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Contribution of internal combustion engine vehicles to the decarbonization of road transport in France

Reconstruction of past trends – extrapolation of capacities and advice on achievable reduction targets for 2030

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The aim of this Policy Brief is to identify the potential benefits that could be made in reducing greenhouse gas emissions over the next decade as a result of changes in the fleet of internal combustion engine (ICE) vehicles on French roads. The analysis is based on a reconstruction of the consumption history of new vehicles and then of the fleet between 2012 and 2022. The model is then used in a predictive manner, incorporating known technological developments and supported assumptions for the expected renewal of the fleet. The analysis provides a clearer picture of changes in average vehicle fuel consumption over ten years and the corresponding emissions. The study focuses on ICE passenger vehicles (including hybrids), with a particular focus on changes in the petrol fleet (the diesel fleet is set to decline sharply) and heavy goods vehicles (HGVs).

KEY MESSAGES

The average consumption of a petrol vehicle in the French fleet fell by 1.07%/year between 2014 and 2021. Our simulations suggest that a similar fall will take place between 2021 and 2030 (including hybrid engines). These figures are based on the structural assumption that the environmental penalty is increased by 5g/year, as has been the case for the past three years. This pathway (a decline of 11.5% between 2019 and 2030) should be seen in the context of the target set by the *Secrétariat général à la planification écologique* (General Secretariat for Ecological Planning – SGPE), which is to achieve a 34% reduction of emissions for all French private vehicles over the same period.

A return to a trend of 19% SUV sales (compared with more than 40% over the last three years) would enable better results than achieved in previous years (excluding sufficiency measures; lower motorway speeds). This scenario would result in a reduction of 3 MtCO2e by 2030 compared with 2019, in line with the target set by the SGPE.[1]

In the case of HGVs, major efficiency gains on new vehicles will make it possible to achieve a reduction that is well above historical levels, with an 11.9% reduction in the average consumption of the fleet between 2019 and 2030. However, this result falls short of the SGPE target (17%).

The results highlight an asymmetry in the achievement of fleet emission reduction targets between light and heavy vehicles. To meet the carbon budget target for transport in 2030, it would be necessary to transfer part of the emissions reduction set aside for HGV fleets to light vehicles. The analysis shows that a greater contribution from light vehicles is possible and achievable. It would not require a continuation of past policies, but a strengthening of their ambition.

1 "La planification écologique dans les transports", 31 May 2023, online: https://www.gouvernement.fr/france-nation-verte/publications

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METHODOLOGY

For this Policy Brief, the *Institut Mobilités en Transition* (Mobility in Transition Institute – IMT) carried out a simulation based on data supplied by its technical partner C-Ways. For passenger cars, the choice was made to focus on the effects of petrol and hybrid-petrol engines, since these will account for more than 90% of new passenger car registrations between now and 2035. The contribution of new diesel vehicles has been considered negligible, with only 460,000 vehicles entering the fleet between now and 2035 (out of a total fleet of 20.1 million units in 2023). The analysis does, however, include the impact in terms of greenhouse gas emissions of replacing some of the scrapped diesel vehicles with new petrol vehicles.

The method used in this Policy Brief aims to single out as clearly as possible the effects of: (1) purely engine efficiency improvements, (2) the market penetration of hybrids and plug-in hybrids, (3) the proportion of SUV sales, (4) changes in the sales mix (vehicle size), (5) the fleet renewal rate and (6) changes in the fleet size in an electrification context. This division of levers and impacts will provide a better understanding of the benefits and efficiencies of different public policy measures, depending on their targets and modes of action.

NEW PETROL PASSENGER VEHICLES

The process of modelling fuel consumption per petrol passenger vehicle was based on new vehicle sales data by fuel type (including hybrids) and on CO_2 emission levels according to traditional vehicle size segmentation (from small A-segment cars up to the largest E-segment vehicles, taking into account a breakdown within each of these categories according to whether the vehicle is an SUV or not). The results are shown in Tables 1 and 2.

Analysis of the data reveals **a strong correlation in recent years between the development of plug-in hybrid powertrains and higher-segment vehicles**. In 2022, plug-in hybrids accounted for virtually no B-segment and below registrations (0.8% of sales in this segment, including B-SUVs), but account for 14.1% of C-segment registrations, 20.4% of D-segment, and up to 46.3% of sales of E-segment vehicles and above.

There is a striking correlation between **plug-in hybrids and SUV body styles**. While 9.6% of non-SUV D-segment cars registered in 2022 were equipped with this powertrain, plug-in hybrids accounted for 31.6% of registrations in this segment for SUV variants; even more so in the E-segment class and above, with 76% of SUVs registered in 2022.

While plug-in hybrid powertrains may offer benefits in terms of reducing greenhouse gas emissions, provided that they are used optimally, it is clear that this powertrain has above all enabled the sale of very large and heavy vehicles, which largely avoid the tax burden associated with CO_2 emissions and perform favourably in terms of the EU CO_2 regulations to which manufacturers are subject.

An analysis of CO_2 emissions by energy and by segment, which we compare with historical data provided by ADEME, enables us to estimate the progress linked purely to engine efficiency improvement (not correlated with vehicle segmentation) at 1.5% annually on average for petrol engines, in terms of type-approved emissions between 2012 and 2019.

It should also be noted that the size of vehicles sold is a powerful lever for increasing or reducing emissions. For example, the type-approved emissions for a C-segment SUV petrol vehicle are 18% greater than a B-segment (or smaller) petrol vehicle. While an E-segment petrol vehicle emits 45% more CO_2 than a C-segment vehicle with the same engine (based on manufacturers' approved values and actual registrations in 2022).

PETROL PASSENGER CAR FLEET

Based on our knowledge of the emissions from new petrol, hybrid and plug-in hybrid vehicles, a second stage of the analysis involves reconstructing the impact of these newly-registered vehicles on the average fuel consumption of the fleet in France.

