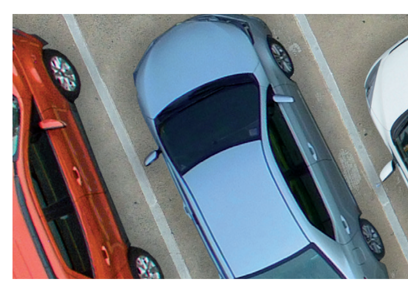
International Transport Forum

Lightening Up: How Less Heavy Vehicles Can Help Cut CO_2 Emissions



Case-Specific Policy Analysis

OECD

Lightening Up: How Less Heavy Vehicles Can Help Cut CO_2 Emissions

Case-Specific Policy Analysis

The International Transport Forum

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Case-Specific Policy Analysis Reports

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ITF thanks the International Energy Agency for the provision of data from their Mobility Model that was used to project the activity of light-commercial vehicles. This data was used in all scenarios with the exception of one for which alternative input data and results are provided in the section on sensitivity analysis.

Table of contents

List of abbreviations

ACEA	European Automobile Manufacturers' Association
BEV	Battery electric vehicle
CNG	Compressed natural gas
CO	Carbon monoxide
EC	European Commission
EAA	European Aluminium Association
EU28	European Union (including its 28 Member States)
FCEV	Fuel cell electric vehicle
GFEI	Global Fuel Economy Initiative
HC	Hydrocarbon
HEV	Hybrid electric vehicle
ICCT	International Council for Clean Transportation
ICE	Internal combustion engine
IEA	International Energy Agency
ifeu	Institut für Energie- und Umweltforschung
ITF	International Transport Forum
LCV	Light-commercial vehicle
LDV	Light-duty vehicle
LPG	Liquefied petroleum gas
MT	Million tonnes / Mega tonnes
NAP	National Academy Press
NMVOC	Non-methane volatile organic compound
NOx	Nitrogen oxides
PC	Passenger car
PHEV	Plug-in hybrid electric vehicle
PM	Particulate matter
TTW	Tank-to-wheel (tailpipe)
WLTP	Worldwide Harmonised Light Vehicles Test Procedure
WTT	Well-to-tank

Executive summary

This study examines how inversing the trend towards ever heavier light-duty vehicles would impact CO_2 emissions from road transport. The average mass of passenger cars in the European Union has increased by around 40% over the past four decades. In 2015, a vehicle weighed on average 1 400 kg, compared to just under 1 000 kg in 1975. Additional mass consumes more energy and results in higher CO_2 emissions, and a reduction in vehicle mass could contribute to achieving emissions reduction goals. Based on a vehicle stock model, the study establishes a baseline scenario, in which current policy trends are supposed to continue, and a mass reduction scenario, in which the average mass of new vehicles is assumed to decline to the levels of four decades ago. The CO_2 impacts of the different scenarios are then compared to assess how much mass reduction can contribute to reducing transport CO_2 emissions. The study also develops cost-benefit assessments for the different scenarios.

What we found

In the baseline scenario, tailpipe CO_2 emissions from light-duty vehicles in 2050 are 21% lower than in 1990 levels. In the vehicle mass reduction scenario, a gradual reduction of vehicle mass down to 1 000 kg for new passenger cars and 1 100 kg for new light-commercial vehicles result in a near doubling of the CO_2 reduction seen in the baseline scenario: CO_2 emissions fall by 39% or 210 Megatonnes by 2050 compared to 1990 levels. Around 85% of these reductions come from passenger cars.

These are significant reductions, yet they are not sufficient in themselves for reaching the European Union's target of a 60% reduction in transport CO_2 emissions by 2050 compared to 1990 levels. One option for closing this gap would be to increase in the share of zero-emission passenger cars in new vehicle sales from 27% in the baseline scenario to 64% by 2050, and from 40% to 68% for light-commercial vehicles.

For consumers, buying lighter-weight passenger cars is beneficial in financial as well as environmental terms, as savings in emissions and for fuel outweighs the increased cost of purchasing lighter and more fuel-efficient vehicles. Looking at changes in fuelling and purchase costs alone, consumers save EUR 213 per tonne of CO_2 not emitted. The picture is less favorable for light-commercial vehicles because reducing vehicle mass is more costly and purchasing them therefore more expensive. Here, owners pay EUR 977 for each tonne of CO_2 saved and the monetised environmental benefits do not outweigh the increased costs for the consumer.

What we recommend

Consider the potential of vehicle mass reduction when designing climate policies

For reaching stringent climate targets, all possible avenues of action for reducing CO_2 emissions need to be considered. In the transport sector, the full potential of vehicle mass reduction does not seem to have been acknowledged. This study finds that reducing the average mass of passenger cars in the European Union from currently c. 1 400 kg to c. 1 000 kg and of light-commercial vehicles from c.1 800 kg to c. 1 100 kg to 2050 can reduce CO_2 emissions from these vehicles by almost 40% compared to 1990 levels. This is nearly twice the reduction projected without a reduction of average vehicle mass.

Do not rely on vehicle mass reductions alone to achieve the European Union's target of a 60% transport CO_2 reduction

Reducing the average mass of light-duty vehicles to about the level of the mid-1970s can approximately halve the gap between the baseline scenario and the European Union's 2050 transport emissions target. To fully reach the targeted 60% less transport CO_2 compared to 1990, other measures will also need to be put into place.

