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What is the real impact, strictly in terms of climate issues, of policies for the accelerated conversion of the internal combustion engine fleet to electric vehicles?

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Low-Emission Zones (LEZs) were conceived and designed to address health issues. One effect of implementing these zones is to accelerate the replacement of older internal combustion engine (ICE) vehicles with more modern versions or with electric vehicles (EVs). Would an accelerated conversion of the fleet, brought about by such a scheme or by measures such as "social leasing", be appropriate in terms of reducing greenhouse gas emissions? When factoring in production impacts, should we not consider extending the lifespan of existing ICE vehicles for as long as possible? This issue is often raised in debates by those who question the relevance of LEZs or the push for vehicle electrification. This Issue Brief attempts to answer these questions?

KEY MESSAGES

Extending the life of an ICE vehicle only marginally reduces greenhouse gas emissions per additional kilometre travelled, because fossil fuel use (the unavoidable part of emissions) accounts for more than 70% of the impact over the entire life cycle of these products.

Extending the life of an EV, conversely, is a major way of reducing greenhouse gas emissions. Encouraging long lifespans for this vehicle type must be the subject of proactive public policy (regulations on battery durability, currently under discussion at the European level, are an important priority in this perspective).

When buying a new vehicle, the most environmentally-friendly option for an owner in terms of the lowest greenhouse gas emissions is to replace an ICE vehicle with an electric one as soon as possible (accounting for the impact of vehicle manufacture and assuming that the ICE vehicle could be driven for four more years).

Extending the lifespan of an ICE vehicles can only be envisaged for low mileage drivers and on the condition that they switch to electric when the vehicle is eventually renewed. Buying a new, more fuel-efficient ICE vehicle to replace an old one, and then keeping it for 18 years (the average lifespan of vehicles in France) represents the worst option in terms of greenhouse gas emissions.

This analysis is an initial response that could be supplemented by a study of environmental indicators in addition to global warming potential: depletion of mineral resources, impact of mining activities, water consumption, etc. Furthermore, the model scenarios intentionally do not consider transport demand, vehicle size or vehicle efficiency, even though action must be taken on all these fronts, because they are undoubtedly intrinsic for the success of the transition.

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1. INTRODUCTION AND METHODOLOGY

Low Emission Zones (LEZ)[1, 2] will gradually restrict the circulation of the oldest ICE vehicles in France, leading to an accelerated renewal of the fleet (through the early replacement of certain vehicles). EVs, a key component of this major territorial challenge, are one of the technological options favoured by governments because they address both the challenges of air quality as well as decarbonization. For this reason, EVs are at the heart of French public policy and under certain conditions buyers are eligible for a purchase incentive (ecological grant) as well as a grant for replacing old vehicles (conversion subsidy), and even sometimes an additional LEZ subsidy. Given the financial incentives, the environmental merits of encouraging the replacement of ICE vehicles with EVs, perceived by some as encouraging consumerism, is a hot topic for debate. This Issue Brief examines the environmental objectification for replacing ICE vehicles with EVs, and also looks at the associated underlying conditions, in a context of relatively new expertise presented in the scientific literature.

The starting point for the method adopted was to consider the ownership of a typical vehicle, one that is representative of a vehicle in the fleet that is affected by an LEZ. For our study we adopted the position of someone in possession of a very old vehicle with a lifespan of three to four more years. We carried out a comparative analysis, in terms of scope and dynamics, of the impact of several scenarios for vehicle replacement, strictly in terms of greenhouse gas emissions. Different technical possibilities and methods for replacing the vehicle were modelled. The analysis accounts for all impacts generated during the vehicle's life cycle, and adds a time dimension to address questions about extending the life cycle of high emitting vehicles, as well as the impacts of production generated by the greater consumption of raw materials due to accelerated vehicle replacement. The results indicate that the early replacement of an old ICE vehicle by a new EV, in addition to significant local benefits in terms of air quality, is also more efficient in terms of greenhouse gas emissions in all normal use scenarios over several years.

2. EXTENDING A VEHICLE'S LIFESPAN: A DIFFERENT RESPONSE FOR EACH ENGINE TYPE

The ICE vehicle has a unique characteristic in that its operation requires large quantities of fossil fuel energy. In 2022, the 39.7 million privately-owned ICE vehicles in France consumed an average of 625 litres of fossil fuels, after deducting the proportion of biofuel consumed. This means that around 45.5 billion litres of 100% fossil fuels were used to power the vehicle fleet in 2022. The combustion of this fuel accounts for more than 70% of greenhouse gas emissions from these vehicles over their entire life cycle. This is shown in **Figure 1** for the Renault Clio V petrol model, which has life cycle emissions of around 200gCO_2e/km.