To estimate these impacts, it is necessary to establish the link between actual consumption and type-approved data (NEDC and WLTP), where it is known that standardized measurement conditions tend to minimize reported fuel consumption. As a first step, the authors of this Issue Brief adjusted the type-approved emissions under the NEDC protocol from January 2012 to March 2020 to express the figures according to the WLTP protocol, which is closer to real-world usage. An increase of 19% was applied on the basis of the known differences between the two standards for certain vehicle models. The adjusted data was then compared with the actual fuel consumption of the fleet, to establish a conversion factor that varies from 19% to 22% depending on the year (an average of a 21% increase is used for the model's projections). Over the historical period analysed, the total difference between the NEDC cycle and actual fuel consumption is over 40%, a figure confirmed by the research work and benchmark tests carried out on this subject by the ICCT.[1]

In addition, for this study the authors made the conservative assumption that the real-world fuel consumption of plug-in hybrids is 30% lower than that of their petrol equivalents due to the use of 100% electric mode. On this issue, data from the SDES (French Statistical Data and Studies Department) shows a 38% difference between the two engine types across the fleet in 2021.

As the purpose of the study was to observe the impact of the forthcoming renewal of the ICE fleet, vehicles leaving the fleet are assumed to have the actual consumption representative of new vehicles registrations 19 years prior to the date on

1 ICCT, On the way to "real-world" CO_2 values: the European passenger car market in its first year after introducing the WLTP, online: https://theicct.org/sites/default/files/publications/On-the-way-to-real-world-WLTP_May2020.pdf

TABLE 1. Market share of new passenger vehicles by energy and segment in France

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
B and below		**44,4%**	**43,7%**	**42,9%**	**42,1%**	**41,3%**	**40,6%**	**39,7%**	**38,2%**	**39,3%**	**37,5%**	**33,9%**
	including petrol	42.0%	48.2%	54.4%	60.7%	66.9%	73.1%	79.3%	81.4%	68.3%	59.8%	56.0%
	including HEV	1.3%	1.6%	1.8%	2.1%	2.4%	2.6%	2.9%	3.0%	7.3%	14.0%	15.1%
	including PHEV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B SUV		**5.2%**	**6.7%**	**8.2%**	**9.7%**	**11.3%**	**12.8%**	**14.3%**	**16.6%**	**18.6%**	**18.7%**	**19.3%**
	including petrol	26.0%	33.6%	41.2%	48.8%	56.4%	64.0%	71.6%	72.7%	59.7%	50.0%	46.8%
	including HEV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	8.5%	19.3%	31.0%
	including PHEV	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.4%	0.5%	2.6%	3.9%	2.3%
C		**28.2%**	**26.8%**	**25.3%**	**23.9%**	**22.5%**	**21.1%**	**19.7%**	**17.1%**	**16.0%**	**14.4%**	**16.1%**
	including petrol	12.0%	16.7%	21.4%	26.1%	30.7%	35.4%	40.1%	42.2%	30.1%	30.6%	32.0%
	including HEV	1.8%	2.2%	2.6%	2.9%	3.3%	3.7%	4.1%	5.0%	10.1%	13.1%	11.0%
	including PHEV	0.0%	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.6%	3.6%	7.9%	7.7%
C SUV		**4.0%**	**6.2%**	**8.4%**	**10.5%**	**12.7%**	**14.9%**	**17.1%**	**18.0%**	**17.3%**	**19.8%**	**21.3%**
	including petrol	12.0%	14.6%	17.2%	19.9%	22.5%	25.1%	27.7%	32.9%	21.3%	18.7%	18.1%
	including HEV	0.5%	1.8%	3.2%	4.5%	5.8%	7.2%	8.5%	10.3%	17.4%	25.6%	33.6%
	including PHEV	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.3%	9.2%	20.4%	18.9%
D		**10.8%**	**9.7%**	**8.7%**	**7.6%**	**6.5%**	**5.5%**	**4.4%**	**4.9%**	**4.4%**	**4.9%**	**3.9%**
	including petrol	11.0%	11.8%	12.6%	13.5%	14.3%	15.1%	15.9%	20.5%	12.5%	12.1%	12.5%
	including HEV	0.3%	0.9%	1.6%	2.2%	2.9%	3.5%	4.1%	6.1%	11.1%	14.8%	20.0%
	including PHEV	0.0%	0.2%	0.3%	0.5%	0.7%	0.9%	1.0%	1.4%	8.9%	10.0%	9.6%
D SUV		**5.9%**	**5.4%**	**4.8%**	**4.3%**	**3.8%**	**3.3%**	**2.7%**	**2.7%**	**2.4%**	**2.7%**	**3.8%**
	including petrol	8.0%	9.3%	10.5%	11.8%	13.1%	14.4%	15.6%	12.5%	6.7%	4.0%	4.9%
	including HEV	0.2%	0.9%	1.5%	2.2%	2.8%	3.5%	4.2%	8.5%	14.5%	24.3%	16.6%
	including PHEV	0.0%	0.6%	1.3%	1.9%	2.5%	3.1%	3.8%	8.6%	31.9%	39.8%	31.6%
E or higher		**1.2%**	**1.2%**	**1.3%**	**1.3%**	**1.4%**	**1.4%**	**1.5%**	**1.6%**	**1.1%**	**1.0%**	**1.0%**
	including petrol	8.0%	9.7%	11.5%	13.2%	14.9%	16.7%	18.4%	21.3%	14.9%	19.1%	22.8%
	including HEV	0.1%	0.2%	0.3%	0.4%	0.6%	0.7%	0.8%	11.7%	15.8%	19.5%	21.9%
	including PHEV	0.0%	0.8%	1.6%	2.3%	3.1%	3.9%	4.7%	4.8%	9.3%	17.4%	22.5%
E or higher SUV		**0.3%**	**0.3%**	**0.4%**	**0.4%**	**0.5%**	**0.5%**	**0.5%**	**0.8%**	**0.8%**	**1.0%**	**0.8%**
	including petrol	7.0%	7.4%	7.8%	8.1%	8.5%	8.9%	9.3%	8.4%	4.5%	2.3%	3.2%
	including HEV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.2%	8.6%	8.5%	8.5%
	including PHEV	0.0%	3.8%	7.6%	11.4%	15.2%	19.0%	22.8%	26.1%	58.5%	81.7%	76.6%

Note: Data between 2018 to 2022 is directly derived from new vehicle registrations in France via the SIV vehicle registration system. The sales data by segment for 2012 are taken from the literature, and the energy mixes by segment for 2012 are calculated using ADEME data by energy and body type. In the absence of raw data for the period between 2013 to 2017, the IMT estimates the values by taking trend developments into account.