Nudge consumers into buying lighter vehicles by emphasising their benefit

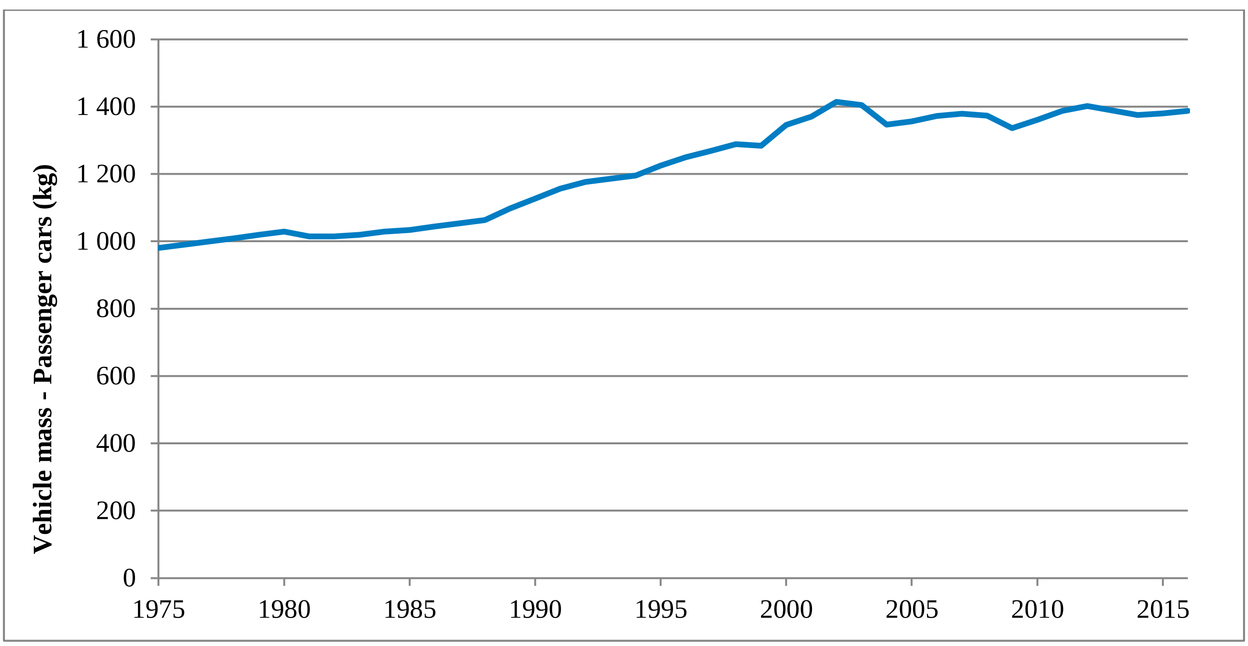
Assuming that vehicle mass reduction does not comprise on the vehicles' safety, lighter cars are advantageous for vehicle owners in delivering a financial benefit. With typical vehicle usage, reduced fueling costs outweigh the increased costs for buying a lighter vehicle. The benefit for the consumer is even higher when also considering environmental benefits.

Study background and objectives

This study assesses the effectiveness of mass reduction of light-duty vehicles (LDVs) for reducing CO_2 emissions in the European Union. Light-duty vehicles comprise passenger cars (PCs, vehicle category M1) and light-commercial vehicles (LCVs, vehicle category N1). The following sections provide an insight into how vehicle mass reduction has increased over time as well as the more specific objectives of this study.

As illustrated in Figure 1, new passenger cars (PC) have become heavier over the past decades in the EU28. Between 1975 and 2015, the average vehicle mass increased around 40%, from c. 1 000 kg to 1 400 kg. Most of this increase took place in the period from 1975 to 2000. Since then, the average mass of new passenger cars has remained relatively stable.

Figure 1. **Past development of the average mass of new passenger cars in the EU28**



Sources: Zachariadis (2006) (for 1975-2000); European Commission (2017a) (for data from 2000-2010); European Commission (2017b) (for data from 2010-2015).

The increase of the average vehicle mass is due to increases across all vehicle segments (Ricardo-AEA, 2015). Figures 2-4 give examples of how the mass of specific vehicle models has developed over time. For example, the mass of the Toyota Corolla has increased by around 60% over a 30-year timeframe. Figure 4 also shows that most recent hybrid or battery-electric versions are typically heavier than their conventional versions. Assuming an increasing uptake of electrified vehicles in the coming years, a further increase of the average mass of newly registered cars in the EU28 is expected.

Figure 2. **Average vehicle mass development example – Opel Corsa**

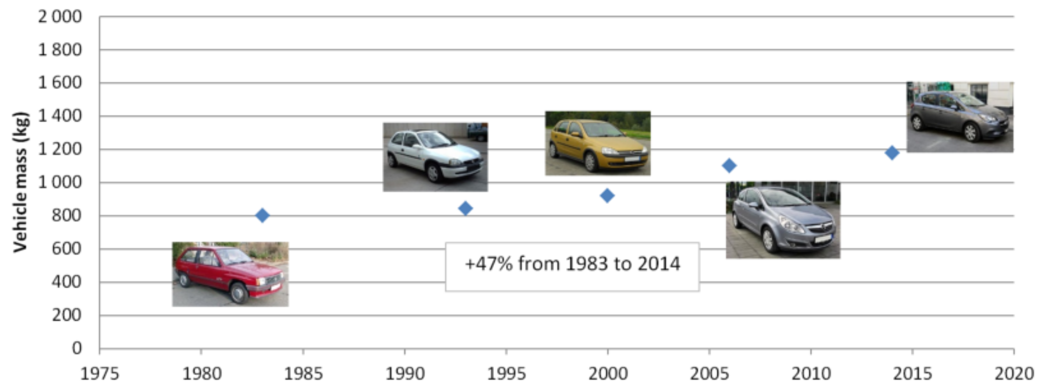


Figure 3. **Average vehicle mass development example – Toyota Corolla**

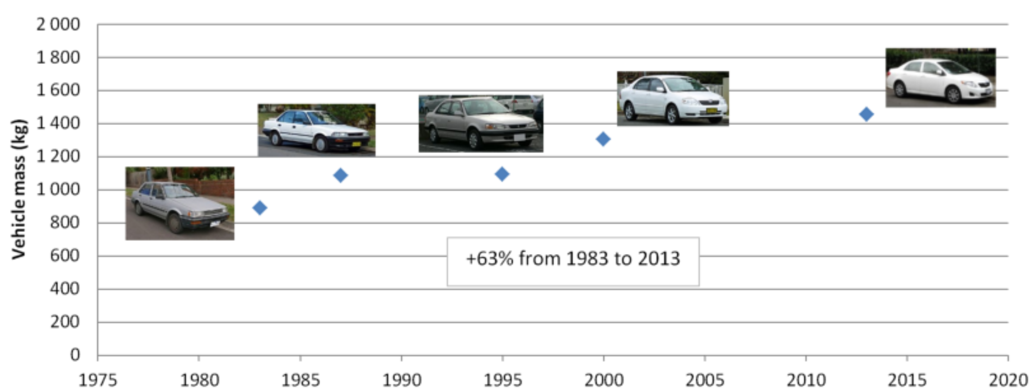
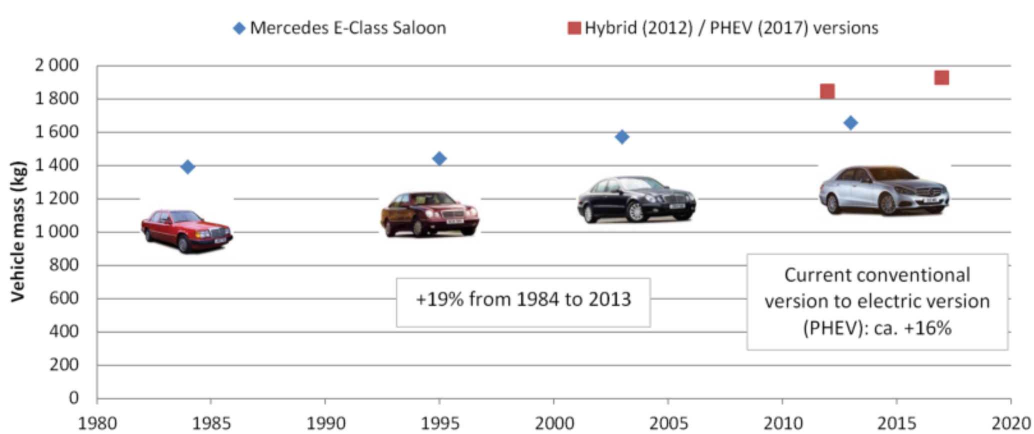


