustion engine, resulting in emissions that remain higher than those of BEVs.

Conversely, the largest gaps occur in use cases with a high share of long-distance travel. In such cases, once the battery is depleted, the combustion engine provides most of the propulsion for a substantial portion of the kilometers driven, leading to significantly higher greenhouse gas emissions.

Figures 11a and **11.b** show the average life-cycle GHG emissions of different powertrains for B-SUV and D-SUV segments, as well as the emission gap between each powertrain and a BEV of equivalent segment, considering all use cases based on their representativeness in the vehicle fleet. *Note: In the EU, over 2035-2040, a B-SUV PHEV mid-capacity battery emits on average 101 gCO_2eq/km over its full life cycle which is +74% higher than a BEV of equivalent segment. This emission gap would range from +42% to +103%, depending on the use case.*

1.2. Origin of these differences

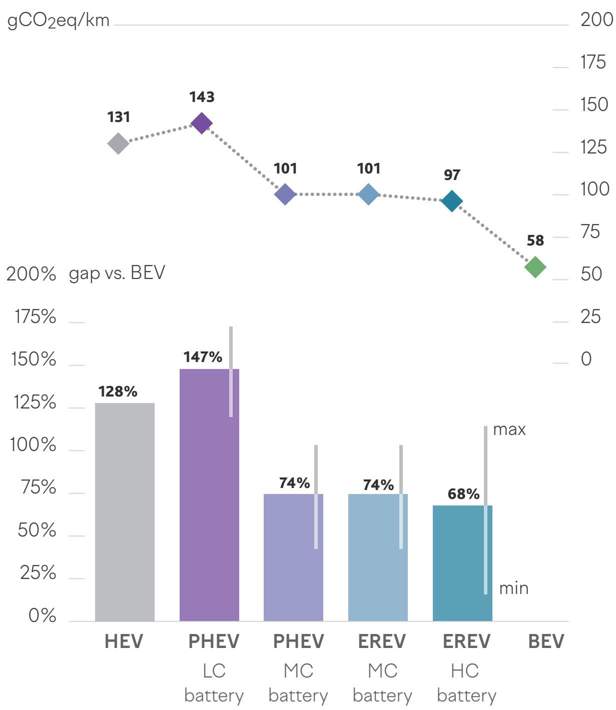
The higher emissions of PHEVs and EREVs compared with BEVs are mainly explained by two factors.

First, their significant consumption of liquid fuels under real-world use cases. In actual use—particularly on long-distance trips—PHEVs and EREVs rely heavily on liquid fuels. The greenhouse gas emissions associated with the combustion of these fuels are considerably higher than those linked to electricity consumption within the European Union over the 2035-2045 period. This difference becomes even more pronounced in use cases where the battery is quickly depleted and the combustion engine is used over long stretches of the journey. Overall,

36 In the remainder of this document, "electric vehicle" refers only to fully electric vehicles, and not to so-called "electrified" vehicles such as plug-in hybrid vehicles or electric vehicles equipped with a range extender using an auxiliary combustion engine.

FIGURE 11.a GHG emissions, all B-SUV average

Forecast 2035-2040. LCA (200 000 km).
Average GHG emissions weighted by actual travel profile of user categories according to their representativeness.

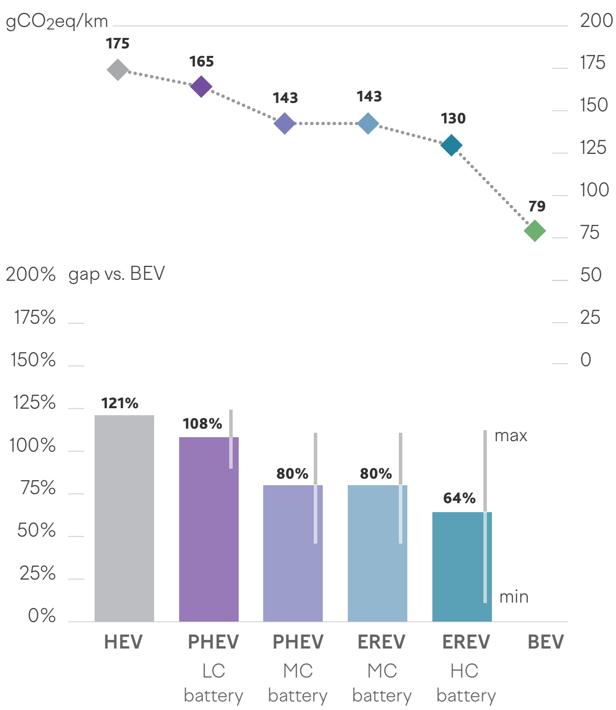


Min-max GHG emissions gap/BEV among all use cases.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

FIGURE 11.b GHG emissions, all D-SUV average

Forecast 2035-2040. LCA (200 000 km).
Average GHG emissions weighted by actual travel profile of user categories according to their representativeness.



Min-max GHG emissions gap/BEV among all use cases.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

the larger the battery capacity, the lower the vehicle's life-cycle GHG emissions.

Second, manufacturing-related emissions, while slightly higher for electric vehicles than for combustion or hybrid vehicles, are more than offset by lower use-phase emissions. BEVs incorporate larger batteries than PHEVs or EREVs, which leads to additional emissions during manufacturing. However, these remain moderate compared with those of current internal combustion engine vehicles and are quickly compensated during use due to the low GHG emission intensity of electricity consumption.

Since PHEVs and EREVs also contain substantial battery capacity, whose production generates non-negligible GHG emissions—combined with the emissions from their combustion engines and more complex architecture—the difference in manufacturing-related emissions between them and BEVs is relatively limited compared with the gap between HEVs and BEVs.

Figure 12 illustrates the breakdown of GHG emissions for a typical use case as an example. *Note: In the EU, over 2035-2040, a B-SUV PHEV mid-capacity battery used by a corporate fleet for intensive long-distance use emits on average 35 gCO_2eq/km from vehicle manufacturing, 6 gCO_2eq/km from electricity production, and 73 gCO_2eq/km from fuel combustion and refining.*

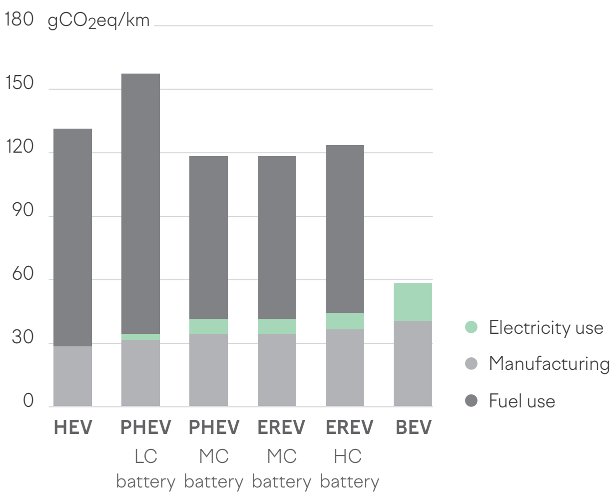
GHG emissions from PHEVs and EREVs can vary by as much as a factor of two, depending on the use case.

For EREVs, emissions depend both on battery size and usage patterns: in most situations, a high-capacity battery leads to higher emissions than a mid-capacity battery, but the opposite can occur in other contexts. There is therefore no universal ratio between combustion and electric operation that can consistently guarantee the lowest emission levels, which complicates the definition of a regulatory or fiscal framework based on such ratios.

FIGURE 12. **GHG emissions**

Corporate fleet for intensive long-distance use, B-SUV

Forecast 2035-2040. LCA (200 000 km).

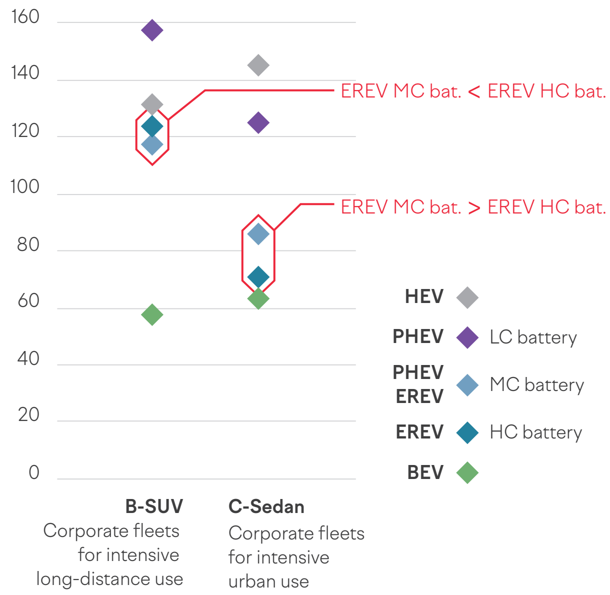


Corporate fleet for intensive long-distance: 62% long distance trips.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

FIGURE 13. **GHG emissions**

Forecast 2035-2040. LCA (200 000 km).



Corporate fleets for intensive long-distance: 62% long distance trips.
Corporate fleets for intensive urban use: 100% short-distance trips.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

Figure 13 illustrate two use cases where the emission ranking between EREV types is reversed. *Note: In the EU, over 2035-2040, a B-SUV EREV high-capacity battery used by a corporate fleet for intensive long-distance use would emit slightly more greenhouse gases over its entire life cycle than an EREV mid-capacity battery used under the same conditions.*

1.3. Impact of biofuel use

The life-cycle greenhouse gas emissions of the various vehicles considered were assessed under the theoretical assumption (see box below) that all vehicles equipped with combustion engines would operate exclusively on bio-gasoline.

Although these fuels are not emission-neutral, their average life-cycle emissions are estimated to halve total emissions compared with an equivalent fossil fuel—that is, - 51% CO_2e/km relative to gasoline, based on a fuel life-cycle analysis only, under a scenario assuming moderate land-use change.[37]

The forward-looking analysis conducted in this study shows that, by 2035-2040, **even under the theoretical assumption of biofuel use, Plug-in Hybrid Electric Vehicles (PHEVs) and Range-Extended Electric Vehicles (EREVs) would still generate higher life-cycle greenhouse gas (GHG) emissions than Battery Electric Vehicles (BEVs) in almost all use cases considered.**

On average, **PHEVs with mid-capacity batteries** would still emit **+23% more GHGs over their full life cycle than BEVs**, across all segments and use cases (+73% without biofuel use). Depending on the segment and use case, this gap would range from +8% to +39%.

On average, **EREVs with high-capacity batteries** would emit **+21% more GHGs over their full life cycle than BEVs**, across all segments and use cases (+61% without biofuel use). Depending on the segment and use case, this gap would range from -3% to +44%.

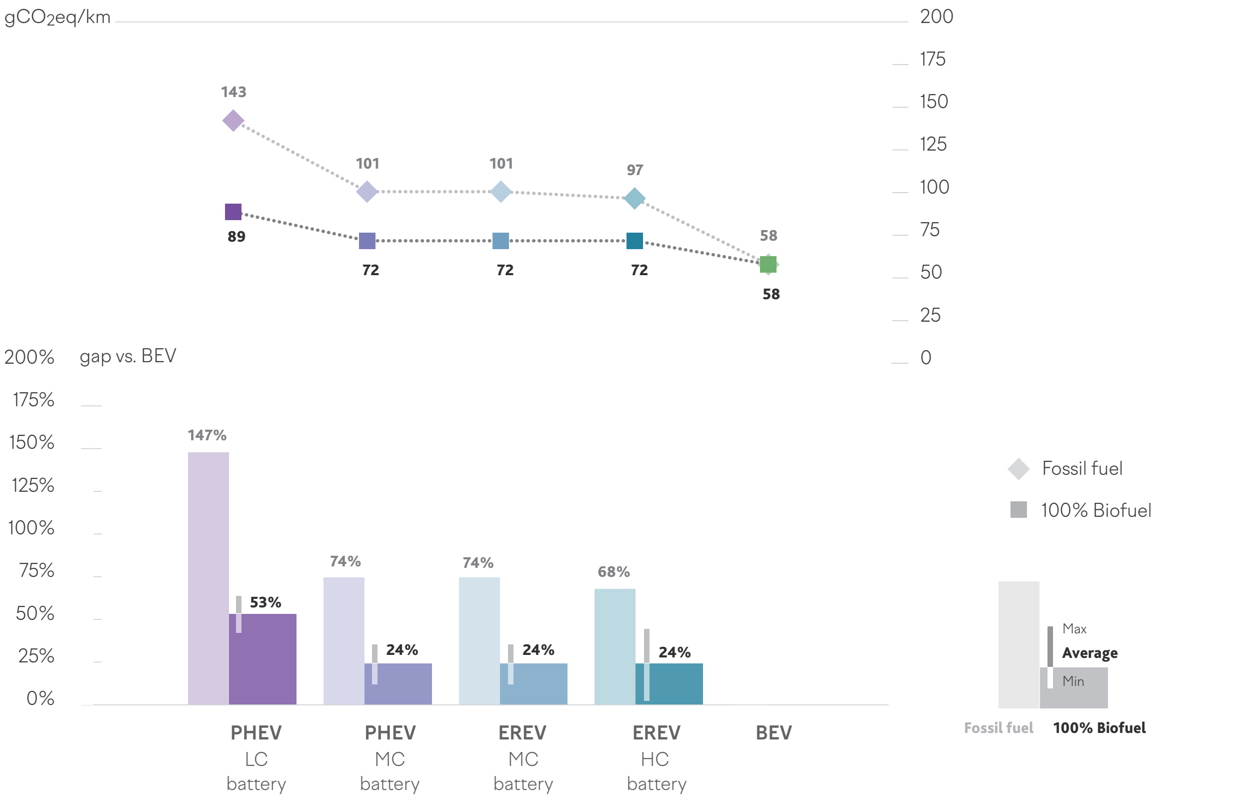
The only use case where an EREV would emit less than a BEV concerns C-SUVs or D-SUVs used by corporate fleets of light vehicles. This result is explained by the very specific driving assumptions in this use case, where 100% of trips are short distances. In this case, using a high-capacity EREV-assuming the battery is recharged before nearly every trip-would be almost equivalent to using a BEV with a smaller battery, since the EREV would operate almost entirely in electric mode. However, such a situation is highly unlikely, as in these conditions an EREV offers no advantage in terms of range or cost compared with a smaller-segment BEV.