TABLE 2. CO_2 emissions in g/km from new passenger vehicles by segment and energy in France

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
B and below		**120.79**						**110.20**	**108.6**	**120.5**	**118.8**	**118.0**
	including petrol	121.55						111.01	109.3	122.1	122.3	122.7
	including HEV	96.32						87.97	86.7	105.5	103.9	100.7
	including PHEV	30.00						30.00	30.0	30.0	30.0	30.0
B SUV		**132.94**						**119.19**	**117.1**	**129.6**	**127.9**	**124.2**
	including petrol	132.94						119.60	117.8	134.7	136.4	133.4
	including HEV	108.95						98.01	96.5	121.1	124.6	116.7
	including PHEV	50.86						50.86	50.9	37.6	36.9	38.0
C		**131.38**						**118.37**	**116.3**	**122.7**	**115.2**	**115.8**
	including petrol	136.53						122.82	121.0	137.3	137.4	136.7
	including HEV	97.06						87.32	86.0	111.8	116.7	117.8
	including PHEV	35.44						35.44	35.4	32.5	27.3	25.8
C SUV		**145.92**						**124.74**	**122.4**	**118.1**	**105.5**	**106.9**
	including petrol	147.33						132.54	130.6	146.8	147.2	144.5
	including HEV	111.89						100.66	99.1	126.9	130.4	127.5
	including PHEV	29.87						29.87	29.9	35.1	36.2	34.3
D		**158.66**						**133.33**	**130.9**	**115.6**	**115.8**	**119.9**
	including petrol	159.38						143.38	141.2	157.5	153.1	154.7
	including HEV	132.26						118.99	117.2	134.2	140.4	141.6
	including PHEV	36.44						36.44	36.4	33.6	34.2	29.9
D SUV		**191.34**						**146.69**	**124.5**	**101.0**	**98.6**	**89.8**
	including petrol	192.18						172.89	170.3	192.3	180.5	158.6
	including HEV	157.85						142.00	139.9	165.9	165.3	160.3
	including PHEV	42.96						42.96	43.0	52.3	49.6	42.1
E or higher		**208.20**						**158.96**	**152.6**	**156.3**	**137.4**	**130.8**
	including petrol	208.87						187.90	185.1	222.9	209.3	198.9
	including HEV	154.58						139.07	137.0	158.3	153.2	151.0
	including PHEV	47.71						47.71	47.7	47.1	40.9	41.9
E or higher SUV		**273.24**						**115.40**	**124.5**	**92.6**	**73.1**	**65.8**
	including petrol	273.24						245.80	242.1	288.2	328.2	318.3
	including HEV	188.30						169.40	166.9	205.1	188.8	186.9
	including PHEV	62.24						62.24	62.2	61.2	53.9	41.7
HEV emissions		**128.11**	**122.7**	**119.9**	**117.0**	**116.8**	**117.0**	**117.46**	**116.21**	**129.69**	**130.53**	**130.49**
VH emissions		98.62	98.2	97.8	97.4	97.0	96.5	96.12	100.03	120.38	122.04	119.29
PHEV emissions		34.38	36.3	38.2	40.2	42.1	44.0	45.97	46.69	41.09	38.42	34.87
Mixed petrol emissions (including hybrid)		126.8	121.3	118.2	115.1	115.1	114.8	115.5	114.1	121.8	116.6	115.5

Note : De 2012 à 2019, les valeurs sont affichées selon le protocole NEDC[a]. À partir de 2021, les valeurs sont systématiquement exprimées selon le protocole WLTP[b]. L'année 2020 constitue une année pivot et comporte pour un tiers des données NEDC et pour deux tiers des données WLTP. Les données d'émissions par segment en 2012 sont reconstruites à partir des valeurs homologuées par énergies fournies par l'ADEME. La reconstruction des émissions entre 2013 et 2017 n'a pas pu être établie par segment mais uniquement par énergie. Ces éléments ne sont pas de nature à remettre en cause l'analyse puisque les années de 2018 et 2022 permettent de statuer sur les effets dissociés des segments et du taux de vente de SUV.

a) The New European Driving Cycle (NEDC) is a vehicle type-approval cycle that first appeared in the 1970s and has undergone a number of changes up to 2018. It is mainly used to compare vehicles on the basis of fuel consumption. .

b) Worldwide Harmonized Light Vehicles Test Procedures (WLTP) is a vehicle type-approval test standard. In particular, it is used to measure tailpipe CO_2 emissions. It was rolled out across Europe in the early 2020s for all registered light vehicles, replacing the previously used NEDC standard.