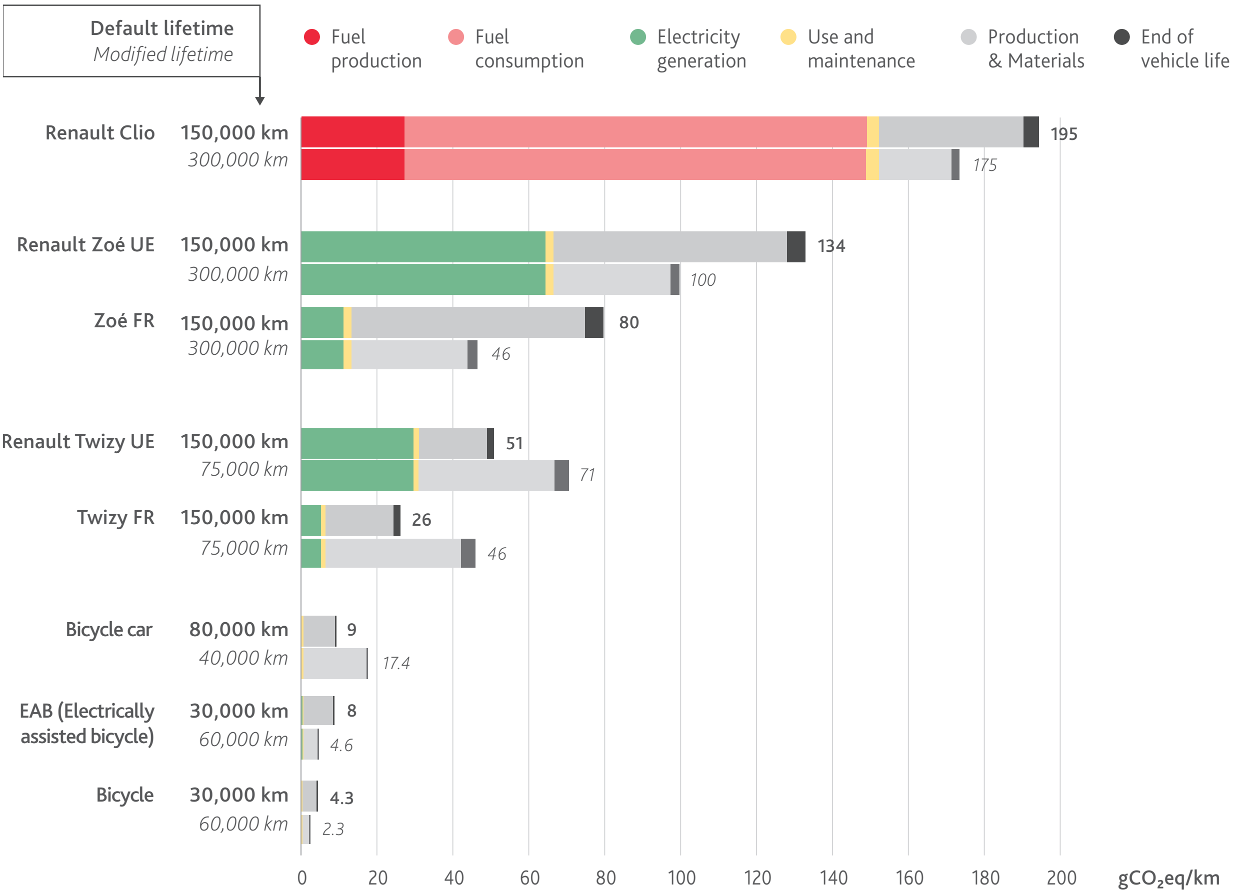
Logically, extending the lifespan of a fleet of ICE vehicles means that fossil fuel consumption will continue in proportion to the additional kilometres driven. Figure 1 shows that extending the life of this particular Renault Clio from 150,000 to 300,000 km will reduce its impact per kilometre driven by 10%, at best.

The analysis shows a highly differentiated and much more favourable situation for EVs represented in the figure by the Renault Zoé. It appears that electric motors are more sensitive to lifespan and total mileage over the life cycle, with a potential carbon emission reduction of 25%, all things being equal within the European Union, for the same use extension, despite a much larger carbon footprint during the vehicle production phase (which is accounted for in the calculations shown). The graph also shows the results for two distinct geographical scales: France and the European Union, two fields of study in which the carbon footprint of EVs is clearly favourable.