HEVs and PHEVs with low-capacity batteries (similar to 2025 models) would consistently emit more than BEVs, by +35% and +40% on average, respectively.

37 Further details are provided in the Methodology section.

FIGURE 14. GHG emissions - 100% biofuel use (theoretical), all B-SUV average

Forecast 2035-2040. LCA (200 000 km). Average GHG emissions weighted by actual travel profile of user categories according to their representativeness.



Biofuels : biogasoline (CO2 emissions equivalent - 51% vs. conventional fuel). Min-max GHG emissions gap/BEV among all use case.

LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

EREVs with mid-capacity batteries would have emissions identical to those of PHEVs with mid-capacity batteries (batteries of a similar size).

Overall, under a theoretical 100% biofuel-use scenario for internal combustion engine vehicles, the emission gap with BEVs would be reduced by a factor of three on average, but PHEVs and EREVs would still remain more emissive than BEVs in nearly all cases.

Figure 14 shows the average life-cycle GHG emissions of the different powertrains for the B-SUV segment and the emission gap between each powertrain and a BEV, with and without biofuel integration. *Note: In the EU, over 2035-2040, a B-SUV PHEV mid-capacity battery running 100% on biofuels would emit on average 72 gCO_2eq/km over its life cycle, +24% higher than a BEV of the equivalent segment, compared with +74% higher in the absence of biofuels.*

It is also conceivable that future **PHEVs/EREVs** could use **biodiesel** (instead of the **bio-gasoline** considered above). The results of such a simulation would be **similar**: the **life-cycle greenhouse gas emissions** of biodiesel vary widely, ranging from levels **comparable to those of bio-gasoline** to **higher than those of fossil fuels**, depending on the **extent of land-use change** involved.[38]

38 **Direction générale des Entreprises (DGE)**. *Overview of alternative technologies to diesel heavy trucks for road freight transport*, July 2025. [available online]

BOX 3. WHY WOULD IT BE UNREALISTIC TO EXPECT A MASSIVE INCREASE IN THE USE OF BIOFUELS IN THE ROAD TRANSPORT SECTOR?

While some biofuels can indeed be considered low-carbon, a significant share of them have actual carbon impacts that are similar to or even higher than those of fossil fuels. Their carbon footprint varies greatly depending on the type of fuel, production methods, land-use change effects, and country of origin.

Their net climate impact can range from an 80% reduction to a 145% increase in emissions compared with fossil fuels.[1] Moreover, biofuel production can cause significant non-climatic environmental impacts, particularly in terms of water consumption, fertilizer and pesticide use, and land-use change.

Each generation of biofuels also faces structural limitations regarding the availability of feedstock. First-generation biofuels, produced from crops that could otherwise serve as food, often have poor climate performance and compete with food production for agricultural land. Second-generation biofuels have a lower climate impact, but are available only in limited quantities, insufficient to supply a significant share of the European vehicle fleet.[2]

Moreover, biofuels represent an essential decarbonization solution for other transport modes—particularly aviation and maritime transport—which, for technical reasons, can only rely on electrification to a limited extent. Using biofuels in road transport, where mature and efficient technologies already exist for decarbonisation through electric vehicles, would therefore amount to wasting these limited resources and slowing the decarbonization of other sectors through a spillover effect.

The biofuels currently used in the EU are largely imported, raising energy sovereignty concerns similar to those associated with fossil fuels. A significant increase in demand would either require greater import volumes or be constrained by the limited availability of feedstock, thereby prolonging dependence on liquid fuels.

Finally, biofuels are more expensive to produce than fossil fuels. Assuming equivalent taxation (excluding environmental taxes), their use would lead to a significant increase in fuel prices for consumers. As bio-based energies, their production is limited by land availability, biological yields, and complex supply chains.

1 Direction générale des Entreprises (DGE). op. cit.

2 In France alone — despite being among the EU countries with the largest potential for biofuel production due to its strong agricultural output — the General Secretariat for Ecological Planning (SGPE) estimates that the available supply of liquid biofuels will remain far below the increase in demand between 2030 and 2050, even in a scenario where the vast majority of road vehicles are electrified. Secrétariat général à la planification écologique (SGPE). Biomass closure: issues and orientations, November 2024. [available online]

1.4. Impact of restricting combustion engine use in hybrid vehicles within urban areas

The life-cycle greenhouse gas emissions of the different vehicles considered were also evaluated under the theoretical assumption (see box below) that all PHEVs and EREVs would have their use of combustion engines restricted in urban zones, through a system that monitors the use of combustion and electric modes based on geolocation, with or without associated penalties.

This scenario assumes that: PHEV low-capacity battery vehicles use their electric motor for 50% of short-distance trips; PHEV mid-capacity battery, EREV mid-capacity battery, and EREV high-capacity battery vehicles use their electric motor for 100% of short-distance trips; for long-distance trips, hybrid vehicle batteries are assumed to be fully charged before departure and not recharged en route.

The forward-looking analysis in this scenario shows that, by 2035-2040, **even assuming restrictions on combustion engine use in urban areas, PHEVs and EREVs would still emit more GHGs than BEVs in almost all use cases considered.**

On average, **PHEVs with mid**-capacity batteries would still emit **+43% more GHGs over their life cycle than BEVs**, across all segments and use cases (+73% without combustion engine restrictions). Depending on the segment and use case, this gap would range from -10% (for the highly specific case of a corporate fleet used almost exclusively for short-distance trips—an unlikely scenario, as such a PHEV would offer no advantage in range or cost compared with a smaller-segment BEV) to +97%.

BOX 4. CAN THE USE OF COMBUSTION ENGINES IN PHEVS/EREVS BE RESTRICTED?

The gap in emissions between PHEVs/EREVs and BEVs could, in theory, be partly reduced by introducing constraints on the actual use of the combustion engine in these vehicles. Such regulation has been proposed by some manufacturers but would, in practice, require binding measures—for example, geolocation tracking and precise monitoring of the respective use of the electric and combustion engines for each PHEV or EREV. This could include, for instance, the introduction of penalties proportional to the distance driven in combustion mode beyond a certain annual threshold.

Under this theoretical scenario, the GHG emission surplus of PHEVs and EREVs compared with BEVs would be reduced by about half, yet PHEVs/EREVs would still be less performant in almost all cases (except for corporate fleets used intensively in urban areas, for reasons similar to those outlined in the section on biofuels).

While such regulation is technically feasible, it appears socially difficult to implement in the current context. For it to be effective, it would require a level of monitoring perceived as intrusive, contradicting the notion of freedom and flexibility often associated with these vehicles by their users. Moreover, such an approach would involve hidden costs (installation or integration of monitoring systems, data processing and security, administrative management, etc.), which would fall on public finances or third-party private actors (e.g., leasing companies).

In practice, controlling the real use of combustion engines would be a necessary but politically and socially unrealistic condition, which greatly limits the credibility of the climate improvement claims made by proponents of extending PHEV and EREV sales after 2035 on the grounds that users will become more disciplined in optimizing driving modes and systematic recharging

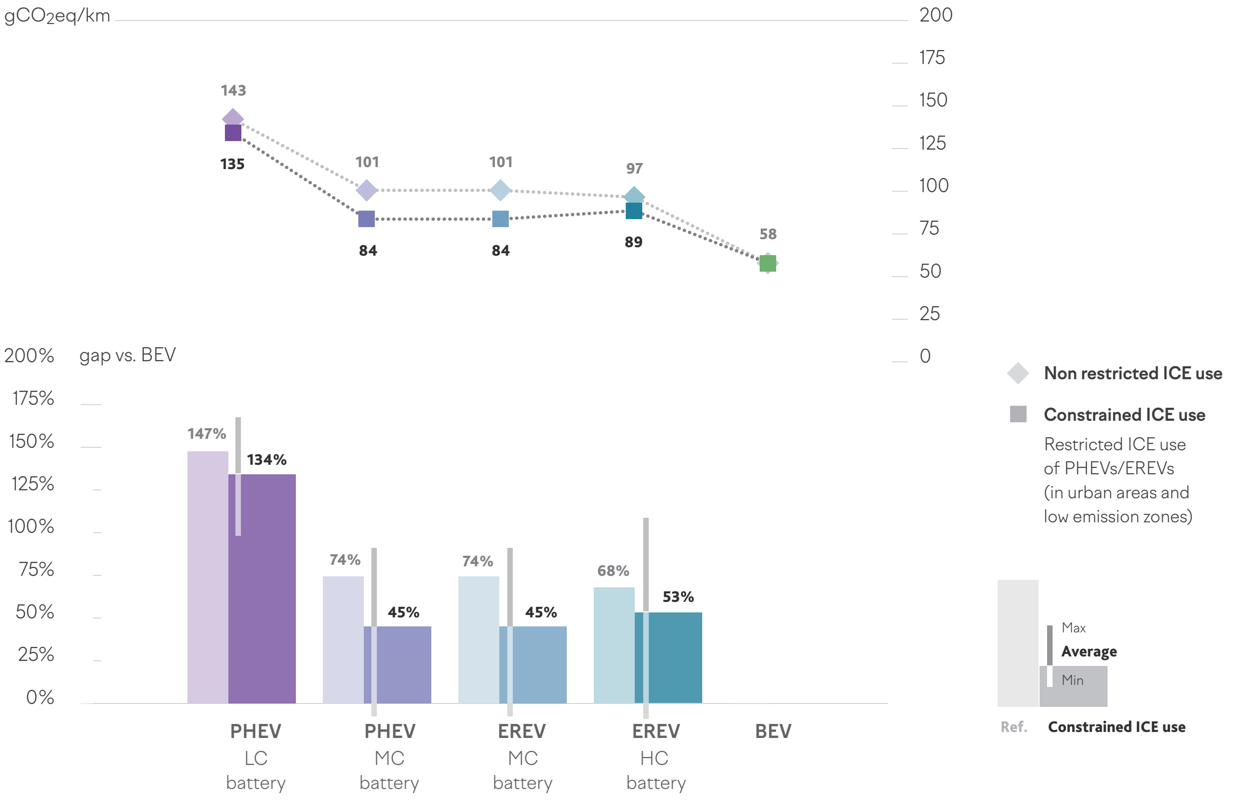
On average, **EREVs with high-capacity batteries** would still emit **+48% more GHGs over their life cycle than BEVs**, across all segments and use cases (+61% without restrictions on combustion engine use). Depending on the segment and use case, this gap would range from -13% to +108%.

PHEVs with low-capacity batteries (similar to models sold in 2025) would still consistently emit more than BEVs, by +108% on average. EREVs with mid-capacity batteries would continue to have emissions identical to PHEVs with mid-capacity batteries (batteries of a similar size).

Figure 15 shows the average life-cycle GHG emissions of the different powertrains for B-SUVs, and the emission gap between each powertrain and a BEV, with and without restrictions on combustion engine use in urban areas for hybrid vehicles. *Note: In the EU, over 2035-2040, a B-SUV PHEV mid-capacity battery with restricted combustion engine use in urban areas would emit on average 84 gCO_2eq/km over its life cycle, +45% higher than a BEV of the equivalent segment, compared with +74% higher without such restrictions.*

FIGURE 15. GHG emissions - Constrained ICE use of PHEVs/EREVs (theoretical), all B-SUV average

Forecast 2035-2040. LCA (200 000 km). Average GHG emissions weighted by actual travel profile of user categories according to their representativeness.



Under restricted usages (geofencing, mandatory electric mode in urban areas and low emission zones), mid-capacity PHEVs & high-capacity EREVs use batteries on 100% of short-distance trips (vs 70% & 90% without constraints).

Min-max GHG emissions gap/BEV among all use case.

LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

1.5. Impact of variations in the emissions of the electricity mix

The GHG emissions of the different vehicle types projected for 2035-2040 are based on the assumption of a progressively decarbonized European electricity mix, reaching an average life-cycle emission level of 100 gCO_2eq/kWh.