TABLE 3. IMT reconstruction of the consumption of petrol and hybrid passenger cars

Actual consumption of the fleet's passenger cars in L/100km	2014	2015	2016	2017	2018	2019	2020	2021
Reconstruction - New petrol vehicles (including hybrids)	6.87	6.76	6.70	6.86	6.90	6.65	6.21	6.02
Reconstruction – New petrol vehicles	6.96	6.85	6.78	6.97	7.01	6.75	6.43	6.32
Reconstruction - New hybrid vehicles	5.68	5.70	5.63	5.75	5.74	5.81	5.97	5.91
Reconstruction – New plug-in hybrid vehicles	4.84	4.76	4.71	4.84	4.88	4.69	4.47	4.83
Reconstruction IDDRI petrol fleet FR	**7.32**	**7.25**	**7.13**	**7.05**	**6.98**	**6.90**	**6.84**	**6.75**
Consumption SDES petrol fleet FR	**7.32**	**7.30**	**7.13**	**7.15**	**7.00**	**6.90**	**6.83**	**6.77**

Note: Data from fleet mileage monitoring typically show that a passenger car in France travels an average of more than 15,000 km/year during the first three years following registration. This figure falls to 7,250 km/year by the nineteenth year (corresponding on average to the end of the vehicle's life). This differentiated vehicle usage rate according to age is a variable that influences the average fleet consumption observed each year. This phenomenon is taken into account in the simulation, since the fleet's historical consumption (SDES data – used for calibration) is calculated on the basis of the rolling fleet and the actual fuel distribution year after year (via CPDP data). It is therefore assumed that the simulated data takes account of an existing flat-rate weighting linked to disparities in mileage depending on the age of vehicles in the fleet. However, given the methodology used, this element is constant in the simulation and does not cause the results to vary considerably over time.

which they exit the fleet. This lifespan was chosen on the basis of known data on the average end-of-life age of vehicles in France.[2]

Finally, the number of vehicles leaving the fleet corresponds to the number of new vehicles joining it, plus the variations in fleet size according to fuel type. In this way, the simulation takes into account the observed trend for old diesel vehicles to be replaced by new petrol vehicles.

The consideration of all these assumptions enables a reconstruction of the fuel consumption trend for petrol vehicles (including hybrids) that is close to the known historical trend. The last two lines of Table 3 compare the results of the IMT simulation with the average for the petrol fleet established by the SDES between 2014 and 2021. The relatively good correlation confirms the methodology used.

TEN-YEAR TRENDS

The modelling tool used allows us to test different development scenarios for the coming decade. The authors chose to consider a baseline scenario in which the French market is stable at 1.8 million vehicles in 2030, and in which the rate of electric vehicle sales by that date is 58%. These two structural assumptions, which we define as constants, **are chosen as conservative values in line with the purpose of the study, which is to determine the contribution of ICE vehicles to decarbonization**. In this sense, any other scenario contributing to accelerating the proportion of electric vehicles in sales (SGPE at 66% in 2030) or accelerating the rate of fleet renewal (*Plateforme de la filière automobile* [PFA] at 2 million new cars in 2030) will only reinforce the achievement of the overall decarbonization objectives, through an increased use of electric vehicles and/or increased renewal of lower-emission ICE vehicles. In addition, the hypotheses chosen represent elements that have been analysed extensively, and pathways that are achievable given the existing regulatory and fiscal framework. The most important facts and figures in relation to the subject of the study are outlined below.

— The authors share the PFA's view of **the importance of the CAFE regulatory framework** (European CO_2 standards that set targets to be achieved for the average sales of each manufacturer, which are increased incrementally every five years) in guiding the products and sales strategies of manufacturers, which thus relatively precisely establish the rate of electric vehicle sales required annually. On the basis of past observations, the authors consider that the incumbent manufacturers will not exceed their obligations in terms of compliance with the CO_2/km targets and electric vehicle sales.
— The analysis also considers that there is **continuity in the French government's fiscal policy**, particularly with regard to the CO_2 penalty, with a higher trigger threshold of 5g/year. For B-segment petrol and hybrid vehicles with emissions of 121 g/km and 99 g/km WLTP respectively, this tax dynamic would lead to a reduction in the purchase price differential of €2,090 in 2030 as a result of the penalty. In view of this additional cost, and the difference in running costs (linked to vehicle fuel consumption and other tax incentives for low-emission vehicles; company vehicle tax), the authors estimate that **if the CO_2 penalty continues to be increased, only full-hybrid and plug-in hybrid petrol vehicles will continue to be sold on the French market in 2030** (with the disappearance of non-hybrid petrol and 48V mild hybrid petrol cars).

The consideration of all these factors enables the prediction of the engine types of new passenger car sales in France, as shown in Table 4.

The halting of investment in ICE vehicles for passenger cars largely supports the equally conservative assumption that there will be no efficiency gains in these engines from 2022 onwards.

Ultimately, new vehicle fuel consumption varies according to just two variables: the proportion of SUV sales (SUV mix) and

2 Ministry of Ecological Transition and Territorial Cohesion, based on ADEME, online: https://www.ecologie.gouv.fr/vehicules-hors-dusage-vhu

TABLE 4. Engine types of new passenger cars sales | baseline scenario

		2023	2024	2025	2026	2027	2028	2029	2030
Annual passenger car sales (in million units)		1.7	1.75	1.85	1.9	1.9	1.85	1.8	1.8
Sales mix | Total petrol vehicles		69.6%	70.3%	66.5%	61.3%	56.1%	50.9%	45.7%	40.5%
	Including petrol only	36.9%	36.2%	30.8%	24.9%	18.0%	11.9%	5.7%	0.0%
	Including hybrids	24.3%	25.8%	27.4%	28.6%	30.8%	32.3%	33.8%	34.8%
	Including rechargeable hybrids	8.4%	8.4%	8.3%	7.8%	7.3%	6.7%	6.2%	5.7%

the proportions of large and small car sales (segment mix). We define three possibilities for the evolution of each of these variables. Regarding SUVs, the authors envisage a ten-year reversal in the market share of this vehicle type. This hypothesis, which would result in SUV sales returning to 19% in 2032, is considered as a possible scenario because it represents the exact opposite dynamic to that observed over the last decade (between 2012 and 2022).