Figure 4. **Average vehicle mass development example – Mercedes E-Class**



Due to the increased driving resistance and inertia of cars with higher mass, heavier cars are less fuel efficient than lighter alternatives. This is especially the case for vehicles that run at relatively low vehicle speeds (up to 60 km/h) and participate in frequent stop-and-go traffic (traffic jams). As a result, heavier cars cause increased levels of CO_2 and pollutant emissions (assuming all else, such as vehicle engine efficiency and powertrain, being equal). Inversely, comparatively lighter vehicles emit lower levels of emissions per kilometre driven or would then at least have the potential to achieve similar emission levels. Reducing the average mass of newly registered vehicles can therefore contribute to reducing CO_2 emissions from road transport.

This study assesses the impact of inversing this trend, i.e. reducing average vehicle mass over the coming decades, on CO_2 emissions from vehicles in the EU28. To achieve this objective, this study will investigate the three following issues:

- **Assess the effectiveness of reducing the mass of light-duty vehicles (LDVs) for decreasing CO_2 emissions from EU road transport up to 2050.**

  For this purpose, a baseline scenario and a mass reduction scenario are developed; CO_2 impacts of the different scenarios are compared to assess how much mass reduction can contribute to CO_2 reduction. Input data and assumptions used to develop the two scenarios are further described in the methodology section.

- **Assess to what degree LDV mass reduction can contribute to the EU 2050 transport decarbonisation targets**.

  The EU transport decarbonisation target was set by the European Commission in the Transport White Paper (European Commission, 2011). It commits to reducing CO_2 emissions from transport by 60% by 2050, compared to 1990 levels. This study assumes that the same target (i.e. a 60% reduction) also applies to the sub-sector of road transport and, more specifically, to LDVs. The gap between the CO_2 emissions reduction achieved in the vehicle mass reduction scenario and the 60% reduction target set by the European Commission is assessed. A so-called target achievement scenario, based on the mass reduction scenario, is developed to show a possible pathway towards achieving the 60% reduction target. The definition of the target achievement scenario and its outputs are provided in the results section of this report.

- **Carry out cost assessments.**

  Cost-benefit assessments are developed for all the different scenarios. The scope of these assessments was set to be monetary consumer costs/benefits (limited to changing vehicle fuel/recharge expenses and vehicle purchase costs), and environmental costs/benefits (limited to CO_2 and specific pollutant emissions). Further information on, and outputs of, the cost assessments can be found in the cost assessment section of this report.

Methodology: From vehicle activity to CO_2 emissions

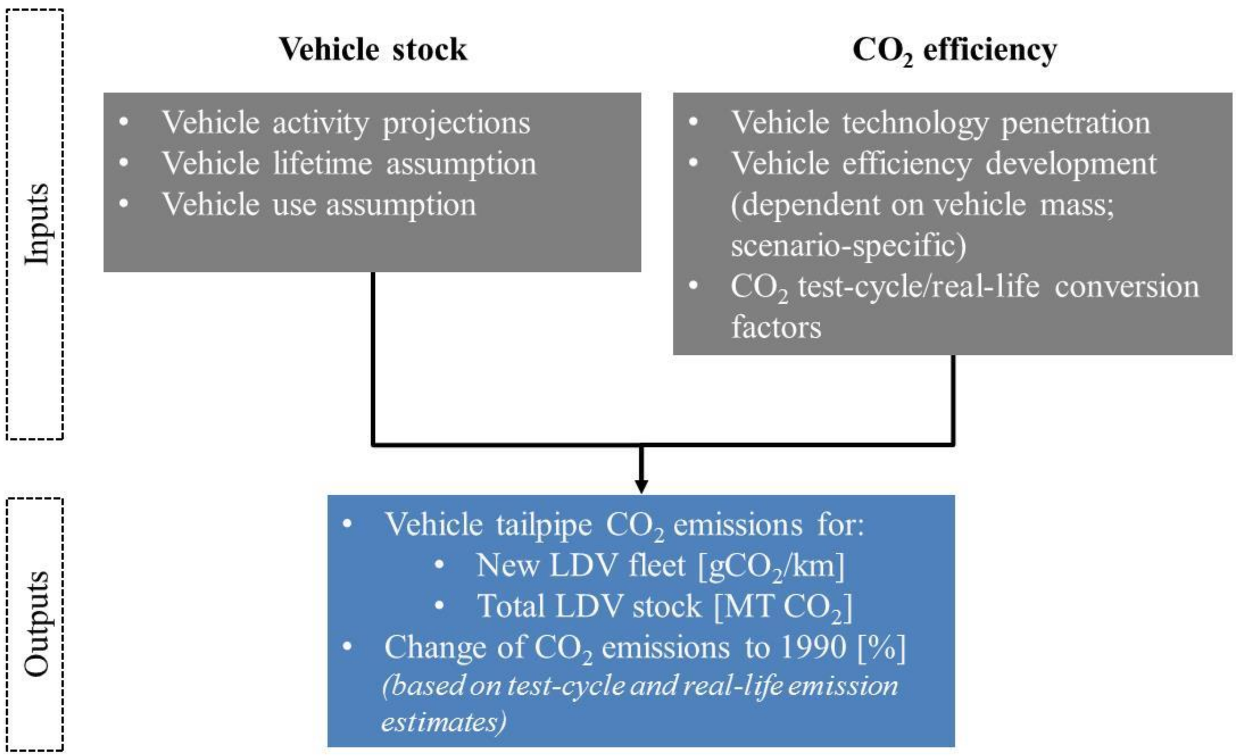
Assessing the effect of new vehicles entering the vehicle fleet on, for example, CO_2 emissions requires a vehicle stock model. In a stock model, new vehicles entering the fleet are traced. This allows meeting the projected demand with vehicle activity. It also retraces when the vehicles leave the fleet - either because they are scrapped, or because they are exported to a secondary market that is not within the scope of the study area. For this study, a spreadsheet vehicle stock model is set up. It represents the EU28 LDV fleet and is based on vehicle activity data projections up to 2050.