However, this average conceals contrasting situations between countries. For example, **assuming a lower-carbon electricity supply, equivalent to France's current electricity mix** (30 gCO_2eq/kWh in 2024[39]), **the GHG emission gap between PHEVs/EREVs and BEVs would further increase** on average, **PHEVs with mid-capacity batteries** would emit **+103% more GHGs over their life cycle than BEVs**, across all segments and use cases, a +30 percentage-point increase compared with an electricity mix emitting 100 gCO_2eq/kWh.

On average, **EREVs with high-capacity batteries** would emit **+86% more GHGs over their life cycle than BEVs**, across all segments and use cases, a +24 percentage-point increase.

BEVs would show an average **21% reduction in life-cycle GHG** emissions across all use cases and segments.

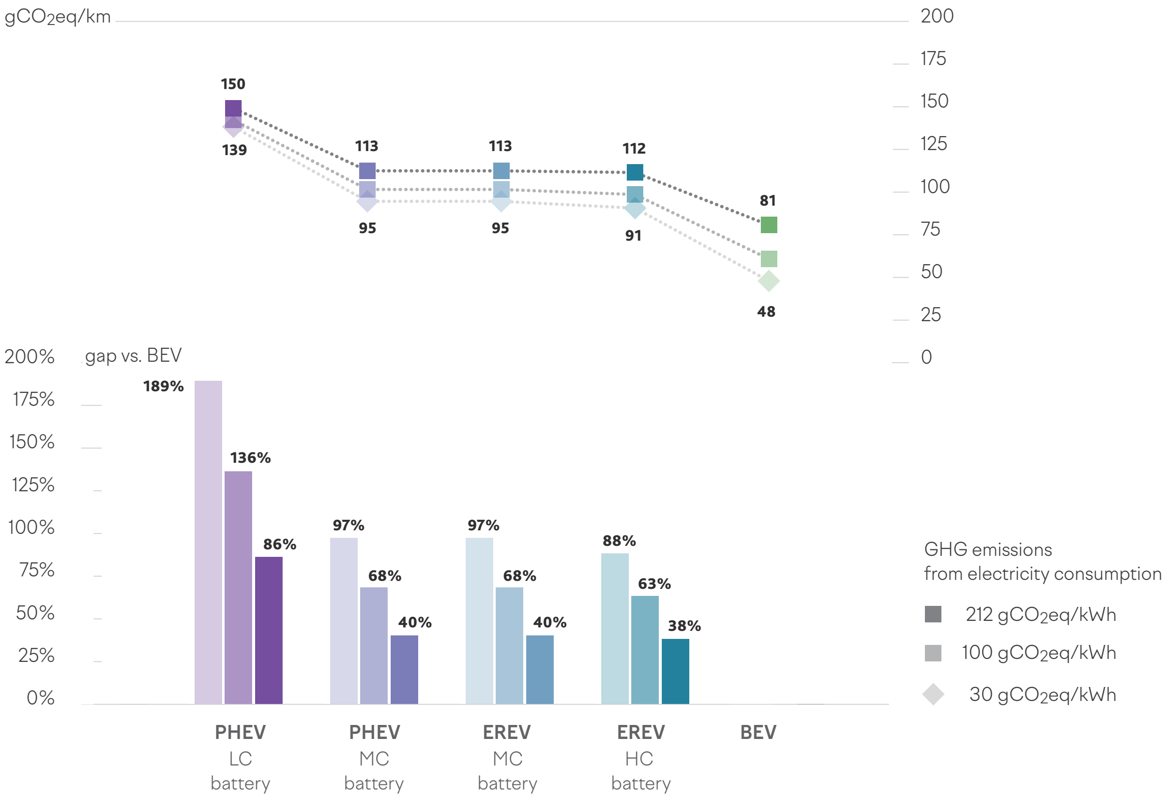
Conversely, assuming no progress in the decarbonization of the European electricity mix after 2024 (217 gCO_2eq/kWh average life-cycle emissions in 2024[40]), the GHG emissions of PHEVs and EREVs would still remain consistently higher than those of BEVs across all use cases studied. Although the gap would narrow, it would still reach +44% for PHEVs with mid-capacity batteries and +37% for EREVs with high-capacity batteries.

39 Réseau de Transport d'Électricité (RTE). *Electricity Balance 2024—Summary*, April 2025. [available online]

40 EMBER. *Global Electricity Review 2025*.2025. [available online]

FIGURE 16. GHG emissions - Sensitivity on electricity mix, all B-SUV average

Forecast 2035-2040. LCA (200 000 km). Average GHG emissions weighted by actual travel profile of user categories according to their representativeness.



Sensitivity on electricity mix, namely european electricity mix 2035-2040 (LCA) : 100 gCO2e/kWh, French electricity mix 2024 (LCA) : 30 gCO2e/kWh, UE electricity mix 2024 (LCA) : 212 gCO2e/kWh.

LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

Figure 16 illustrates the average GHG emissions of different powertrains for a B-SUV, as a function of the emissions related to the production of electricity. *Note: In the EU, over 2035-2040, a B-SUV PHEV mid-capacity battery powered by an electricity mix emitting 212 gCO_2eq/kWh (equivalent to Germany's 2024 mix) would emit on average 113 gCO_2eq/km over its full life cycle, +40% higher than a BEV of the equivalent segment, compared with +74% higher under the average EU electricity mix.*

This comparison of life-cycle emissions between PHEVs, EREVs, and BEVs shows that allowing the sale of PHEV or EREV vehicles after 2035, especially if they are granted as low or even zero-rated standardized emissions, would be misleading regarding their actual climate impact, which is significantly higher than that of electric vehicles. This conclusion remains valid even under the assumption of biofuel use.

KEY MESSAGES

— Across all **use cases** studied, the **life-cycle GHG emissions** of **PHEVs** and **EREVs** remain **significantly higher** than those of **BEVs**.

— On average, **PHEVs with mid-capacity batteries** emit **+73% more** than BEVs across all segments and use cases (**minimum: +36%**; **maximum: +111%**).

— **EREVs with high-capacity batteries** would emit **slightly less GHGs** than mid-capacity PHEVs but would still remain **more emissive than BEVs**.

— This persistent gap is explained by the fact that, although **BEVs have slightly higher manufacturing emissions** than internal combustion engine or hybrid vehicles, these are **more than offset by their much lower use-phase emissions**, giving BEVs a **clear advantage in decarbonization throughout their full life cycle**.

2. ALLOWING THE SALE OF PHEVS/EREVS AFTER 2035 WOULD ALSO BE DETRIMENTAL TO PURCHASING POWER

While Plug-in Hybrid Electric Vehicles (PHEVs) and Range-Extended Electric Vehicles (EREVs) generate higher life-cycle greenhouse gas emissions than Battery Electric Vehicles (BEVs), the call by some manufacturers for a regulatory relaxation after 2035 is also based on another argument: according to them, these vehicles would offer users more affordable options while preserving sufficient profit margins to maintain manufacturers' competitiveness.

To assess this claim, the Total Cost of Ownership (TCO) of the different powertrain types was estimated for the 2030-2040 period. The analysis follows the same segmentation used for GHG emissions: ten representative use cases associated with different purchase types and vehicle ages (new versus used vehicles), applied across six vehicle segments and six powertrains.

The TCO considered here includes: the purchase cost of the vehicle, distinguishing between new car buyers, 2nd hand buyers, and 3rd hand buyers (depending on vehicle age, financing conditions, maintenance costs, and residual value); the cost of electricity charging (including surcharges for fast charging when long-distance trips exceed battery range) and fuel costs; the installation cost of charging infrastructure for rechargeable vehicles; the cost of insurance, parking, and maintenance.

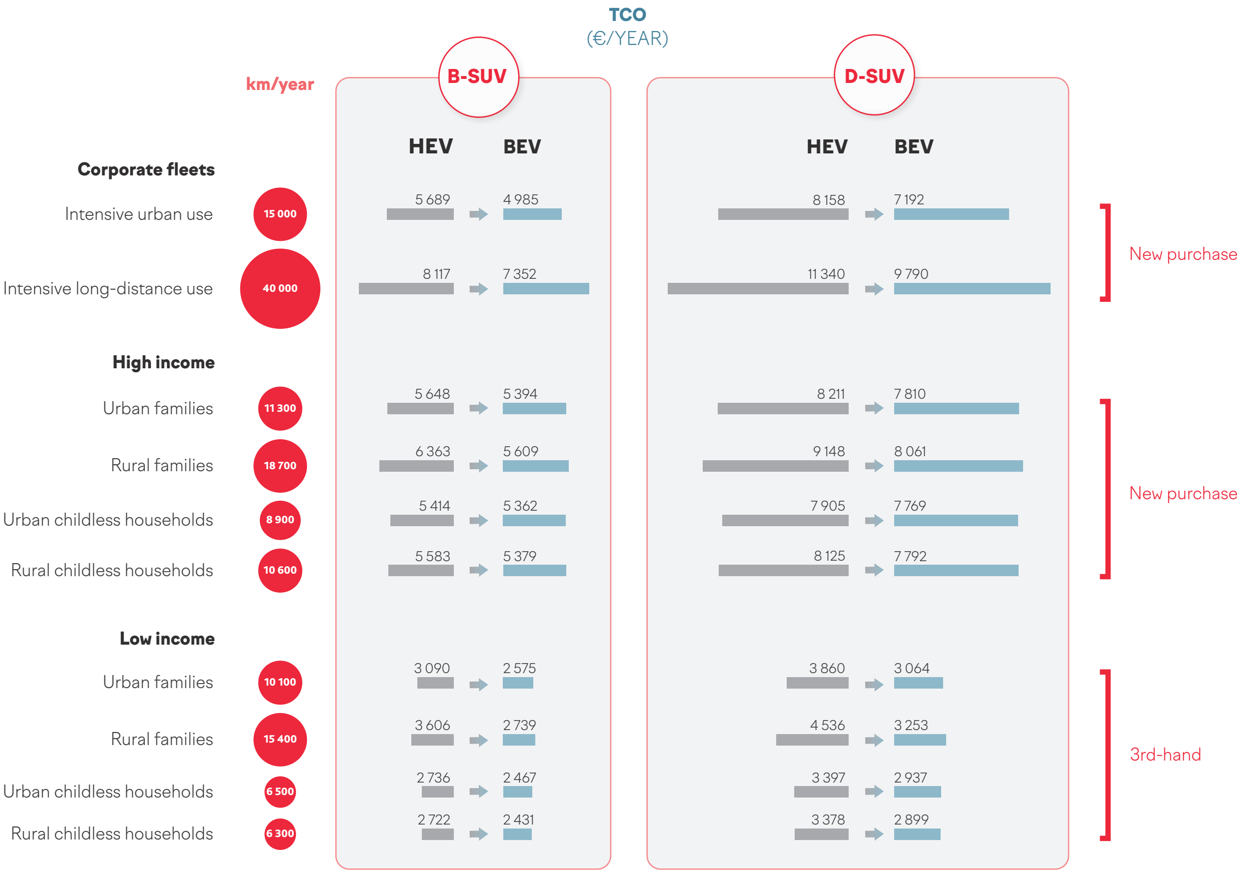
Each cost component was estimated using conservative assumptions, based on EU-wide averages for the 2030-2040 period.[41]

Figure 17 illustrates part of the results from the more than 1,000 simulations conducted for this study, comparing the annual TCO of several vehicle types purchased new and as 3rd hand vehicles. *Example: In the EU, over 2030-2040, a B-SUV HEV purchased new and used by a corporate fleet for intensive urban use would have a total annual cost of €5,689/year, compared with €4,985/year for an equivalent BEV, all other factors being equal.*

41 Further details can be found in the Methodology section.

FIGURE 17. Advantage of owning a BEV vs. HEV

Forecast 2035-2040



2.1. Comparison of total cost of ownership

The forward-looking analysis conducted in this study shows that, by 2030-2040, Plug-in Hybrid Electric Vehicles (PHEVs) and Range-Extended Electric Vehicles (EREVs) will have a consistently higher total cost of ownership (TCO) than Battery Electric Vehicles (BEVs) across all use cases considered. The estimated additional cost is similar for PHEVs with mid-capacity batteries and EREVs. This difference is not limited to new purchases—it widens for 2nd hand and 3rd hand buyers, further favoring BEVs.

To illustrate the TCO differences observed in our simulations (expressed in €/km for each ownership phase), we also translated them into an equivalent increase in the price of gasoline (€/l) for a 2025 combustion vehicle. The purpose of this indicator is to show the impact on household budgets—particularly for low-income used-car buyers—of continuing to drive plug-in hybrids after 2035, in comparison with the major inflation shock of 2022 (when fuel prices rose by €0.20-€0.40/l). The TCO gaps estimated in this study are significantly higher than those values.