TABLE 5. Segment sales mix forecast from now to 2032

Segment mix in 2032	Corresponding share of A and B segment sales	Reference year
Baseline	53%	2022
Median A+B segment	57%	2020
Strong A+B segment	64%	/

TABLE 6. SUV sales mix forecast from now to 2032

SUV mix in 2032	Corresponding share of SUV sales	Reference year
Baseline	45%	2022
SUV-	32%	2017
SUV--	19%	2013

Two extreme scenarios are presented in the table below:

TABLE 7. Assumptions used for the SUV and segment mixes in the two scenarios analysed

Scenarios	Segment mix	SUV mix
1 – Baseline	Baseline	Baseline
2 - Increased decarbonization	Strong A&B segment	SUV --

Figure 1 shows the results obtained for the type-approved emissions of new vehicles in the two scenarios selected.

Analysis. Historical fuel consumption figures show a sharp fall between 2012 and 2015 due solely to efficiency gains linked to the renewal of certain internal combustion engines (PSA's 1.2 L PureTech and Renault's TCe engine and EDC gearbox), while hybrid engines remained insignificant in terms of sales. The years 2015 to 2019 saw a significant increase in petrol vehicle sales in the wake of Dieselgate[3] (from 38% to 58% market share). This increase is mainly due to significant C-segment growth. This expansion into a higher segment, coupled with the growth of SUVs, leads to a plateauing of emissions (neutralizing the efficiency gains taking place during the same period). The year 2020 was one of transition, both in terms of the method of calculation, with the switch from the NEDC standard to the WLTP standard, and in terms of the take-off of hybrid sales, which rose from 5.7% in 2019 to almost 15% in 2020. This crossover effect translates into an apparent increase in emissions of 6.8% in 2020. While admittedly this is a high figure, it is largely due to the change in standards without any real change in vehicle performance (for the purposes of representation, we maintain the comparison in Figure 1, but specify the nature of the test cycle used).

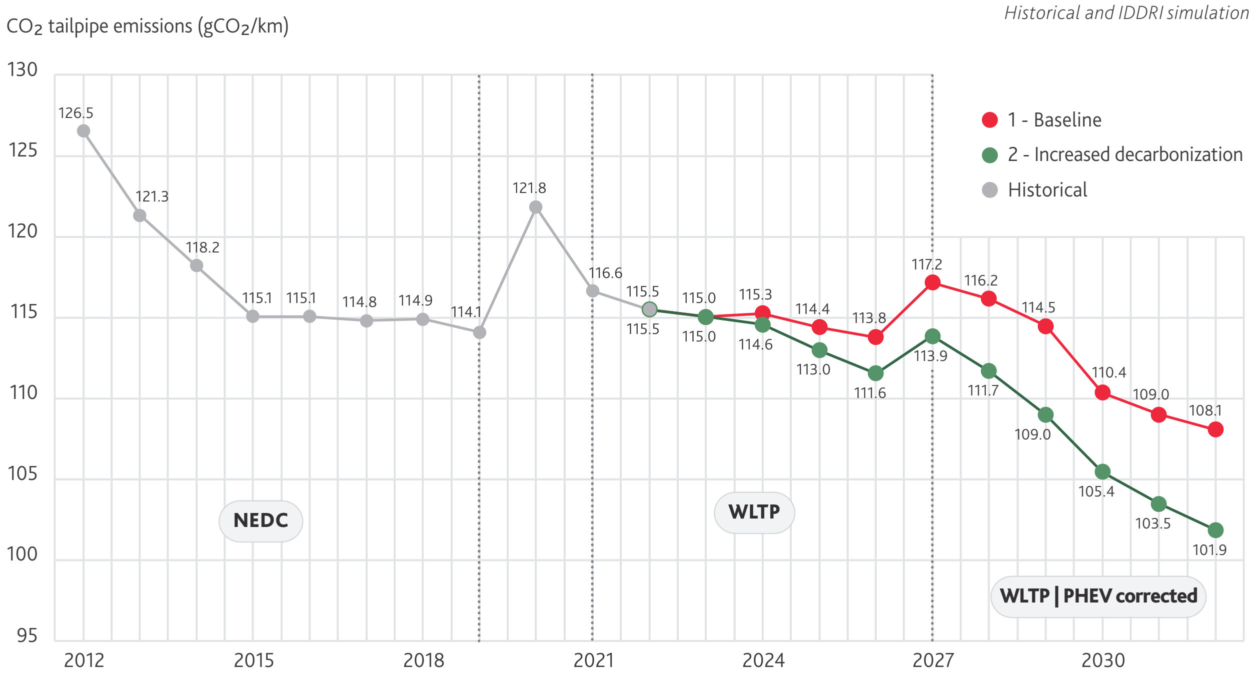
Regarding **future trends**, from 2027 onwards, changes in the test protocols for plug-in hybrid vehicles will lead to a doubling of type-approved emissions for this engine type, and consequently to an increase in approved emissions from new registrations (here again, this adjustment is intended to approximate actual usage conditions). This upward curve does not imply any change in the real-life emissions considered in the simulations. However, in terms of type-approved emissions and in the most optimistic of scenarios, petrol and hybrid vehicle emissions will fall by only 8.4% by 2030, compared with 2022. It should be remembered that achieving this scenario requires: (1) a strengthening of the 5g/year penalty that determines the speed of the switch in sales between hybrid and non-hybrid petrol vehicles; (2) a return to a 19% share of SUV sales; and (3) a shift in sales to smaller models (A and B segments).

Figure 2 transcribes the previous type-approved emissions results into actual average fuel consumption figures for new registrations. The impact on fleet fuel consumption is also projected.

Analysis of the two scenarios shows that the average petrol vehicle fuel consumption (including hybrids) in the fleet in 2030 will fall by between 9.5% and 10.2% compared with 2021. This reduction is largely due to hybrid powertrains and the retirement of older, more fuel-hungry vehicles. Among new vehicles, it is worth noting that the non-hybrid petrol range is disappearing

3 Dieselgate is a health and industrial scandal involving the Volkswagen Group that broke at the end of 2015. There is evidence of widespread deception regarding the real-life emissions of nitrogen oxides from the Group's diesel-powered light vehicles in relation to the regulations in force in the USA and Europe.