Setting up a vehicle stock model requires a set of input assumptions – such as future vehicle activity (from which the required future vehicle stock can be derived), future vehicle characteristics, future vehicle use and the vehicles' lifetime. Whenever available, input assumptions were based on either the baseline scenario of the ITF model framework (for a more detailed description see ITF, 2017,) or the European Commission 2016 reference scenario (European Commission, 2016). The following section provides more information on specific assumptions and input data, and highlights inputs that could not be based on either of the two preferred sources.

Furthermore, assessing CO_2 emissions from the vehicle fleet requires accounting for vehicles' real-life emission values. Real-life emission values can be derived from test-procedure emission values, stemming from the CO_2 and pollutant assessment of vehicles based on, for example, the Worldwide Harmonised Light Vehicles Test Procedure (WLTP, the new emission laboratory test procedure that will be used by the European Commission to set vehicle CO_2 standards) or the New European Driving Cycle (NEDC) test procedure (that has been used for European Union target setting vehicle CO_2 emission targets until today). In this study, conversion factors to derive real-life emission values from test-procedure values are based on ICCT (2015). It was assumed that discrepancies between real-life and test-procedure values remain stable over time up to 2050, i.e. they remain at the levels that were estimated for the most recent year (or, where available, projected for the year 2020). Note that this study accounts for vehicle tailpipe (or tank-to-wheel) emissions only; upstream (or well-to-tank) emissions for any vehicle technology are not considered.

Figure 5 shows the inputs and outputs of the vehicle stock and the emissions model which was developed for this study. The following section sets out the key input data and assumptions in more detail, and develops the baseline and the mass reduction scenarios. The section is structured into three parts, each referring to a different set of data/assumptions for defining the vehicle stock; defining CO_2 emissions from the available vehicle stock; and defining the mass reduction scenario (where different to the baseline scenario).

Figure 5. **Inputs and outputs of the vehicle stock and emissions model**



Vehicle stock

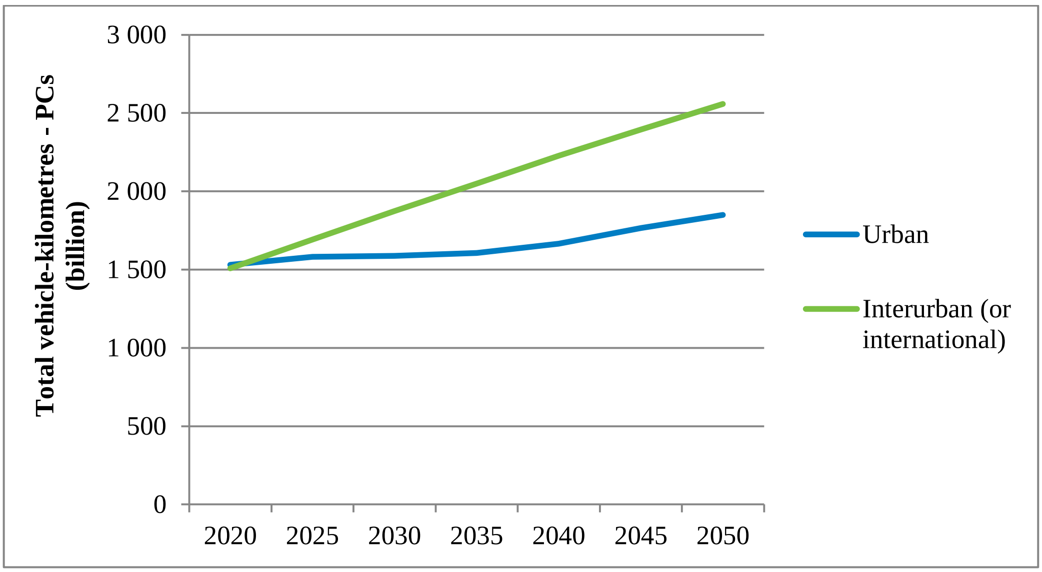
Defining the vehicle stock in the future mainly requires projections of vehicle activity. Figures 6 and 7 provide such projections for the EU28 for LDVs. They are based on the ITF baseline scenario for passenger cars and IEA's MoMo model (IEA, 2016) for light-commercial vehicles.

Total vehicle-kilometres of passenger cars are projected to increase by around 45% in the period from 2020 to 2050. This increase is mainly due to GDP (and related income) growth in former Eastern European countries. The total growth can be broken down into an increase of vehicle activity of around 20% in the urban sector and an increase of around 70% in the inter-urban sector (see Figure 6). The comparatively low increase in the urban sector is thanks to a range of policy measures that help reduce vehicle use in urban areas, such as vehicle use restrictions and measures that enhance mode shift to public transport. Such measures are assumed to be adopted in the baseline scenario, for example, because of the commonly accepted urgency to reduce congestion and pollution in cities. For the inter-urban sector, such measures to control the growth in vehicle activity are limited because of the lack of alternatives and the absence of direct impact of transport on people's quality of life.

Total vehicle-kilometres of light-commercial vehicles are projected to remain stable from 2020 to 2050. Figure 7 shows, however, that urban light-commercial vehicle activity is projected to increase. This is due to a growth of urban areas and a related increase in delivery activities that are carried out with this type of vehicle. Inter-urban activity is projected to decrease, as the increased freight traffic between urban centres is expected to be increasingly covered by heavy duty vehicles, leading to a decline of light-duty vehicle activity in this sub-sector.