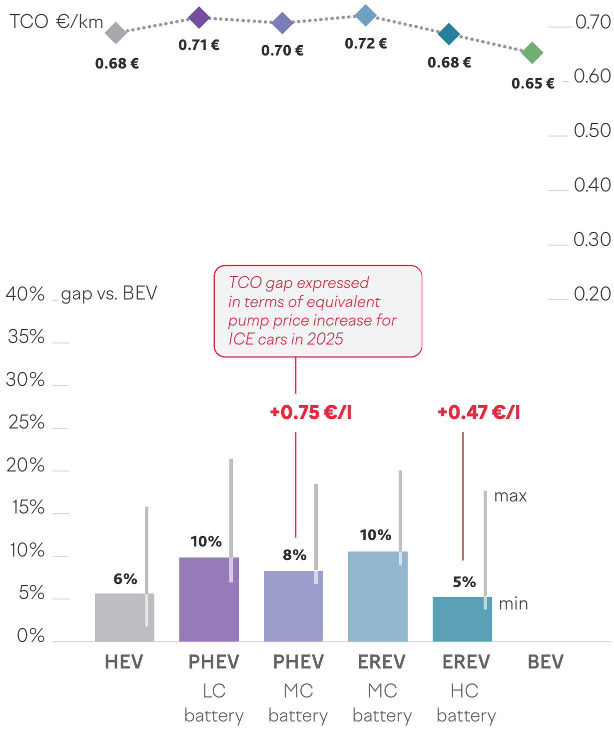
For new vehicles, on average, new PHEVs with mid-capacity batteries show a TCO (€/km over ownership period) that is +7% higher than BEVs, across all segments and use cases. Depending on the segment and use case, this gap ranges from +4% (for a C-SUV used by a high-income urban childless household) to +18% (for a D-SUV used by a corporate fleet for intensive long-distance use). This average TCO gap would correspond to an increase of approximately €0.64/l in gasoline price for a 2025 combustion vehicle.

On average, EREVs with high-capacity batteries have a TCO that is +8% higher than BEVs, across all segments and use cases. Depending on the segment and use case, this gap ranges from +4% (for a D-SUV used by a corporate fleet for intensive urban use) to +18% (for a D-SUV used by a corporate fleet for intensive long-distance use). This average extra cost would be equivalent to a €0.67/l increase in gasoline price for a 2025 combustion vehicle.

HEVs show a slightly smaller TCO gap with BEVs (+5% on average). The gap is larger for EREVs with mid-capacity batteries (+9%) and PHEVs with low-capacity batteries (+11%), which have the highest average TCOs overall.

FIGURE 18.a TCO new car buyer, all D-SUV average

Forecast 2035-2040. Average TCO weighted by actual travel profile of user categories according to their representativeness.

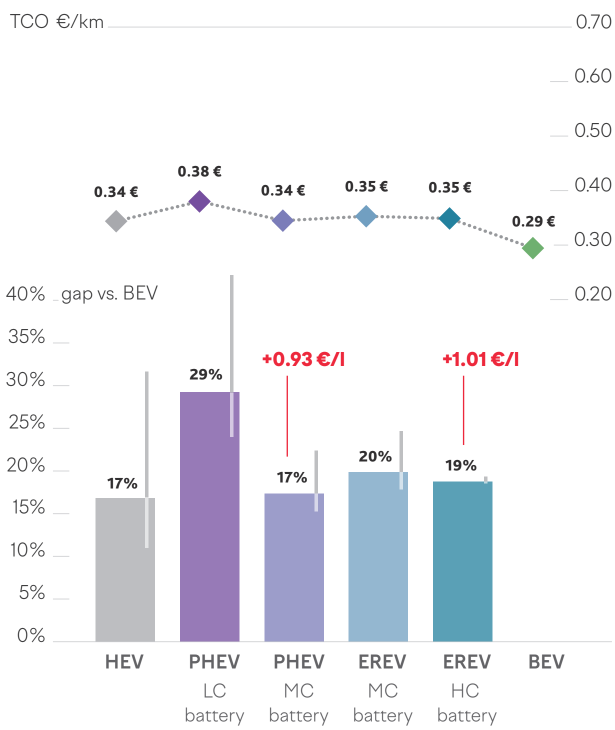


Min-max TCO gap/BEV among all use case. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

FIGURE 18.b TCO 3rd-hand buyer, all B-SUV average

Forecast 2035-2040. Average TCO weighted by actual travel profile of user categories according to their representativeness.



Min-max TCO gap/BEV among all use case. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

Figure 18.a illustrates the TCO, the TCO gap relative to BEVs, and the TCO expressed as an equivalent gasoline price increase, for D-SUVs purchased new and used by high-income households and corporate fleets. *Note: In the EU, over 2030-2040, a D-SUV PHEV mid-capacity battery purchased new would have an average total cost of €0.70/km, i.e. +8% higher than an equivalent BEV—corresponding to an equivalent fuel price increase of +€0.75/l for a 2025 combustion vehicle. This total cost difference would range from +7% to +18%, depending on the use case.*

For 3rd hand vehicles, across all **use cases** considered, the **TCO gap** increases significantly: The difference in TCO between **PHEVs with mid-capacity batteries** and **BEVs** is, on average, **2.5 times greater** for a **3rd hand vehicle** than for a **new vehicle**. On average, **PHEVs with mid-capacity batteries** have a **TCO (€/km over the ownership period)** that is **+18% higher** than BEVs, across all segments and use cases. Depending on the segment and use case, this gap ranges from +14% (for a C-Sedan used by a low-income urban childless household) to +29% (for a D-SUV used by a low-income rural family with children). This average extra cost would be equivalent to an **increase of about €0.92/l** in the gasoline price for a 2025 combustion vehicle.

On average, **EREVs with high-capacity batteries** have a **TCO** that is also **+18% higher** than BEVs, across all segments and use cases. Depending on the segment and use case, this gap ranges from +16% (for a B-SUV used by a low-income rural childless household) to +21% (for a D-SUV used by a low-income rural family with children). This average difference would correspond to an **equivalent fuel price increase of about €0.94/l** for a 2025 combustion vehicle.

Figure 18.b illustrates the TCO, the TCO gap relative to BEVs, and the TCO expressed as an equivalent increase in gasoline price, for B-SUVs purchased as 3rd hand vehicles and used by low-income households. *Note: In the EU, over 2030-2040, a B-SUV PHEV mid-capacity battery purchased as a 3rd hand vehicle would have an average total cost of €0.34/km, i.e. +17% higher than an equivalent BEV—corresponding to an equivalent fuel price increase of +€0.93/l for a 2025 combustion vehicle. This total cost difference would vary from +15% to +22%, depending on the use case.*

These additional cost levels are comparable to—or even higher than—the price surge observed during the 2022-2023 energy crisis, when the average pump price of gasoline (SP95-E10) in the EU increased by approximately €+0.40/l.[42,43] The results show that, depending on the use case and across all hybrid powertrains, the TCO gaps would correspond to equivalent fuel price increases ranging from one to four times those observed in 2022.

2.2. Origin of these cost differences

The TCO gaps between powertrains are mainly explained by two key components: fuel costs and maintenance costs. These same factors explain why the economic advantage of BEVs increases as vehicles change owners on the used-car market. Indeed, these costs are lower in absolute value and either stable (energy price) or rising (maintenance cost) over the vehicle's lifetime. As a result, their relative weight in the TCO becomes dominant by the third ownership stage, further strengthening the comparative advantage of BEVs.

The projection of a higher TCO for PHEVs with mid-capacity batteries and EREVs with high-capacity batteries, compared with BEVs, when considering a new vehicle purchase, is mainly driven by two mechanisms:

Purchase price parity. By 2030-2040, the projected purchase price of PHEVs and EREVs is close to that of BEVs within the same segment. The additional cost of larger BEV batteries, which is expected to shrink due to the projected decline in battery prices by that time, is offset in PHEVs/EREVs by their smaller battery combined with a dual powertrain (electric and combustion). For instance, for a high-income rural family purchasing a new C-Sedan, the leasing share of the TCO would be slightly higher for a BEV (58%) than for a PHEV mid-capacity battery (54%) or an EREV high-capacity battery (57%), with no significant absolute difference (€0.19/km vs. €0.20/km and €0.21/km, respectively).

42 This increase occurred between October and February 2023. Over the period from March 2022 to 2024, several successive consumer price increases took place. The second-largest peak corresponded to a rise of €0.26/l for SP95-E10 and €0.18/l for diesel (between April and June 2022). Roole. Evolution of fuel prices in France (2007–2025), October 2025. [available online].

43 Mobilizing over €10 billion in public mitigation measures in France. The mitigation measures were implemented successively: a fuel price discount of €0.15/l excluding taxes (27 March 2022 – 31 August 2022), €0.25/l excluding taxes (1 September 2022 – 15 November 2022), and €0.8/l excluding taxes (16 November 2022 – 31 December 2023). Starting 1 January 2023, a €100 allowance was provided for households with a taxable income below €14,700 who use their vehicle to commute to work. For 2022, the public cost is estimated based on data from the Comité des Professionnels du Pétrole. Comité des professionnels du pétrole. L'intégral pétrole 2023, July 2024. [available online]. For 2023 and 2024, the public cost was derived from a Banque de France bulletin. Banque de France. Energy price shield in France: what assessment?, July 2024 [available online].

Lower operating and maintenance costs for BEVs. A BEV is systematically advantaged by its lower cost per kilometer for electricity compared with fossil fuels, and by reduced maintenance costs. These two components represent the main competitive advantages of BEVs from the first ownership stage onward. They account for slightly less than one quarter of total TCO, regardless of powertrain, but vary in absolute value depending on driving patterns.

Figure 19 shows the breakdown of the TCO across different powertrains for a C-Sedan purchased new by a high-income rural family with children, and how this breakdown evolves by buyer type. *Note: In the EU, over 2030-2040, the leasing repayment alone for a C-Sedan BEV purchased new and used by a high-income rural family with children would amount to €0.34/km.*

As vehicles enter the used-car market, particularly at the third ownership stage, the economic advantage of BEVs becomes significantly stronger compared with other powertrains. This effect is driven by the changing dynamics of TCO components: the relative weight of leasing costs decreases over time, while fuel and maintenance costs gain importance. Since the absolute values of these costs remain much lower for BEVs than for PHEVs or EREVs, the comparative advantage of BEVs widens over the vehicle's lifetime.

For third-hand owners, the cost structure reverses: the purchase cost represents only about one quarter of the TCO, while fuel and maintenance together account for more than half. For example, for a high-income rural family with children owning a C-Sedan, the automotive loan would represent 22% of the TCO for a BEV, 20% for a mid-capacity PHEV, and 23% for a high-capacity EREV. This share is less than half that of a first-hand purchase, and the absolute cost per kilometer is divided by more than four-and is identical across all three powertrains.

Conversely, fuel costs remain stable in absolute value (€0.05/km for BEVs, €0.07/km for PHEVs, and €0.06/km for EREVs), but their relative weight in TCO becomes dominant: 30%, 34%, and 30%, respectively-about twice as high as for first-hand vehicles. The same trend applies to maintenance costs, which increase both in absolute and relative terms, further reinforcing the economic advantage of BEVs on the used market.

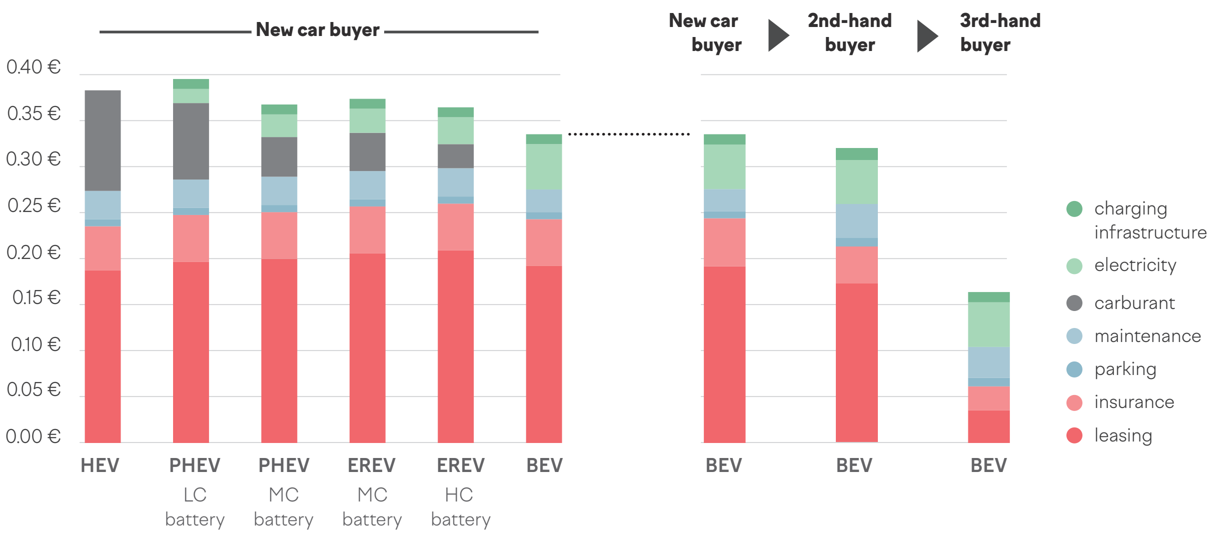
Driving patterns also play a critical role in determining the TCO per kilometer.