FIGURE 1. Trends in type-approved emissions from petrol passenger cars (including hybrids)



Note: PHEV = Plug-in Hybrid Electric Vehicle

primarily from the higher segments. Only a few entry-level models (such as the Dacia B-segment in France) will continue to be sold without hybridization before 2030. Average emissions from non-hybrid petrol vehicles will fall by around $1gCO_2$/km between 2022 and 2029 as a result of the imminent disappearance of pure petrol engines from the higher segments.

While the annual reduction in the vehicle fleet's fuel consumption was 1.07%/year between 2014 and 2021, the analysis shows that the future trend will be at least equivalent between 2021 and 2030, with the achievement of a credible reduction of 1.05%/year due to the massive development of hybrid powertrains (subject, once again, to a delay in the triggering of the 5g/year environmental penalty – identical to the historical trend in this tax system).

To achieve the enhanced decarbonization scenario (see Figure 2), other public policy measures must be implemented to reduce the proportion of SUV sales and encourage the sale of smaller models (enhanced decarbonization scenario described in Table 7). In these circumstances, it would be possible to improve on the past trend in fuel consumption reductions, achieving a decline of 1.14%/year – i.e. a fleet-wide reduction of 10.2% between 2021 and 2030, an increase of 7% compared to the baseline scenario. Based solely on this condition, a reduction of 3 Mt of CO_2 between 2019 and 2030 as envisaged by the General Secretariat for Ecological Planning is achievable for a conservative annual mileage of 7,500 km.[4]

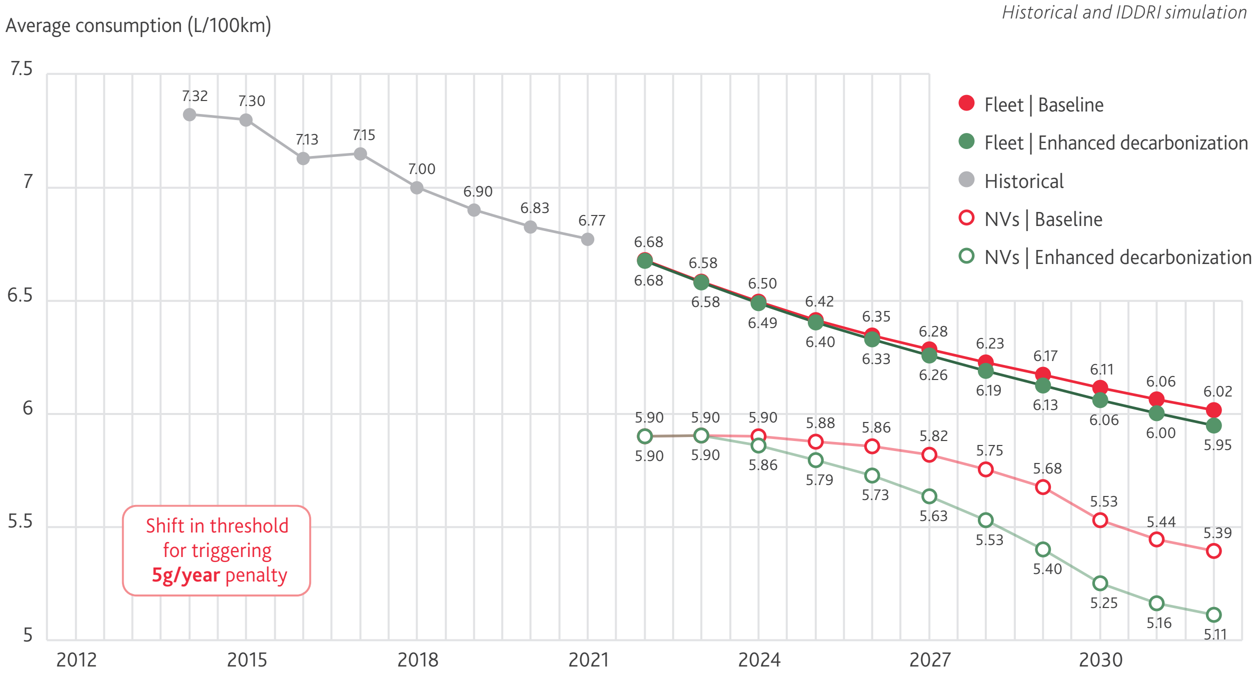
4 This assumption was also considered by the SGPE in its 31 May 2023 publication: "*La Planification écologique dans les transports*", which can be viewed here: https://www.gouvernement.fr/france-nation-verte/publications

It should be noted that by 2030, the French passenger vehicle fleet will include 1.3 million plug-in hybrids, for which public policies need to encourage preferential use of electric power. If the vehicles in this fleet switch an additional 7,000 km of annual mileage from internal combustion engine to purely electric mode, the additional GHG emissions reductions will amount to 1 $MtCO_2e$ compared with the previously established scenario. This quantification is in line with the target defined by the SGPE. This scenario requires PHEVs to achieve 80% of their annual mileage in 100% electric mode. This ambitious target may be considered achievable by 2030 because ownership of such vehicles, initially concentrated among businesses, will spread to private customers (the typical leasing contract is 4 years) and because the range for new PHEVs in 100% electric mode will increase.

Finally, the authors studied the sensitivity of results in a scenario of a reduced increase in the CO_2 penalty. If the trigger threshold is assumed to increase by only 2g/year, the price increase, for example, of a current typical B-segment non-hybrid vehicle would only be around €300 (CO_2 penalty). Under these conditions, non-hybrid petrol vehicles would be sold until 2032 (instead of 2030), even though manufacturers have already achieved their European CAFE targets. Their share of sales would be around 35% higher each year than in the baseline scenario, until the end of the decade.