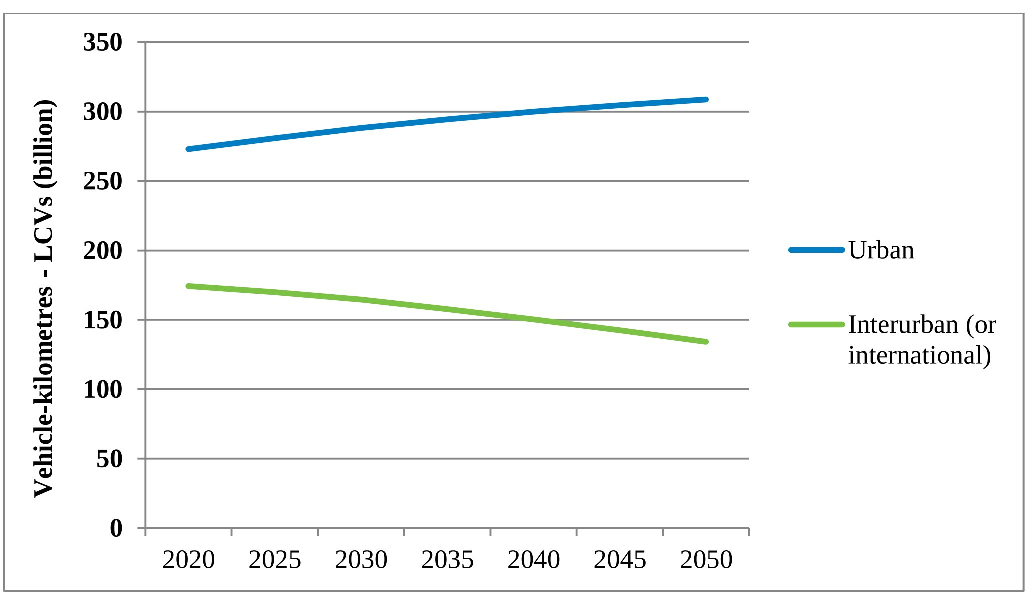
Vehicle activity projections are assumed to be independent of vehicle efficiency. This means that increased vehicle efficiency does not lead to increased vehicle activity as driving gets cheaper for the vehicle user. As vehicle activity projections are a key input assumption to the build of the vehicle stock model, a sensitivity analysis around these projections was carried out. More specifically, the impact of changing the above vehicle activity projections from the European Commission 2016 reference scenario was assessed (see the section Sensitivity Analysis).

Figure 6. **Total vehicle-kilometres forecasts for the EU28 – passenger cars (PCs)**



Source: ITF baseline scenario (ITF, 2017).

Figure 7. **Total vehicle-kilometres forecasts for the EU28 – light-commercial vehicles (LCVs)**

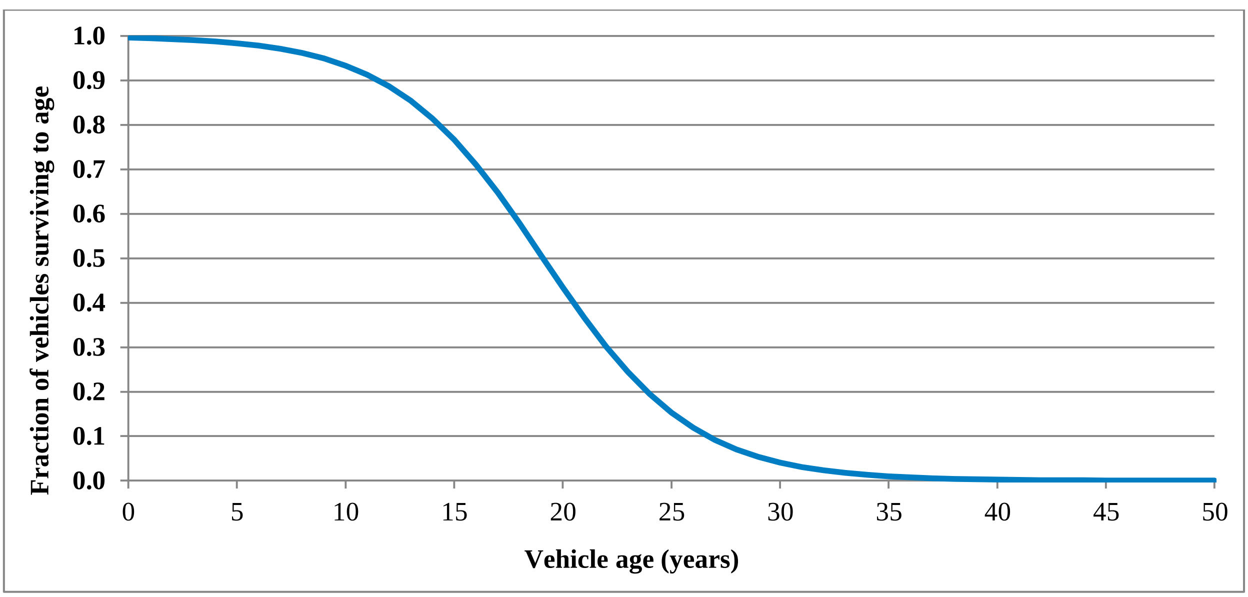


Source: IEA MoMo model (IEA, 2016).

The build of a vehicle stock model also requires assumptions on the typical vehicle lifetime. This allows projecting how many new vehicles will need to enter the fleet at any point in time, to ensure that the future demand for vehicle activity is met. Figure 8 shows the survival curve used for this study. It gives information on the likelihood of a vehicle remaining in the EU28 fleet for at least one more year after having reached a certain age. For example, a 15-year-old vehicle has a likelihood of around 80% of remaining in the fleet for at least one more year. Inversely, there is a 20% likelihood that this vehicle will be scrapped or exported to a non-EU28 market. The curve is assumed to be the same for passenger cars and light-commercial vehicles.

The curve was initially developed for the SULTAN model – a model that was developed for the European Commission for transport policy assessments. It was last updated based on TRACCS data (Ricardo, 2016a) (TRACCS, 2013). The TRACCS data implies an average vehicle age of passenger cars in the European Union of around 10 years in 2010. This is in line with statistics from the European Automobile Manufacturers Association that show an average age of 11 years in 2015 (ACEA, 2017). Despite the age increase of the EU passenger car fleet that these two sources suggest (an increase that is also found in the statistics of ACEA, 2017), the curve is assumed to be constant over time for this study.

Figure 8. **Applied vehicle survival curve (same for PCs and LCVs)**



Source: SULTAN Model (see Ricardo (2016a) and Ricardo (2016b) for more information).