1 https://www.iddri.org/en/publications-and-events/report/successfully-implementing-low-emission-mobility-zones-businesses

2 https://www.iddri.org/en/publications-and-events/blog-post/implementing-low-emission-mobility-zones-it-possible-under

FIGURE 1. Carbon impact per kilometre over entire life cycle



Source: LPG Conseil, based on data from: Groupe Renault, Trek Bicycle Corporation, ADEME, GREET Model - Year 2021

3. ASSESSMENTS OF CARBON FOOTPRINT REDUCTIONS MUST ACCOUNT FOR VEHICLE REPLACEMENT METHODS AND CONSIDER A MEDIUM TO LONG-TERM TIMEFRAME

As discussed above, extending the life of an ICE vehicle decreases the margin of opportunity in terms of reducing greenhouse gas emissions per kilometre travelled. However, the leverage provided by extending the life of an ICE vehicle can only be assessed by calculating the benefits provided by the alternatives with which it could be replaced. Therefore, the graphical presentation of cumulative CO_2 emissions linked to vehicle replacement trends is a valuable exercise. Figure 2 illustrates several ownership pathways for an individual owner who needs to replace an old vehicle.

The following variables have been included (and their impacts highlighted in six scenarios):

— Renewal timing
— Replacement vehicle fuel type
— Size of replacement vehicle - by default, all vehicles are B-segment (multi-purpose city cars)
— Possibility of changing to a new or used vehicle

Three key messages from the simulation:

— Of the ownership scenarios modelled, the one that emits the least greenhouse gases involves replacing an ICE vehicle, ahead of schedule, with an electric one (taking into account the impact of vehicle manufacture and considering that the ICE car could have been driven for four more years).
— Extending the lifespan of an ICE vehicle can only be envisaged if the vehicle is changed for an EV when it is ultimately replaced. The purchase of a new low-consumption ICE vehicle to replace an old one is the worst-case scenario.
— The difference in emissions between an ICE vehicle and an EV will only increase structurally over time due to: the maximum potential for the efficiency of ICE vehicles; the expected decarbonization of the European electricity mix (included in the Green Deal); and the reduction in the carbon footprint of battery manufacture (technological optimization, decarbonization of the energy used in production plants relocated in Europe, and the progressive use of recycled materials).

This simulation has limitations that must be noted, but their consequences do not fundamentally question the nature of the exercise:

— This simulation does not include the emission reduction potential offered by the circular economy, for which the EV is an excellent candidate (due to its battery recyclability), as well as enabling the possibility of exchanging the battery to extend the vehicle's life beyond its nominal first life mileage.
— This simulation does not include the possibility of using synthetic fuels to decarbonize the use of ICE vehicles, given that this solution cannot be applied to the entire ICE vehicle fleet due to the time needed to reach an industrial scale, the availability of decarbonized electricity, and the purchase price (which will remain prohibitive).
— This simulation does not include the emission reduction potential offered by the conversion of a petrol or diesel vehicle to an electric one, given that the conditions for industrializing this process are currently difficult to meet. The only viable economic model conceivable for such a process would only be able to convert a marginal proportion of the fleet. On the other hand, this option makes strong economic and environmental sense for light to medium-duty vehicles that have undergone a major and costly conversion and/or have specific technical characteristics (converted commercial vehicles, ambulances, school buses, etc.).

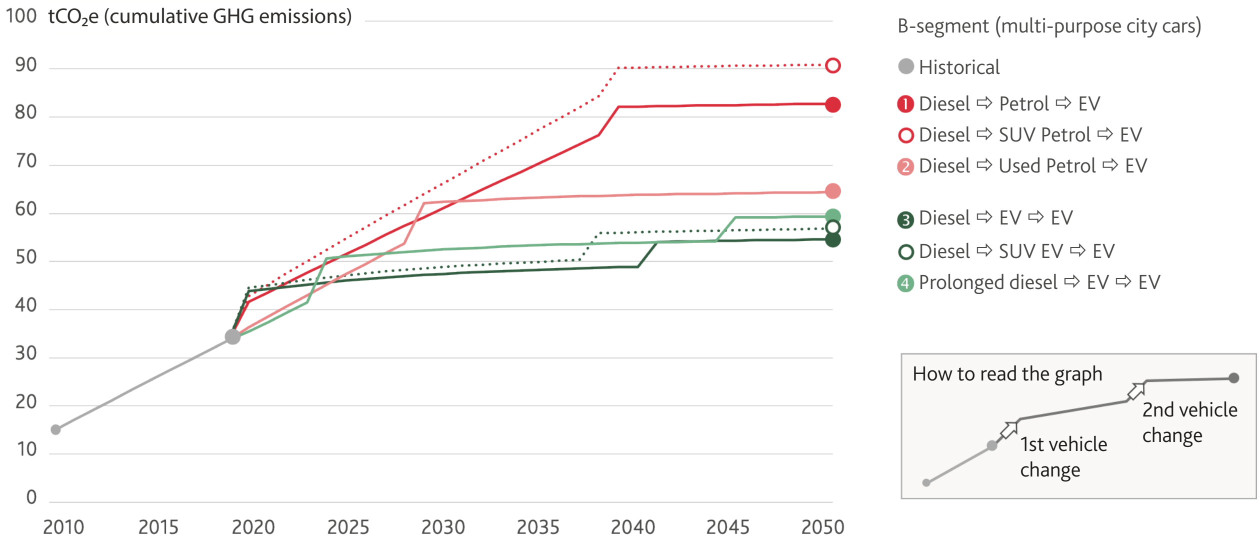
SUMMARY

Strictly from a climate impact perspective, this analysis shows that in the vast majority of cases it would be beneficial to replace the fleet of diesel and petrol vehicles with new or second-hand electric vehicles. From this standpoint, LEZs, which were conceived and designed to reduce health impacts, therefore offer the co-benefit of reducing greenhouse gas emissions.