According to these assumptions (2g/year increase in the penalty from 2024), the fuel consumption of the vehicle fleet increases by 0.04 L/100km on average in 2030 compared with the previous simulations. The benefits of renewing the fleet to reduce fuel consumption are significantly reduced (emissions from the fleet and new vehicles are closer together in Figure 3 than in Figure 2).

FIGURE 2. **Trends in passenger car petrol consumption (Fleet and NVs; including hybrids)**



Note: NVs = new vehicles

Finally, this simulation supports the choice of short-term public policies aimed at reducing tailpipe CO_2 emissions, and therefore the widespread use of hybridization, **as well as the introduction of measures aimed at achieving the necessary sufficiency in the size and weight of vehicles on the road**. The challenge is to avoid any rebound effects in terms of fuel consumption if we are to achieve the carbon budget targets set at the French level. From this perspective, the CO_2 penalty plays a very important role as an incentive. The weight penalty, if increased by the French Draft Finance Bill (PLF) 2024 and in future, will also play an important additional role.

DIESEL HGVS

The analysis for HGVs is based on the same methodology as that used for passenger cars. In 2023, the fleet will consist of 616,467 vehicles, including 307,433 lorries, 89,200 specialized motor vehicles[5] and 219,834 tractor units. This latter vehicle category is the one that is renewed most rapidly and has the highest annual mileage.

5 "VASP" in French

The HGV sector is strongly governed by the cost of use, and therefore by fuel consumption, which accounts for up to 30% of the operating costs of hauliers. This highly differentiating factor compared with private vehicles guides the choice of vehicle fleets and their renewal. Following this rationale, HGV manufacturers have invested heavily in diesel technology to reduce vehicle fuel consumption. As a result, HGVs that have been on the market for less than 2 years have fuel consumption levels that are 10% lower in real use than their predecessors. It appears that this will be the main factor leading to the observed fall in fuel consumption. Market dynamics and the rate of fleet renewal, if they remain stable, will mean that 46% of vehicles on the road in 2030 will benefit from these new technologies.

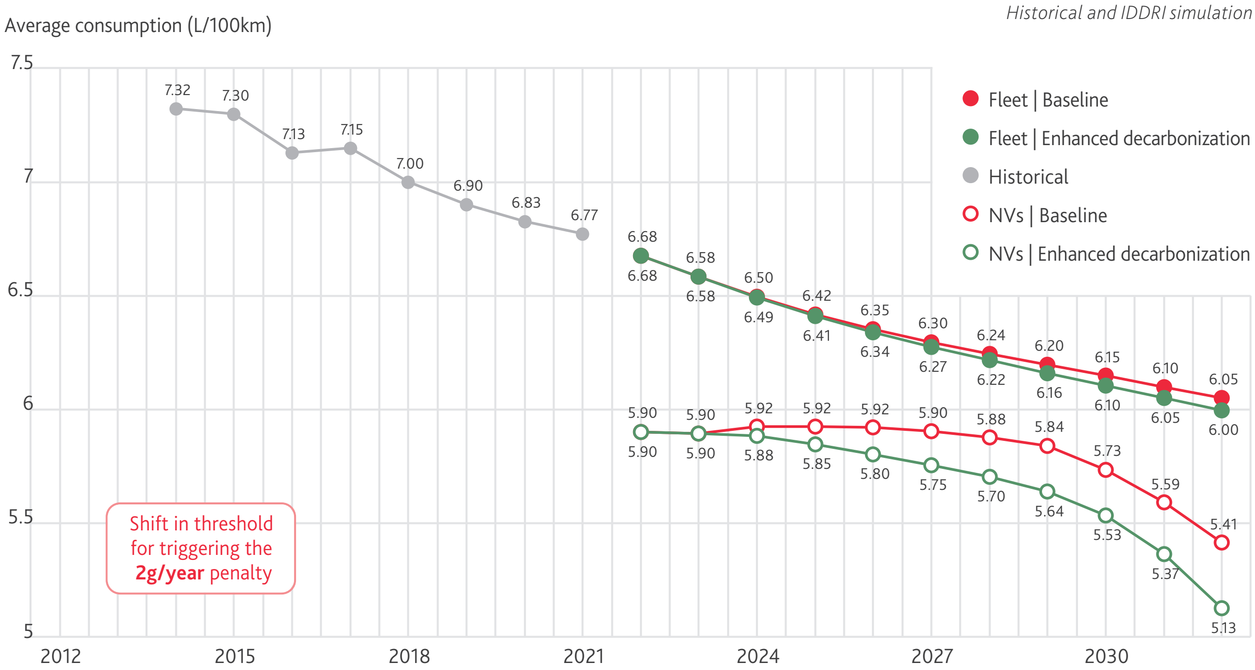
The analysis also accounts for the rise in fatty acid methyl esters (FAME) biodiesel vehicles, which have a 2% higher fuel consumption. Lastly, the decline in the diesel vehicle fleet will be driven more significantly by low-tonnage HGVs between now and 2030, as these vehicles have the potential to be electrified sooner. The fuel consumption of vehicles with a gross vehicle weight (GVW) of less than 26 tonnes is considered to be 10% lower. Although significantly lighter, these vehicles are used more extensively in urban areas and/or have auxiliary functions that require the use of diesel engines when stationary.