Another relevant input assumption for the vehicle stock model is the vehicle-kilometres covered by a vehicle in a given year. Typically, annual vehicle-kilometres decrease with vehicle age. This trend is accounted for in the stock model, using the TRACCS data that provides averages for the EU28. Table 1 shows the annual vehicle-kilometres by vehicle type and age group. The values provided are assumed to remain constant over time and to be independent of vehicle technology. This is despite the fact that certain vehicle technologies (e.g. diesel, hybrid) frequently show above-average vehicle use. However, given the assumed penetration of different vehicle technologies over time, the assumption of technology-neutral vehicle mileage was judged to be the most suitable in the context of this study.

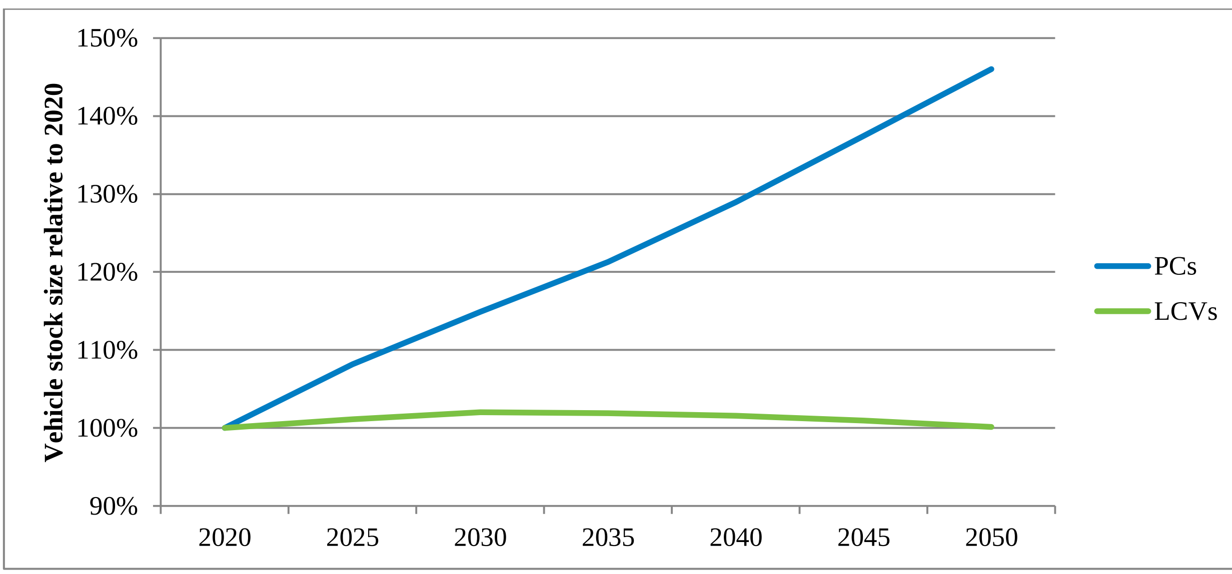
Table 1. **Annual vehicle-kilometres by vehicle type and age group**

Vehicle age	Annual vehicle-kilometres (rounded) PCs	LCVs
0-5	21 400	28 400
5-10	14 600	18 600
10-15	9 700	12 600
15-20	6 700	8 900
20-25	4 800	6 000
25-30	3 200	3 000

Source: Derived from TRACCS (2013).

Figure 9 provides the evolution of the vehicle stock resulting from the above-introduced vehicle activity projections, assumed vehicle lifetimes and annual vehicle-kilometres. Since vehicle lifetimes and annual vehicle-kilometres are constant over time, the stock size development follows the trend of the activity data projections (see Figures 6 and 7).

Figure 9. **Projected vehicle stock growth**

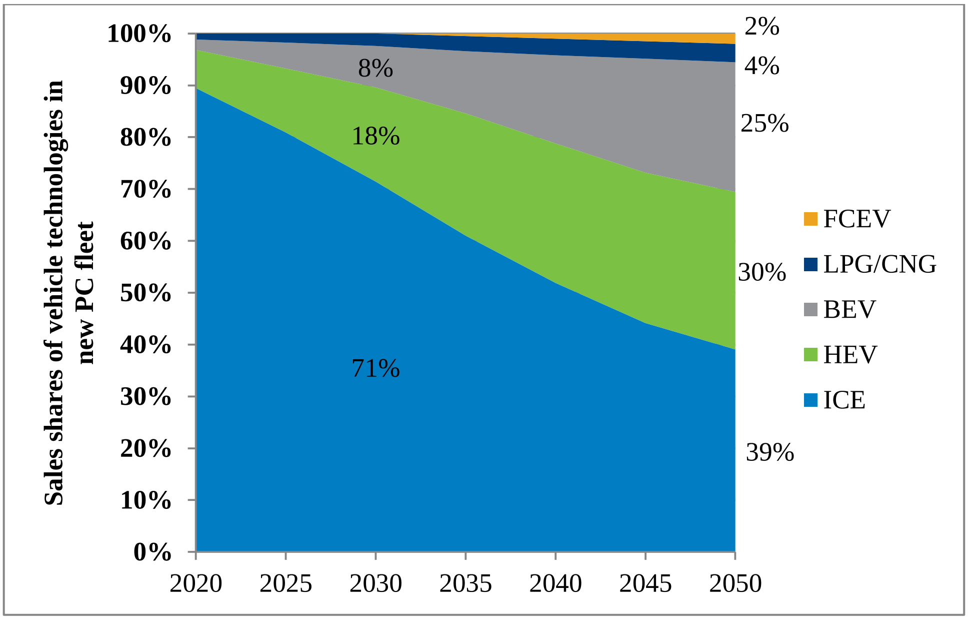


CO_2 emissions from new vehicles up to 2050

The vehicle stock model defines the vehicle fleet in terms of its size and age. To assess the CO_2 emissions resulting from this fleet, it is essential to define its CO_2 characteristics. These depend on the shares of the different vehicle technologies and the average vehicle efficiency per vehicle technology (as well as their respective projections over time).