- The most favorable scenario for a PHEV mid-capacity battery corresponds to a high-income urban childless household owning a C-SUV as a new vehicle: in this case, the TCO gap with a BEV is only +4%.
- The least favorable scenario involves a low-income rural family with children owning a D-SUV: here, the PHEV would be +32% more expensive than a BEV.

This wide observed range illustrates how TCO optimization depends not only on powertrain choice but also on the matching between vehicle type and driving profile. It also highlights the structural influence of the new vehicle market composition -i.e., the segment-powertrain combinations initially placed on the market-which determines the economic performance of vehicles later available in the used market.

FIGURE 19. TCO, C-Sedan, change during vehicule lifetime

Forecast 2035-2040. New car buyer : high income rural families. 2nd and 3rd-hand buyer : low income rural families.



High income rural families : annua mileage : 18 700 km/year. Low income rural families : 15 400 km/year, 81% short distance.

LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

Figure 20 presents the absolute TCO values for use cases showing the smallest and largest TCO gaps between mid-capacity PHEVs and BEVs. *Note: In the EU, over 2030-2040, a D-SUV PHEV mid-capacity battery purchased 3rd hand by a low-income rural family with children would have a total cost +35% higher than an equivalent BEV, all other factors being equal.*

2.3. Impact of biofuel use

A theoretical scenario was also tested, assuming that vehicles equipped with combustion engines would run exclusively on biofuels (E85 type) instead of gasoline. The price of these biofuels was estimated to be about €1/l higher than that of gasoline, taking into account their higher production costs, the end of public support schemes, and tax rates equivalent to those applied to gasoline per liter of fuel.[44]

The forward-looking analysis conducted in this study shows that, by 2030-2040, replacing fossil fuels with biofuels would lead to a sharp increase in the TCO of Plug-in Hybrid Electric Vehicles (PHEVs) and Range-Extended Electric Vehicles (EREVs), further widening the gap with Battery Electric Vehicles (BEVs) across all use cases considered.

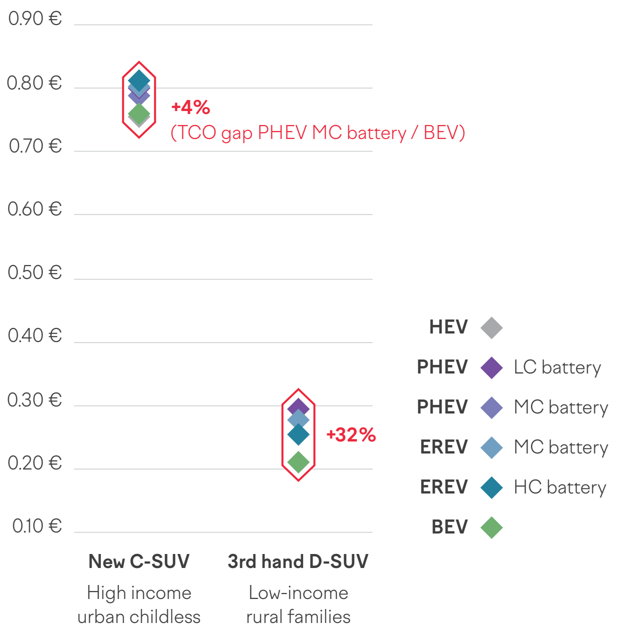
For **new purchased vehicles,** on average, **new PHEVs with mid-capacity batteries** would have a TCO (€/km over the ownership period) that is **+14% higher than BEVs**, across all segments and use cases (+7% without biofuels). Depending on the segment and use case, this gap would range from +10% (for a C-Sedan used by a corporate fleet for intensive urban use) to +43% (for a D-SUV used by a corporate fleet for intensive long-distance use). This average additional cost would be equivalent to an increase of about €1.22/l in the gasoline price for a 2025 combustion vehicle (vs. €0.64/l without biofuels).

On average, **new EREVs with high-capacity batteries** would have a TCO that is **+13% higher than BEVs** (+8% without biofuels). This would correspond to an equivalent fuel price increase of around €1.15/l for a 2025 combustion vehicle (vs. €0.67/l without biofuels).

For **3rd hand vehicles:** On average, **PHEVs with mid-capacity batteries** purchased 3rd hand would have a TCO that is **+29% higher than BEVs** (+18% without biofuels). Depending on the segment and use case, this gap would range from +22% (for a D-SUV used by a low-income rural childless household) to +45% (for a D-SUV used by a low-income rural family with children). This average cost difference would be equivalent to an increase of about €1.49/l in the gasoline price for a 2025 combustion vehicle (vs. €0.92/l without biofuels).

FIGURE 20. TCO (€/km) according to buyer profile

Forecast 2035-2040



LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

On average, **EREVs with high-capacity batteries** purchased 3rd hand would have a TCO that is **+27% higher than BEVs** (+18% without biofuels). This would correspond to an equivalent fuel price increase of approximately €1.40/l for a 2025 combustion vehicle (vs. €0.94/l without biofuels).

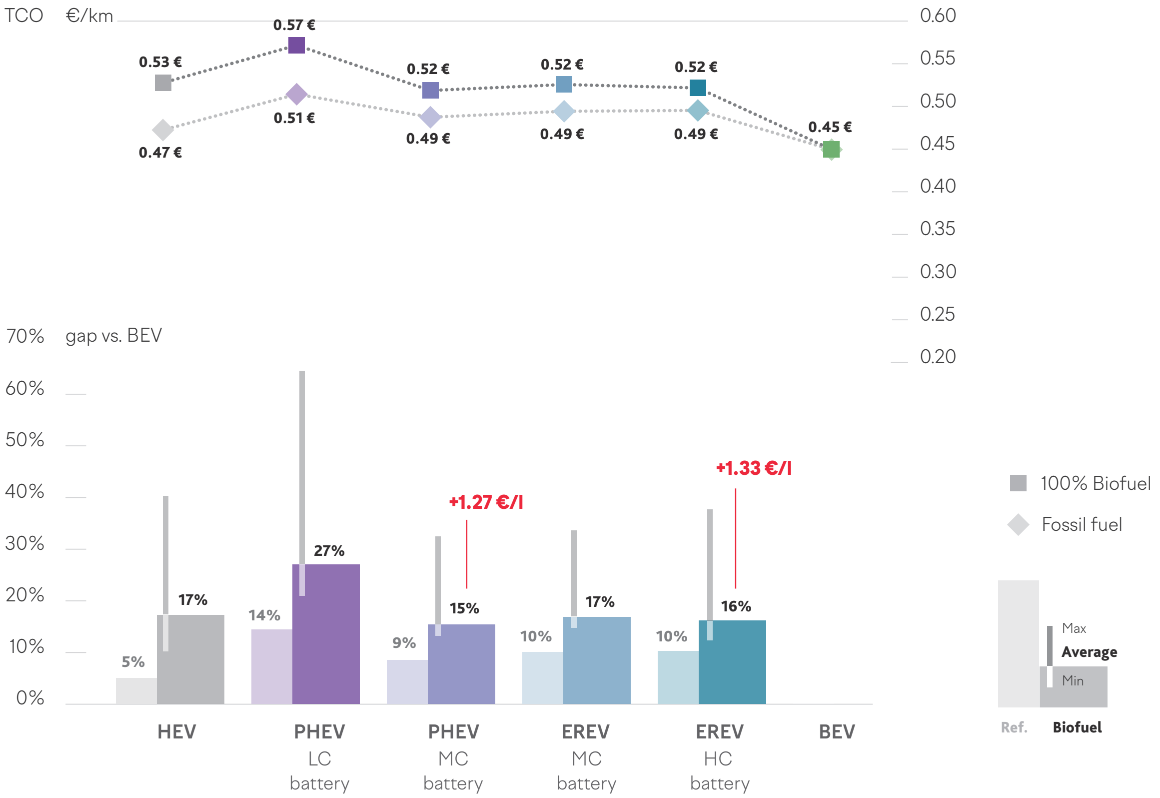
For other powertrains studied: In this biofuel-only scenario, HEVs and EREVs with mid-capacity batteries would show a slightly higher TCO than mid-capacity PHEVs, both for new vehicles (+16% on average) and for 3rd hand vehicles (+38% and +32%, respectively).

In contrast, PHEVs with low-capacity batteries would have the highest TCO among all powertrains analyzed (+22% for new purchases, +43% for used vehicles).

44 Further details are provided in the Methodology section.

FIGURE 21.a TCO, all B-SUV average, with and without biofuel, new car buyer

Forecast 2035-2040. Average TCO emissions weighted by actual travel profile of user categories according to their representativeness.

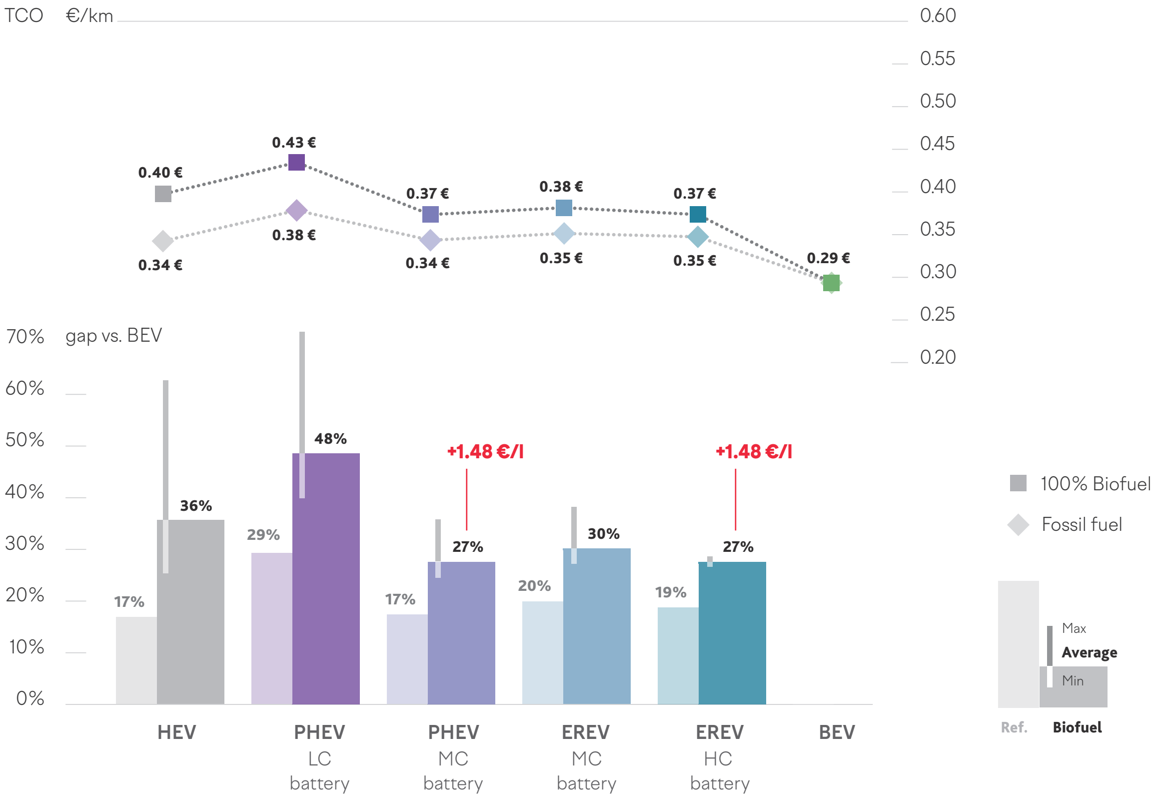


Biofuel is considered at 2,8 €/L (without government incentive and assuming fuel taxation €/L equivalent to current petrol taxes).
Min-max TCO gap/BEV among all use case. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.
LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

Figures 21.a and **21.b** below illustrate the TCO, the TCO gap compared with BEVs, and the TCO expressed as an equivalent increase in the price of gasoline, for B-SUVs purchased new and as 3rd hand vehicles. *Note: In the EU, over 2030-2040, a B-SUV PHEV mid-capacity battery purchased new and running 100% on biofuels would have an average total cost of €0.52/km, i.e. +15% higher than an equivalent BEV—corresponding to an equivalent fuel price increase of +€1.27/l for a 2025 combustion vehicle. This total cost gap would range from +13% to +32%, depending on the use case.*

FIGURE 21.b **TCO, all B-SUV average, with and without biofuel, 3rd-hand buyer**

Forecast 2035-2040. Average TCO emissions weighted by actual travel profile of user categories according to their representativeness.



Biofuel is considered at 2,8 €/L (without government incentive and assuming fuel taxation €/L equivalent to current petrol taxes).
Min-max TCO gap/BEV among all use case. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.

LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

2.4. Impact of electricity price variation

Electricity prices vary significantly across EU member states, ranging from €0.10/kWh (Hungary) to €0.39/kWh (Germany) in the second half of 2024.[45] To illustrate this variability, two additional scenarios were analyzed: one assuming an electricity price half the EU average (€0.10/kWh), and another assuming an electricity price twice the EU average (€0.40/kWh). The cost of fast charging follows the same proportional change. These scenarios are deliberately conservative, as they do not account for the expected decline in electricity prices driven by the increasing share of wind and solar generation in countries such as Germany, where electricity production still relies heavily on coal and fossil gas, which are more expensive.