Nevertheless, in the legitimate debate on the targeting of efforts and the speed of implementing LEZ restrictions, it might be worth extending this reasoning (focused on individual owners) in a representative and proportional way to include all vehicle segments and annual sales that ultimately make up the French vehicle fleet. A complementary approach would make it possible to provide input for the calendar scenarios and for the targeting of financial support for conversion or exemption schemes within LEZs to encourage an efficient fleet renewal dynamic, accounting for usages/mileage and vehicle types (size, weight, etc.) or the social categories and means of car owners. This approach could lead to a prioritization/planning of the need for electrification based on resource constraints, in particular materials that are critical to the transition, and by seeking a balance between maximizing impact and the actual financial capacity of owners to convert. The objectives must be to minimize CO_2 and pollutant emissions, while making the most efficient possible use of the materials mobilized by the transition. It must be remembered that the challenge is not so much about replacing the fleet, but more concerns the need to maximize the proportion of vehicle kilometres travelled using low-carbon vectors, while limiting the overall number of kilometres travelled wherever possible. Over the next decade there is therefore a need to: (1) reduce the growth of ICE SUVs, (2) optimize the use of existing EVs that have the lowest environmental impact (which happen to be the vehicles with the lowest marginal ownership costs), and to (3) prioritize the electrification of vehicles with a high use intensity.

Even though the scaling up of electrification raises questions today regarding the availability of raw materials (a subject on which we will be publishing at the end of 2023), this work on

FIGURE 2. **Scenario illustrating the cumulative life cycle GHG emissions of different vehicle ownership pathways**



Explanatory note: this exercise assumes a hypothetical owner renews their old ICE vehicle in response to the introduction of an LEZ or a "social leasing" scheme; the graph shows the cumulative greenhouse gas emissions induced by different renewal scenarios; the initially owned vehicle is a diesel city car weighing 1075 kg that was first registered in 2005. Then, from 2019 and 2023 onwards, different ownership paths are simulated, as shown in the figure's legend. We assumed that the owner will drive 466,000 km between 2010 and 2050 (i.e. 11,650 km/year), regardless of whether the vehicle is renewed. For the purpose of the exercise, emissions from vehicle manufacture are considered to be released on the date of purchase. The emission factors considered are estimated on a European Union scale for the carbon footprint of the electricity used for EVs, which account for developments in terms of the decarbonization of the electricity mix and fuels. Progress towards decarbonization in the manufacture of batteries and new vehicles is taken into account, in line with the statements of manufacturers (35% reduction in the carbon footprint of batteries in 2030 compared to 2019). B-segment cars are considered as representative of the majority of vehicles on French roads (which is a fairly conservative assumption). The dotted curves show the sensitivity of scenarios, given the possibility that consumers switch to SUV B-segment cars. In the calculations made here, the choice of replacing an old diesel vehicle with a used petrol vehicle (scenario 2) results in the elimination of emissions at the time of manufacture, which we consider to be attributable to the previous owner of the petrol vehicle. It should be noted that, in many cases, the switch to petrol engines is likely to increase greenhouse gas emissions on the road by around 20% (this is the observation we have made in our modelling, which means that the curves between scenarios 2 and 4 do not overlap between 2019 and 2023). Finally, a conservative estimate of 6L/100km was made regarding the average consumption of ICE vehicles, which is representative of the real-world consumption of new petrol city cars, even though many vehicles in the fleet have higher fuel consumption. However, this methodological bias does not question the validity of the above conclusions, but rather reinforces them. It should be noted that with the transfer of emissions to manufacturing during electrification, the cumulative emission curves may cross. It is therefore important to look at the medium to long term to determine the actual emission reductions achieved by electrifying the fleet.

replacement dynamics refutes Toyota's assertion that, from an emissions perspective, it is preferable to produce a large number of hybrid vehicles rather than a smaller number of EVs.[3] On this note, the analysis shows that the fundamental issue lies in the pace and prioritization of electrification, rather than in questioning the transition to 100% electric vehicles, which are the only vehicles that allow us to envisage a complete phase-out of liquid fossil fuels in the long term.

3 https://media.toyota.fr/la-strategie-multitechnologies-de-toyota-detaillee-par-gill-pratt-au-forum-economique-de-davos/

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