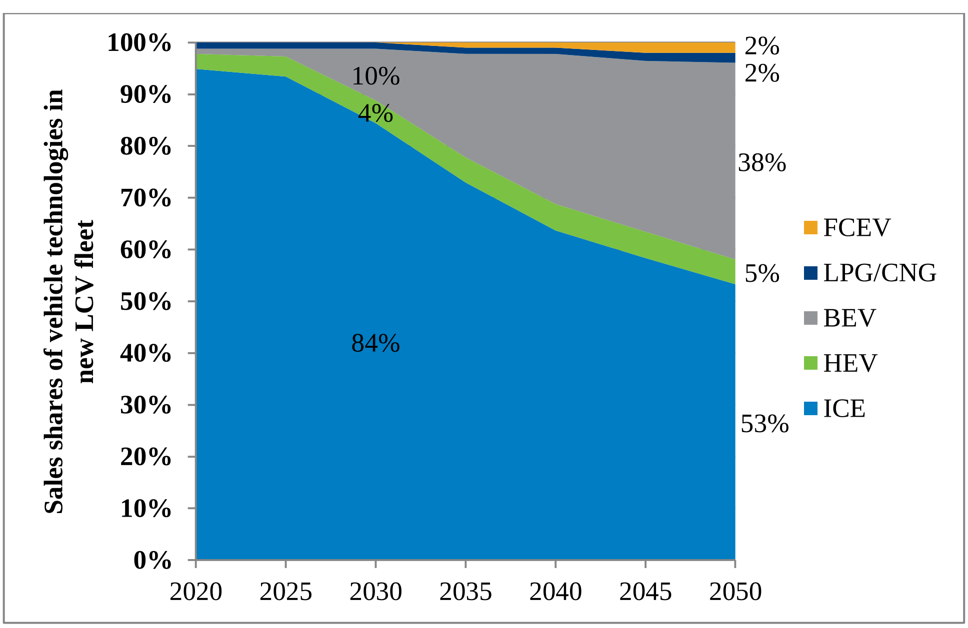
Figures 10 and 11 show the assumed uptake of different vehicle technologies in the EU28 up to 2050 (for passenger cars and light-commercial vehicles respectively). These uptake assumptions are based on the European Commission (EC) 2016 reference scenario (European Commission, 2016) that provides projections for vehicle activity of the total fleet by technology up to 2050. However, given further policy announcements in mid-2016 of several EU Member States that are seen to especially promote the uptake of full electric vehicles (BEVs), it was decided to increase the share of BEVs over time for the baseline, mainly at the cost of hybrid electric vehicles (see Figure 12).

Figure 10. **Assumed sales shares of vehicle technologies in the EU28 – Passenger cars (PCs)**



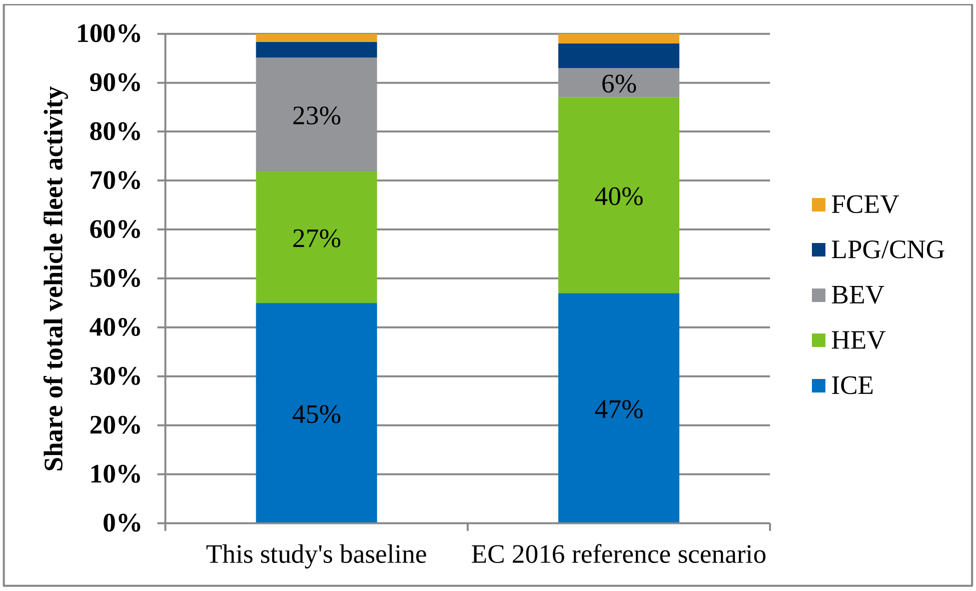
Notes: FCEV – Fuel cell electric vehicles; LPG/CNG – Liquefied petroleum gas/Compressed natural gas vehicles; BEV – Battery electric vehicles; HEV – Hybrid electric vehicles; ICE – Internal combustion engine vehicles

Figure 11. **Assumed sales shares of alternative fuel vehicles in the EU28 – Light-commercial vehicles (LCVs)**



Notes: FCEV – Fuel cell electric vehicles; LPG/CNG – Liquefied petroleum gas/Compressed natural gas vehicles; BEV – Battery electric vehicles; HEV – Hybrid electric vehicles; ICE – Internal combustion engine vehicles

Figure 12. **Total vehicle fleet activity shares by technology - comparison baseline with EC reference scenario (PCs and LCVs combined)**



Notes: FCEV – Fuel cell electric vehicles; LPG/CNG – Liquefied petroleum gas/Compressed natural gas vehicles; BEV – Battery electric vehicles; HEV – Hybrid electric vehicles; ICE – Internal combustion engine vehicles

In the baseline scenario, the future vehicle mass of passenger cars follows the trend of the relatively modest mass increase of the period from 2000 to 2015 (see Figure 1). Given the lack of comparable data, LCVs are assumed to follow the same development. This moderate increase (of around 2% over the period 2015-50) is applied to each vehicle technology, resulting in a comparatively higher increase of the fleet average given the increasing share of heavier vehicle technologies (e.g. hybrid vehicles) over time (as shown in Figures 10 and 11 for PCs and LCVs respectively). Table 2 shows the assumed fleet average mass development for PCs and LCVs in the baseline scenario.

Table 2. **Assumed baseline vehicle mass development – average of new vehicle fleet (PCs and LCVs)**

	Observed	*Assumed baseline development*						
(in kg)	**2015**	*2020*	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
PCs	1 380	1 386	1 409	1 411	1 429	1 454	1 480	**1 496**
LCVs	1 758	1 695	1 655	1 629	1 607	1 585	1 576	**1 565**

Note: Accounting for changing sales shares of different vehicle technologies - as provided in Figures 10 and 11.