Nevertheless, even assuming an electricity price twice the EU average, the 2030-2040 projections show that the TCO of PHEVs and EREVs remains at best equivalent to BEVs for new car buyers, and higher for used car buyers.

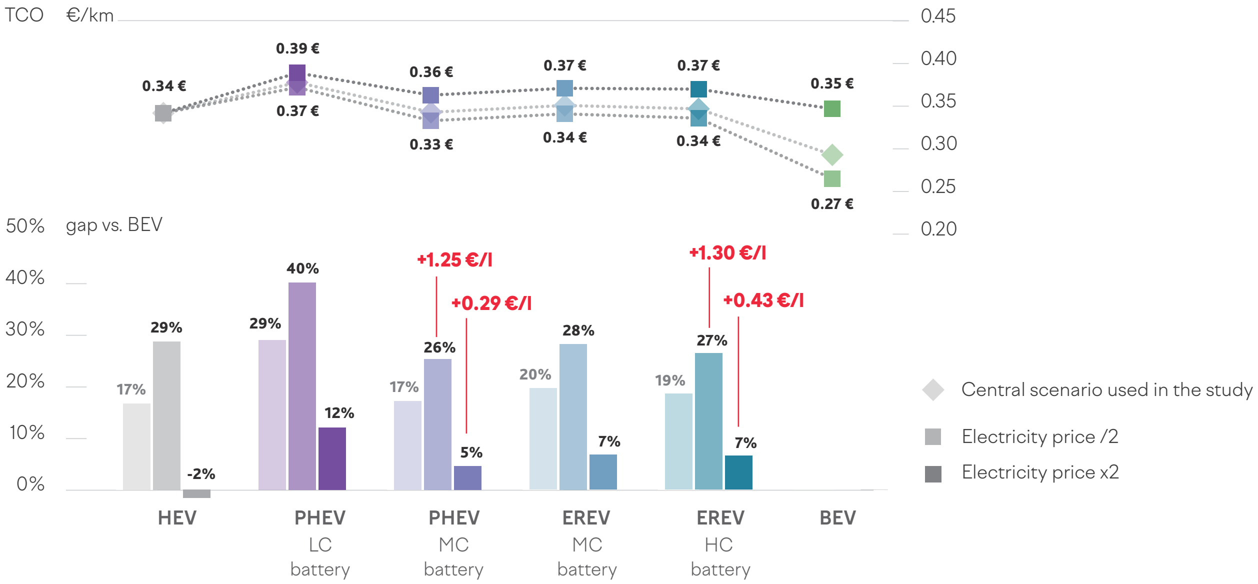
On average, **new PHEVs with mid-capacity batteries** would have a TCO (€/km over the ownership period) **equivalent to BEVs**, across all segments and use cases (vs. +7% with the reference EU electricity price). Across the segment and use case, the gap would vary greatly depending on the share of long-distance travel. PHEVs used by profiles with a high share of long distance trips would result in a lower TCO than BEVs, due to the very high cost of fast charging (€1.20/kWh), which makes long-distance trips more expensive in electric mode than in combustion mode.

On average, **PHEVs with mid-capacity batteries purchased 3rd hand** would have a TCO **+5% higher than BEVs** (vs. +18% under the reference EU electricity price). For used car buyers, the number of use cases where certain PHEV configurations perform better than BEVs decreases sharply. This average cost gap would

45 EUROSTAT. (2025). COMEXT. Electricity price by partner country. [available online]

FIGURE 22.a **TCO, all B-SUV average, sensibility to electricity prices, 3rd-hand buyer**

Forecast 2035-2040. Average TCO emissions weighted by actual travel profile of user categories according to their representativeness.



Min-max TCO gap/BEV among all use case. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.
LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

correspond to an equivalent gasoline price increase of +€0.30/l for a 2025 combustion vehicle (vs. +€0.92/l under the reference scenario). In this configuration, PHEVs with low-capacity batteries and EREVs would show TCO gaps similar to mid-capacity PHEVs, while HEVs would have a lower TCO than BEVs for new buyers (-6%) and an equivalent TCO for 3rd hand buyers.

Conversely, assuming an electricity price half the EU average, the 2030-2040 projections show that the TCO gap between PHEVs, EREVs, and BEVs would widen sharply across all use cases. On average, new PHEVs with mid-capacity batteries would have a TCO +13% higher than BEVs (vs. +7% under the reference electricity price).

For used car buyers, the TCO gap for mid-capacity PHEVs would rise to +26% (vs. +17% under the reference price).

Figure 22.a shows the TCO and the TCO gap relative to BEVs for different electricity price scenarios for a B-SUV. *Note: In the EU, over 2030-2040, a B-SUV PHEV mid-capacity battery purchased 3rd hand and charged with electricity costing €0.40/kWh for home charging would have an average total cost of €0.36/km, i.e. +5% higher than an equivalent BEV, compared with +17% under the reference electricity price scenario (twice cheaper)—equivalent to a fuel price increase of +€0.29/l for a 2025 combustion vehicle.*

2.5. Impact of oil and battery material price variations

Future oil price projections remain highly uncertain, due to both regulatory developments (notably the implementation of the ETS2, which will likely increase fuel costs) and the growing scarcity and extraction cost of oil resources, which could, in turn, also raise electricity prices.

Assuming a **+20% increase in oil prices**, similar to the rise observed between 2019-2024, the 2030-2040 projections show that the TCO gap between PHEVs, EREVs, and BEVs would widen by about 3 percentage points on average, on average, **new PHEVs with mid-capacity batteries** would have a TCO **+10% higher than BEVs** (vs. +7% in the baseline fuel price scenario).

This average cost gap would correspond to a gasoline price increase of about +€0.84/l for a 2025 combustion vehicle (vs. +€0.64/l in the baseline scenario).

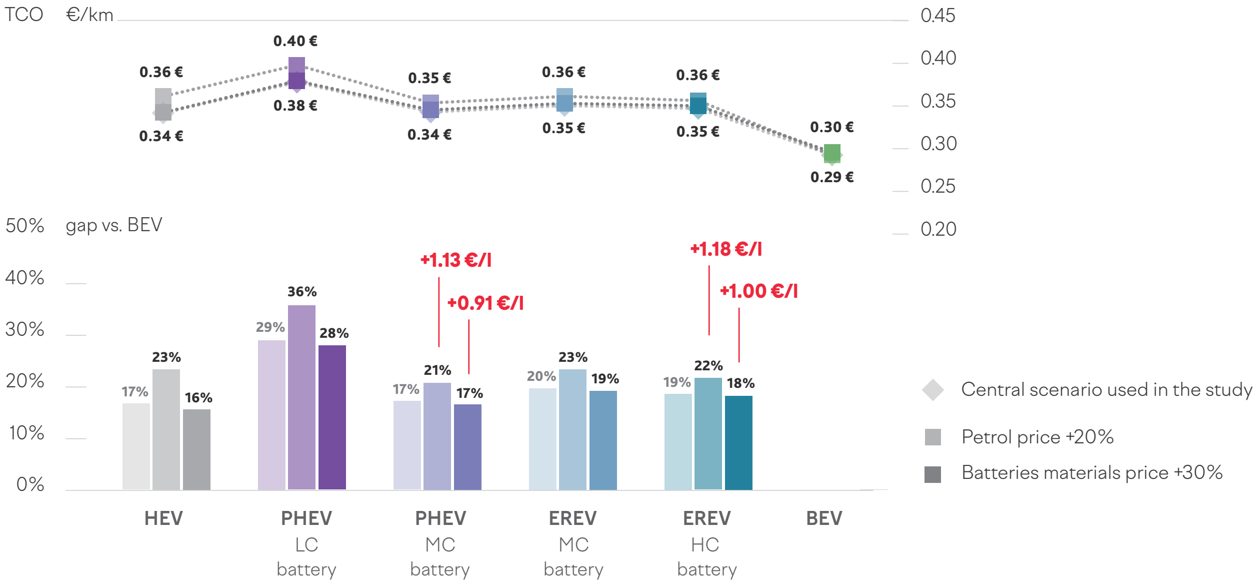
For **used car buyers, mid-capacity PHEVs** would show a TCO **+22% higher than BEVs** (vs. +17% in the baseline scenario), equivalent to a fuel price increase of +€1.12/l (vs. +€0.92/l).

Similarly, the future price of batteries will depend largely on future variations in raw materials prices. Assuming that raw materials account for 63% of the total cost of NMC batteries produced in the EU,[46] and that

46 Knehr, K., Kubal, J., & Anl. (2024). *EV Costs 2024 for GPRA reporting.* Argonne National Laboratory. [available online]

FIGURE 22.b TCO, all B-SUV average, sensibility to oil and batteries materials prices, 3rd-hand buyer

Forecast 2035-2040. Average TCO emissions weighted by actual travel profile of user categories according to their representativeness.



Fuel price: from €1.79/L → €2.16/L. Batteries materials price: +30%, assuming material prix eq. 63% batteries price.
Min-max TCO gap/BEV among all use case. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.
LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

raw material prices increase by +30%, the 2030-2040 projections show that the TCO gap between PHEVs, EREVs, and BEVs would narrow slightly-by **about 1 percentage point on average**, but BEVs would still retain a lower TCO in all use cases, On average, **new mid-capacity PHEVs** would have a TCO **+6% higher than BEVs** (vs. +7% in the baseline battery price scenario), equivalent to a gasoline price increase of +€0.57/l (vs. +€0.64/l).

For **used car buyers**, the TCO gap would remain **+17%**, equivalent to +€0.90/l (vs. +€0.92/l).

Figure 22.b illustrates the TCO and the TCO gap relative to BEVs under these different oil and battery material price scenarios for a B-SUV. *Note: In the EU, over 2030-2040, a B-SUV PHEV with a mid-capacity battery purchased 3rd hand and running on gasoline priced +20% higher than in the reference scenario would have an average total cost of €0.35/km, i.e. +21% higher than an equivalent BEV, compared with +17% under the reference fuel price—equivalent to a fuel price increase of +€1.13/l for a 2025 combustion vehicle.*

2.6. Tightening budget constraints and growing inequality: the risk of a two-speed transition

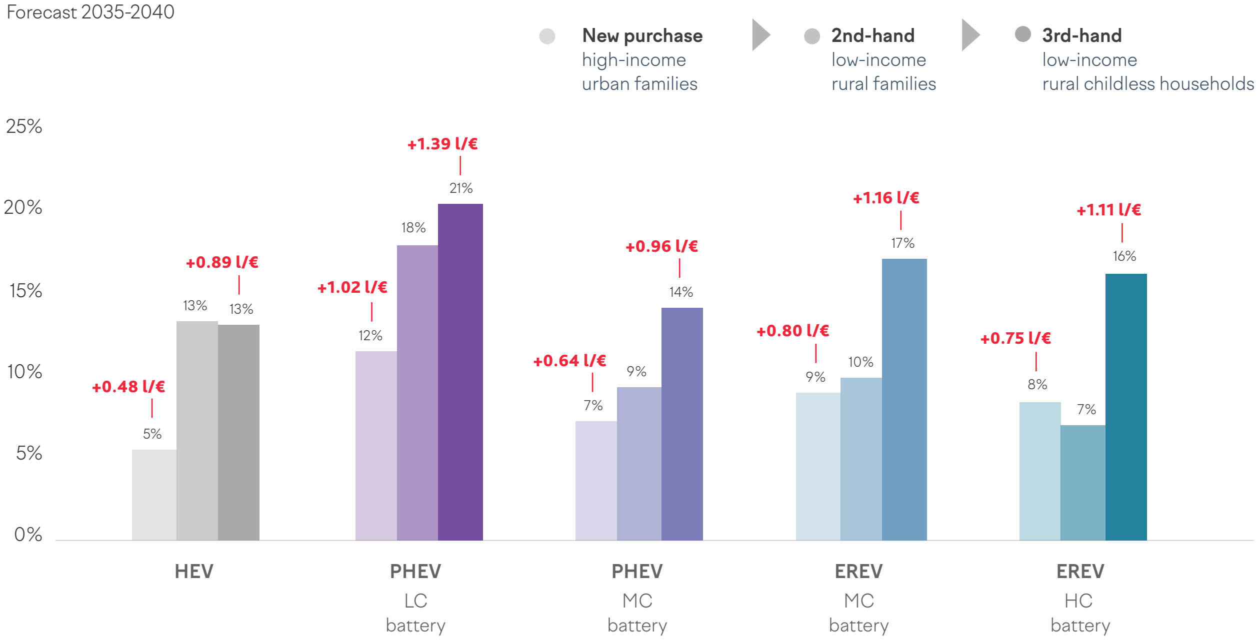
Allowing regulatory flexibilities after 2035, such as the continued sale of PHEVs or EREVs, would widen socio-economic inequalities in access to mobility and, in the long term, weaken overall vehicle demand, which has already been declining since 2019, thereby exacerbating the market difficulties reported by car manufacturers.