TABLE 8. **New HGV registrations by energy | baseline scenario**

	2023	2024	2025	2026	2027	2028	2029	2030
Annual sales of HGVs over 7.5 t	46 k	46 k	46k	46k	46 k	46 k	46 k	46 k
Including diesel + biodiesel + hybrid	93.9%	92.8%	90.7%	80.7%	70.8%	60.8%	50.8%	40.8%

FIGURE 3. Trends in petrol passenger vehicle fuel consumption (Fleet and NVs; including hybrids)

Historical and IDDRI simulation



Between now and 2030, the analysis shows that the average consumption of diesel HGVs in the fleet will fall by 3L/100km over the next seven years, compared with 2L/100km over the last seven years, as a result of fleet renewal bringing performance gains and changes in the tonnage mix at the pace of electrification, which varies according to GVW class. This means that future reductions are likely to be around 50% more rapid than previously observed. In other words, annual progress will average 1.16%/year between 2021 and 2030, compared with 0.77%/year previously. This dynamic, made possible by recent innovations, can also be explained by a faster fleet renewal rate than for private vehicles. Despite this, the maximum achievable efficiency gains between 2019 and 2030 for the fleet as a whole will only be 11.9%. **This is insufficient to meet the 17% target of the SGPE**. As a result, greenhouse gas emission reductions achieved strictly through fleet renewal will not be as high as hoped, amounting to 2.3 $MtCO_2e$ by 2030 compared with 2019 (assuming an average annual mileage of 42,000 km). This reduction corresponds roughly to the SGPE's credible target for this lever (3 $MtCO_2e$), but is well below the 7 $MtCO_2e$ needed to meet the carbon budget envisaged more generally for freight transport (including LCVs). This finding raises questions about the distribution of expected efforts within the road transport sector.

CONCLUSION

Eight million new petrol and diesel passenger cars and 244,000 new ICE HGVs will be introduced into the French fleet between 2024 and 2030. As reiterated in the preparatory work for the French energy-climate strategy,[6] if the objective is to respect the carbon budgets set as part of ecological planning, the penetration of low-emission ICE vehicles into the fleet (hybrids or smaller vehicles) is an essential element alongside an increasing number of electric vehicles.

The analysis demonstrates the usefulness over the next few years of public policy tools to control the future fuel consumption of the French ICE and hybrid vehicle fleet. The traditional and existing tools (the CO_2 penalty and the weight penalty) are effective and will need to be established with long-term visibility if this effectiveness is to be maintained. Moving the threshold for triggering the CO_2 penalty by 5g/year for the next three years, and lowering the weight penalty to 1,600kg on 1 January 2024 will enable the targets set in the ecological plan to be achieved in the short term, regarding emissions reduction linked to better sufficiency of the private vehicle fleet.

The targets will, however, be difficult to achieve for HGVs. The levers for action are also limited (there are virtually no plug-in hybrids and no segment or SUV variables to modulate sales emissions). Public authorities must ensure the renewal of the HGV fleet to disseminate the latest technologies in terms

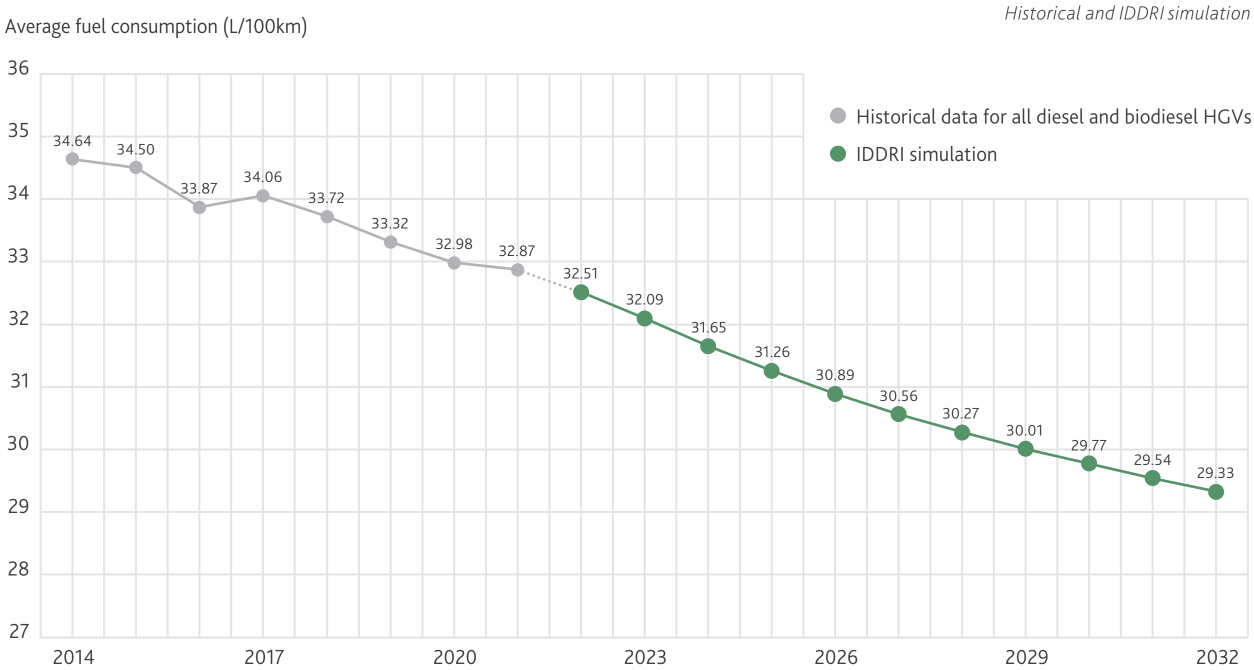
6 Preparatory work for the French energy/climate strategy, September 2023, viewable online: https://www.ecologie.gouv.fr/sites/default/files/DP_strategie_fr_energie_climat.pdf

of energy efficiency, however, this will not be sufficient and the SGPE's assumption of a 17% reduction in the fleet's fuel consumption by 2030 compared with 2019 will require a specific action plan that goes beyond the currently projected trends and pathways. A reduction of around 12% as envisaged in this analysis is a credible and achievable target.

As a result, increasing the ambition of public policies in the private vehicle sphere (compared with the measures mentioned above) seems fully justified in a context where the technical levers available in the short term for HGVs in the ICE fleet will be stretched to the limit.

Finally, to achieve further emissions reductions, the effects on the fleet of the widespread use of very low rolling resistance tyres and low-viscosity engine oils need to be analysed in detail. Actual fuel consumption figures may differ by more than 10% for vehicles fitted with or without these technologies.

FIGURE 4. Trends in HGV fuel consumption in France



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