This study shows that the TCO gap between BEVs and PHEVs/EREVs widens sharply with each resale: for a mid-capacity PHEV, it is on average multiplied by 2.5 between the first and third owners. Yet, the older a vehicle becomes, the more its buyers fall under the lower-income households category.[47] As a result, the extension of PHEV/EREV sales would have a regressively distributive effect: their higher total ownership costs, which increase with each resale, would disproportionately burden low-income households, who represent the majority of used-car buyers. Importantly, this used-vehicles market already accounts for most annual vehicle transactions

47 As an example, in France, only 25% of new car buyers have an income at or below the median, compared with 48% for used vehicles aged 5 to 10 years and 60% for vehicles aged 10 to 15 years. SDES-INSEE, Car purchases in 2022: fewer combustion powertrains and newer vehicles for higher-income households, March 2024. [available online]

FIGURE 23. Average TCO gap vs. BEV - C-Sedan, example of ownership change during vehicle lifetime

Forecast 2035-2040



Min-max TCO gap/BEV. €/l : TCO gap expressed in terms of equivalent pump price increase for ICE cars in 2025.
LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

in the EU. Therefore, such a shift could also slow fleet renewal, leading to an older average vehicle age and a further drop in new car sales.

Figure 23 illustrates the average evolution of the TCO gap between hybrid and electric drivetrains for a C-segment sedan. *Note: In the EU, over 2030-2040, the cost gap between a C-segment PHEV (mid-capacity battery) and a BEV would increase from +7% for a new car purchased by a high-income, urban household with children, to +14% for a used car purchased by a low-income, rural household without children.*

Beyond the direct impact on TCO, extending PHEV and EREV sales beyond 2035 would deepen social inequalities through an indirect monetary effect. The widening cost gap between BEVs) and hybrid powertrains stems from a shift in expenditure structure for private car owners: a growing share of ownership costs is linked to vehicle use, notably fuel and maintenance.

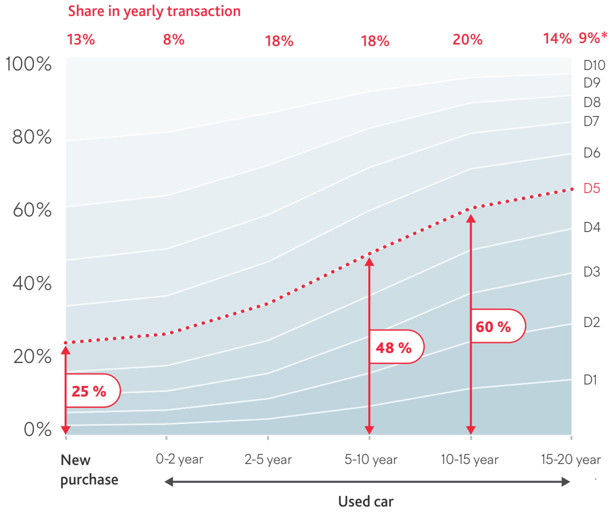
These cost components share two characteristics: they are unavoidable, as they depend on mileage driven, and they are proportionally heavier for lower-income households, whose available income is smaller and dependency on cars greater. As a result, any increase in use costs produces a regressive effect: the additional financial burden represents a larger share of income for low-income households than for wealthier ones.

This dynamic particularly affects peri-urban and rural households, where the lack of alternative transport options amplifies car dependency. Consequently, even a marginal rise in usage costs further widens living conditions disparities across socio-economic and geographic groups.

Finally, the technological complexity associated with dual powertrains, especially in PHEVs, exposes these vehicles to a higher risk of malfunction and maintenance needs. This is especially true for second- and third-hand users, since new-car buyers are generally protected by warranty coverage. In practice, repair and servicing costs would fall disproportionately on lower-income users, further reinforcing inequalities in access to affordable mobility.

FIGURE 24. Share of vehicle purchases by income

Share of vehicle purchases by equivalised disposable income decile and vehicle age in France - 2022

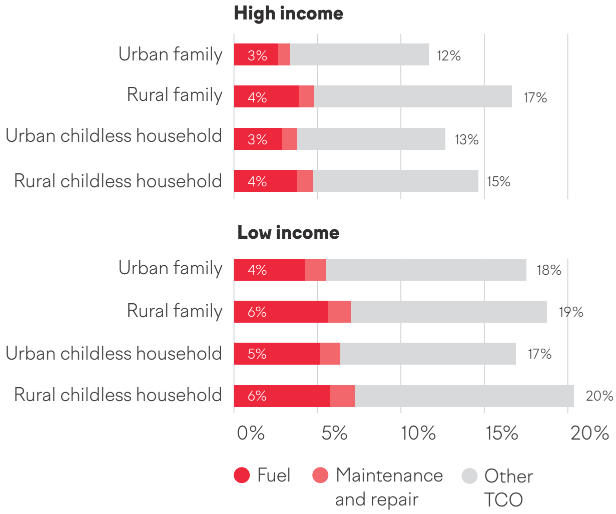


* Share of vehicles over 20 years old in total transactions.

SDES-INSEE, Rsvero, Fidéli, 2022. Data processing by IMT.

FIGURE 25. Share of car-related expenses in household budgets

Share of disposable income by use case, empirical.



Clustering based on the Enquête Budget de Famille in France (INSEE, 2017) for households owning at least one vehicle less than 28 years old and actively using it/them.
All engine types included. Excluding coporate fleet vehicles.

BOX 5. FOCUS ON FRANCE

France provides a clear illustration of these dynamics. The distribution of vehicle purchases by income level shows that the lower half of the population is largely absent from the new-car market: they represent only around 25% of new vehicle buyers, compared with 48% of buyers of used vehicles aged 5-10 years, and 60% of buyers of vehicles aged 10-15 years.

This progression highlights how lower-income households become increasingly dominant in the used-car market as vehicles age, confirming that the additional costs associated with less efficient powertrains (such as PHEVs and EREVs) would disproportionately affect the lowest income brackets.

Figure 24 shows, for France, the distribution of vehicle purchases by income decile and vehicle age. *Note: the poorest 50% of French households (deciles D1 to D5) account for 25% of new vehicle purchases, compared with 48% of purchases of used vehicles aged 5-10 years.*

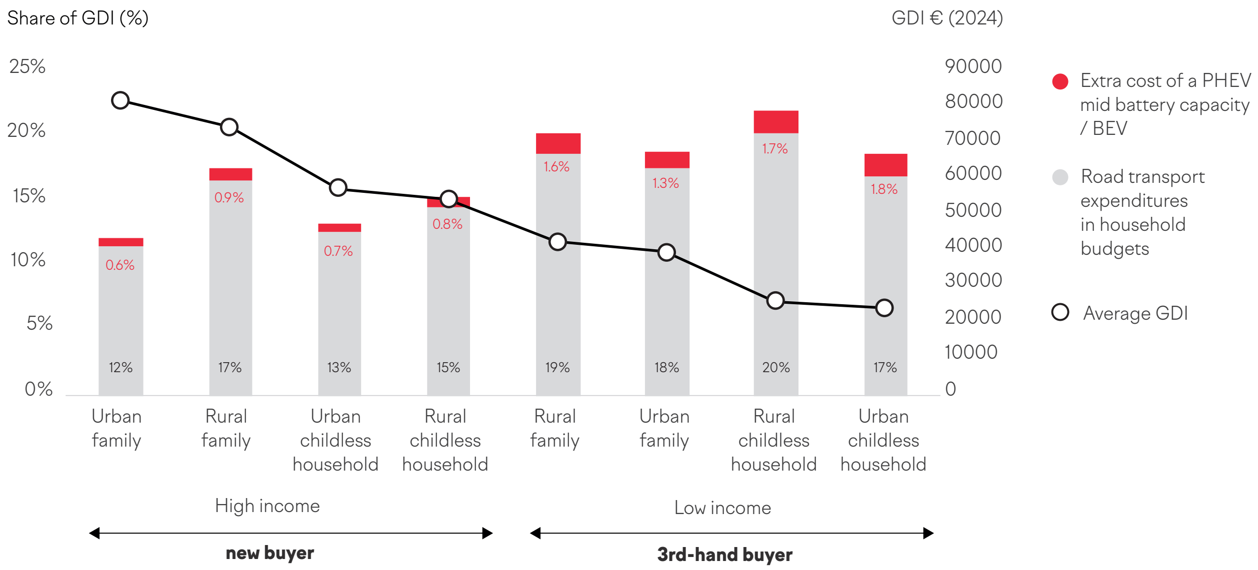
The analysis of automotive budget allocation across the user profiles defined in this study highlights two main findings. First, the share of household expenditure devoted to cars is inversely proportional to income level: the lower a household's total budget, the greater the burden of car-related expenses. Second, this relationship is equally evident when focusing specifically on fuel and maintenance costs, which already represent the most constraining expenditure items for low-income households.

Figure 25 illustrates the share of each household's budget devoted to road transport-related expenses, as well as their breakdown by category. *Note: High-income urban households with children spend on average 3% of their total budget on fuel for their vehicles.*

Finally, the comparison of the additional cost associated with owning a mid-range battery PHEV (B-SUV segment) versus a BEV confirms that this difference would weigh proportionally more on low-income households.

FIGURE 26. Additional anual cost of owning PHEV mid-battery capacity vs. BEV

Forecast 2035-2040. Share of the annual average gross disposable income (GDI) by driving pattern, B-SUV



Additional cost of PHEV is a forecast for 2030-2040.
Disposable income by cluster is estimated from the Enquête Budget de famille (INSEE, 2017) for France, inflation adjusted, clustered on households owning and actively using at least one vehicle under 28 years old (all engine types), excluding corporate fleets. Curve reflects relative trends across clusters.

When related to the average disposable income of different household types in France, this additional cost would represent around 1% of income for the wealthiest households, compared with 2% for lower-income households. Yet, the latter already devote a larger share of their resources to owning and using their vehicles. This relative increase would therefore intensify the financial pressure on the already most constrained households and widen the gap in automotive purchasing power between social categories.

Figure 26 shows the share of each household's budget lost when using a B-SUV PHEV with a medium-capacity battery instead of a less expensive BEV, compared both to the household's total budget and to the share of that budget currently devoted to road mobility. *Note: High-income urban households with children currently spend around 12% of their budget on road mobility. Using, in 2030-2040, a mid-range battery B-SUV PHEV purchased new instead of a BEV would result in an additional cost equivalent to +0.6 percentage points of their household budget.*

KEY MESSAGES

- The forward-looking analysis conducted in this study highlights that by 2030-2040, within the European Union:
- The **TCO of PHEVs and EREVs remains higher than that of BEVs across all use cases** examined. The gap is particularly signficant for 3rd hand buyers, with a TCO on average 2.5 times higher than for a new car buyer.
- On average, a **PHEV** mid-capacity battery entails a **TCO that is +8% higher than that of a BEV for a new car buyer, and +18% higher for a 3rd hand buyer** (ranging from +14% to +29%), across all vehicle segments and use cases.
- This additional cost corresponds, in comparable terms, to an increase in petrol prices for an ICE vehicle in 2025 of around **+€0.64/l for a new car and +€0.92/l for a 3rd hand vehicle**—that is, an impact 2 to 3 times greater than the fuel price inflation observed during the 2022 energy crisis.
- EREVs high-capacity battery models show a TCO similar to that of PHEVs mid-capacity battery.
- This projection mainly relies on a reasonable decline in battery prices, a lower per-kilometre electricity cost compared to fossil fuels, and reduced maintenance costs—which are the main competitive advantages of EVs from the first ownership onward, and even more so for 3rd hand buyers. These results are obtained despite conservative assumptions favourable to ICE vehicles, including identical manufacturer margins across powertrains and the discontinuation of public subsidies for electric vehicles.
  In the theoretical scenario of a 100% biofuel supply, the emissions gap between PHEV mid-capacity battery and EVs would narrow but remain significant (+23%). Conversely, the TCO gap between PHEVs/EREVs and EVs would increase substantially: +14% on average (equivalent to +€1.22/l) for new car buyers and +29% on average (equivalent to +€1.49/l) for 3rd hand buyers, due to higher production costs of biofuels compared to fossil fuels.

3. OTHER COMPARATIVE ELEMENTS

This impact assessment shows that authorizing the sale of plug-in hybrid vehicles (PHEVs) and electric vehicles equipped with a range extender using an auxiliary combustion engine (EREVs) after 2035—whether or not subject to a blending requirement—would bring no economic or climate benefits compared to the battery electric vehicles (EVs) available by that time.

Nevertheless, other factors may come into play, particularly the actual or perceived comfort offered by these different powertrains. Improved comfort, whether real or perceived, could constitute—especially for corporate fleets (seeking to reassure employees skeptical about EVs) or for high-income households making intensive use of their vehicles—a motivation to purchase PHEVs or EREVs, even if this entails higher costs and additional environmental impacts compared to an equivalent EV.

To assess this hypothesis, several comfort-related indicators were compared for vehicles expected to be sold over the 2035-2040 period. The analysis is based on the same segmentation and conservative performance assumptions as in the previous section. It focuses in particular on real-world battery performance and capacity, namely: electricity consumption per kilometre actually observed on the road (rather than regulatory values reported by manufacturers), and an effective usable capacity corresponding to 80% of the total battery capacity, to reflect the fact that a battery is neither fully charged nor fully discharged in order to prevent premature wear.[48]

3.1. Range

The projection for the 2035-2040 period shows that, for equivalent vehicle segments, the real-world driving range of PHEVs and EREVs will remain two to three times higher than that of EVs.

Nevertheless, all vehicles concerned—including A-segment electric vehicles—will offer a real-world range largely sufficient to cover all daily trips (<100 km) without recharging. This covers the vast majority of total distances driven: in France, 70% of kilometres driven by passenger car are associated with trips shorter than 80 km.[49]

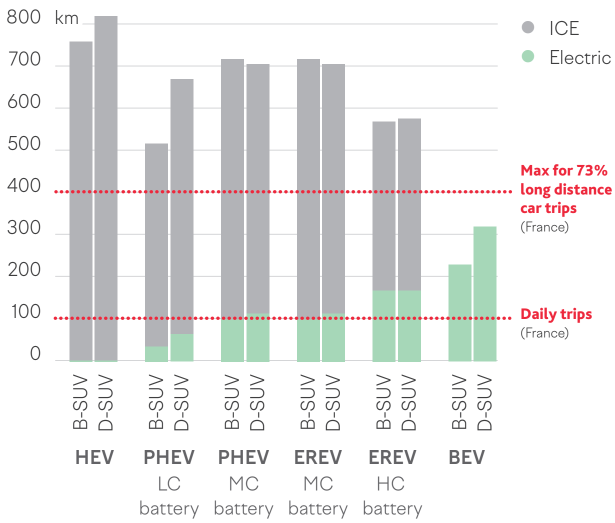
All B-segment sedan and higher-segment electric vehicles will have sufficient range to cover at least 400 km with a full charge, which corresponds to 73% of all long-distance trips—and the entirety of short, daily trips.

48 Further details can be found in the Methodology section.

49 Ministère de la Transition écologique et de la Cohésion des territoires. Local and long-distance mobility of the French population – National travel survey 2019, April 2023 [available online]

FIGURE 27. Autonomy

Forecast 2035-2040



Real autonomy, considering real-world consumption and net battery capacity.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

Importantly, the additional time required to recharge an EV during a long-distance journey (a maximum of 30 minutes) corresponds to the break time recommended for road safety. Moreover, over the course of a year, this "lost" time on long-distance trips is offset by the time saved thanks to home charging, whereas PHEVs and EREVs still require refuelling at petrol stations, often located away from home.

Conversely, the shorter electric range of PHEVs and EREVs means that users need to recharge their batteries more frequently—two to three times more often than EV drivers—if they wish to cover their daily trips in electric mode (which remains the cheapest option). The supposed "advantage" of reduced charging constraints for long-distance travel must therefore be put into perspective, given the higher charging frequency required for daily use. Once again, the trade-offs offered by plug-in hybrids is more favourable to users who frequently drive long distances—corresponding, in the use case clusters considered here, to higher-income households (holiday trips, second homes, etc.).

Figure 27 compares the projected 2035-2040 range of the different powertrains for B-SUV and D-SUV segments. *Note: In the EU, in 2035-2040, a B-SUV HEV would have a real-world range of 756 km in combustion mode, versus 3 km in electric mode.*

3.2. Battery ageing

The projection for the 2035-2040 period, based on a vehicle lifetime of 200,000 kilometres, shows that the number of battery charge/discharge cycles can be up to four times higher for PHEVs/EREVs than for EVs over the full vehicle lifespan.

For B-SUVs, the number of charge/discharge cycles for PHEVs mid-capacity battery would on average be +159% higher than for EVs, and +28% higher for EREVs high-capacity battery. This ratio would vary across use cases, but at most, electric vehicle batteries would undergo around 900 charge/discharge cycles over their lifetime, compared to an average of 2,300 for PHEVs mid-capacity battery and 1,100 for EREVs high-capacity battery.

All else being equal, the batteries of PHEVs and EREVs would therefore be more heavily used than those of EVs by new car buyers, potentially accelerating the battery ageing that can be attributed to charge/discharge cycling. While current and future batteries are robust enough to maintain performance over such a number of cycles, this nevertheless implies a lower state of health (SoH) for PHEV and EREV batteries compared to EVs. This could lead to a gradual loss of range (not accounted for in this study), progressively increasing energy consumption—and thus GHG emissions and TCO—for PHEV/EREV users. In practice, low-income households (2nd hand buyers and 3rd hand buyers) would bear most of the risks associated with battery ageing.

Figure 28 compares, over the vehicle's lifetime, the number of charge/discharge cycles for each powertrain and use case for a B-SUV. *Note: In the EU, in 2035-2040, a PHEV low-capacity battery used by a Corporate fleet for intensive urban use would need to be recharged around 4,000 times over its lifetime.*

Allowing the sale of PHEVs and EREVs after 2035 would lead to greater battery usage among New car buyers compared with EVs, thereby increasing financial risks—particularly for used vehicle owners.

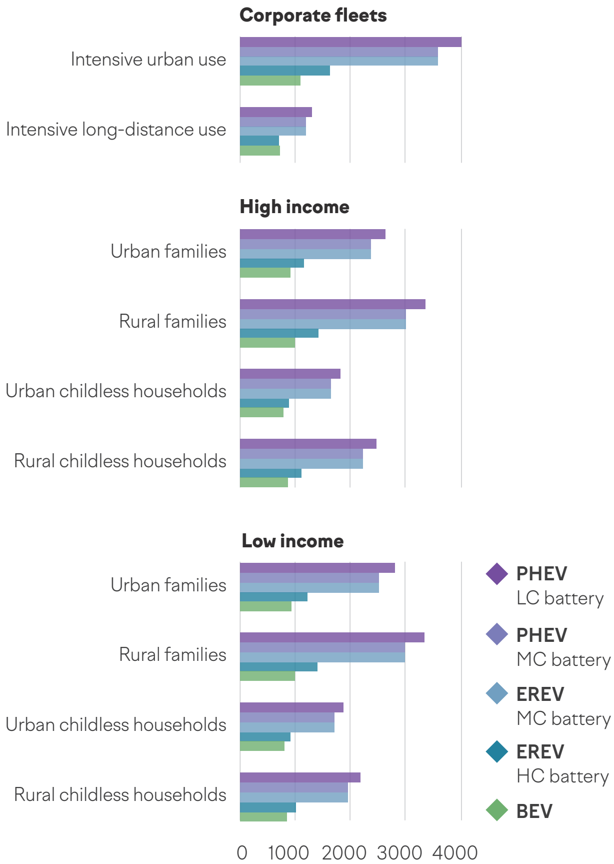
3.3. Trade deficit

The import of oil and vehicle batteries generates an extra-EU trade deficit. The amount of oil and battery imports required per vehicle was estimated under the following assumptions:

- By 2035-2040, 50% of batteries will be produced in Europe, with only 50% of their added value being European;
- Imported batteries will be 20% cheaper than those produced within the EU;

FIGURE 28. Number of charges over B-SUV lifetime

Forecast 2035-2040



Real autonomy, considering real-world consumption and net battery capacity.

LC / MC / HC battery:
Low Capacity / Medium Capacity / High Capacity battery.

- 63% of battery costs will be associated with imported materials;[50]
- 85% of oil consumed within the EU will continue to be imported from outside the Union;
- Refining results in a 30% loss of imported crude oil;
- All imported crude oil will be refined in Europe.

Under these assumptions, on average, the use of an electric vehicle (EV) would generate an extra-European trade deficit twice as low (-51%) as that of a PHEV or EREV;

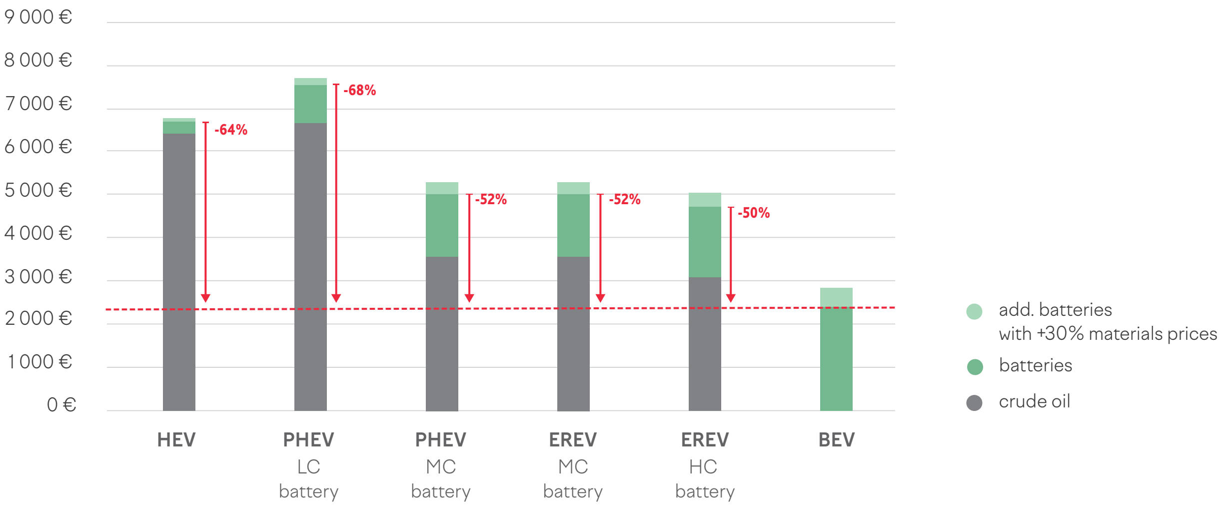
This deficit gap would be even greater when comparing an EV to a hybrid vehicle (HEV), whose associated deficit would be three times higher;

This difference arises from the fact that battery use—even assuming most of the added value remains outside

50 Knehr, K., Kubal, J., & Anl. *EV Costs 2024 for GPRA reporting.* Argonne National Laboratory. 2024. [available online]

FIGURE 29. Average extra-European import costs : crude oil and batteries, B-SUV

Forecast 2035-2040



200,000 km over vehicle lifetime. 50% of batteries are produced in Europe, with 50% of their value-added generated locally.
% reduction in imports when choosing a BEV instead of the given powertrain.
LC battery: Low Capacity battery – MC battery: Medium Capacity battery – HC battery: High Capacity battery.

the EU—combined with European electricity, requires far less extra-EU import value than petroleum;

Even assuming a 30% increase in raw material prices, the use of EVs remains beneficial for the trade balance, reducing the deficit by -44% on average compared with PHEVs or EREVs.

Considering the entire European vehicle fleet (259 million vehicles), the exclusive use of PHEVs mid-capacity battery would result in an annual trade deficit **€41 billion higher** than that of a fleet composed solely of EVs.

Overall, the use of electric vehicles would therefore contribute significantly to reducing the European Union's trade deficit compared with HEVs, PHEVs, or EREVs by 2035-2040.

Figure 29 illustrates the trade deficit linked to battery and crude oil imports over the full vehicle life cycle for each powertrain of a B-SUV. *Reading note: In the EU, in 2035-2040, using a B-SUV PHEV mid-capacity battery would result in an average trade deficit of -€3,566 due to crude oil imports, and -€1,463 due to battery imports over its lifetime. The trade deficit related to battery imports would increase by an additional -€277 if battery material prices rose by +30%.*

KEY MESSAGES

- The forward-looking analysis conducted in this study highlights that by 2035-2040, within the European Union:
- The projected real-world range of PHEVs and EREVs would remain two to three times higher than that of EVs. However, even B-segment sedans in their electric version would cover three-quarters of long-distance trips with at most one recharge (based on real-world performance). The cumulative number of charging cycles would be much higher for PHEV/EREV batteries, leading to faster wear and higher maintenance or replacement costs.
- On average, considering only batteries and oil, the use of a PHEV mid-capacity battery would generate an extra-EU trade deficit twice as high as that of an EV—even assuming that most of the battery's added value remains outside Europe.
- Maintaining the planned trajectory for PHEV utility factors, upholding the ban on the sale of fully or partially combustion-powered vehicles after 2035, while enforcing strict tailpipe emission standards and complementing them with industrial measures (battery regulation, charging infrastructure, sectoral instruments), appears necessary to effectively reduce GHG emissions, avoid increases in total vehicle costs (for both new and used vehicles), and send a stable signal to investors and the electric mobility ecosystem.
- In parallel, European support for the demand for small "Made in Europe" electric vehicles (through social leasing schemes, specific obligations for corporate fleets and public procurement) would be fiscally justified and would help accelerate the development of a broader, faster, and more accessible second-hand market—particularly for low-income and middle-class households.

Plug-in hybrid vehicles and the 2035 objective: analysis of the socio-economic and climate impacts of a prolonged authorization of sales in the name of 'technological neutrality'

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Addendum, 25 November 2025

This version of the report incorporates an additional methodological note concerning the identification of travel patterns specific to the B-SUV segment and above (p. 9).

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