Tables 3 and 4 provide the assumed development of vehicle fuel/CO_2 efficiency by technology (expressed in gCO_2/km; based on NEDC and WLTP values) up to 2050. It is assumed that European Commission 2020/2021 CO_2 targets for the average vehicle fleet are met (i.e. 95g CO_2/km for passenger cars and 147g CO_2/km for light-commercial vehicles). To define the respective vehicle efficiency values by vehicle type, observed vehicle efficiency values (in gCO_2/km) from the year 2015 (European Commission, 2017b) are assumed to decrease uniformly until 2020 targets are met. Each technology, except those with zero tailpipe emission, is assumed to experience the same relative efficiency improvement.

After 2020, vehicle efficiency values by technology improve moderately, i.e. by 0-2% over each five-year period (despite the assumed vehicle mass increase of 2% over the period 2015-50 per vehicle technology). It is assumed that such moderate improvements reflect consumer-driven vehicle efficiency gains. Additional efficiency improvements due to potentially increasingly stringent policy measures (such as tighter vehicle CO_2 standards) are not considered. Note that fleet average values improve by more than 0-2% over each five-year period. This is due to an increasing share of cleaner, more fuel-efficient technologies entering the vehicle fleet over time (in line with Figures 10 and 11).

Battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) are considered to be zero-emission vehicles – in line with how European Commission CO_2 standards are set and how transport-sector emissions are typically assessed. As already mentioned earlier, this means that only vehicle tailpipe, or tank-to-wheel (TTW), emissions, but no upstream (or well-to-tank, WTT), are considered for any of the vehicle technologies in this study's CO_2 assessment.

As mentioned previously, conversion factors in line with ICCT (2015) are used to derive real-life emission values from test-procedure emission values (and vice-versa). Depending on the test procedure, ICCT (2015) provides year-specific conversion factor estimates (for around 5-year intervals) up to the year 2020 (for NEDC) and 2025 (for WLTP). For later years, these most recent conversion factors are assumed to stay constant – this means that the discrepancy between test-procedure emission values and real-life emission values remains stable up to 2050. On average, a NEDC conversion factor of 1.5 was applied for passenger cars, and of 1.4 for light-commercial vehicles from 2020 onwards (meaning that real-life emissions are approximately 50%, or respectively 40%, higher than test-cycle values based on the NEDC). To give an idea of approximate respective WLTP-based values, a corresponding factor of around 1.3 for passenger cars and light-commercial vehicles was applied from 2025 onwards (meaning that real-life emissions are assumed to be approximately 30% higher than values based on the WLTP). The exact conversion factors vary with vehicle fuel type and type of vehicle-kilometres driven (urban vs. non-urban), in line with ICCT (2015). As a result of the projected changes in vehicle technology shares and urban vs. non-urban kilometres (as presented earlier), average conversion values (for the whole vehicle fleet, but also for single vehicle technologies) vary slightly over the regarded timeframe.

Table 3. **Assumed vehicle efficiency development of new vehicles by technology (in NEDC and WLTP values) – PCs**

(in gCO_2/km)	2020	2025	2030	2035	2040	2045	2050
NEDC							
ICE	101	100	98	97	96	95	95
LPG/CNG	94	93	91	89	88	87	87
HEV	49	45	43	42	41	41	41
BEV	0	0	0	0	0	0	0
FCEV	0	0	0	0	0	0	0
WLTP							
ICE	123	114	112	111	110	108	109
LPG/CNG	113	106	103	101	100	99	99
HEV	60	51	49	48	47	46	46
BEV	0	0	0	0	0	0	0
FCEV	0	0	0	0	0	0	0

Table 4. **Assumed vehicle efficiency development of new vehicles by technology (in NEDC and WLTP values) – LCVs**

(in gCO_2/km)	2020	2025	2030	2035	2040	2045	2050
			NEDC				
ICE	151	146	142	140	138	136	136
LPG/CNG	126	124	121	120	119	118	118
HEV	91	89	87	86	84	82	80
BEV	0	0	0	0	0	0	0
FCEV	0	0	0	0	0	0	0
			WLTP				
ICE	167	153	149	147	145	143	142
LPG/CNG	144	134	131	129	128	126	126
HEV	102	94	92	91	89	86	85
BEV	0	0	0	0	0	0	0
FCEV	0	0	0	0	0	0	0

Mass reduction scenario

In the mass reduction scenario, the average vehicle mass reduces to 1 000 kg (from 1 380 kg) for passenger cars, and to 1 100 kg (from 1 758 kg) for light-commercial vehicles, by 2050. This mass reduction was assumed to happen linearly over time. Table 5 shows the resulting assumed vehicle mass development by technology. Studies have shown that such mass reductions can be achieved without compromising safety or general vehicle performance (see e.g. Busse et al., 2017), or even argue that they bring benefits for, for example, road safety, driving comfort and road wear (e.g. GFEI, 2017; EAA, 2015).

Table 5. **Assumed average vehicle mass development for the mass reduction scenario - by vehicle technology, new vehicle fleet**

	Observed	*Assumed vehicle mass development in mass reduction scenario (new vehicle average mass)*						
(in kg)	**2015**	*2020*	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
				PCs				
ICE	1 379	1356	1 279	1 180	1 091	1 019	956	893
LPG/CNG	1 292	1 295	1 214	1 138	1 067	1 000	937	879
HEV	1 600	1 703	1 513	1 387	1 296	1 214	1 137	1 066
BEV	1 589	1 593	1 493	1 400	1 312	1 230	1 153	1 081
FCEV	1 922	1 927	1 806	1 693	1 587	1 488	1 394	1 307
Average of new fleet	*1 380*	1386	*1 317*	*1 234*	*1 168*	*1 112*	*1 058*	***1 000****
				LCVs				
ICE	1 762	1 699	1563	1 460	1 364	1 273	1 193	1 114
LPG/CNG	1 624	1 628	1 539	1 455	1 375	1 300	1 229	1 162
HEV	1 352	1 659	1 566	1 479	1 398	1 304	1 209	1 121
BEV	1 491	1 495	1 413	1 336	1 263	1 193	1 128	1 066
FCEV	1 736	1 740	1 645	1 555	1 470	1 390	1 314	1 242
Average of new fleet	*1 758*	*1 695*	*1 560*	*1 449*	*1 348*	*1 253*	*1 175*	***1 100****

Notes: Fleet averages account for changing sales shares of different vehicle technologies - as provided in Figures 10 and 11.
* Target value

The vehicle efficiency gains related to mass reduction come from a study carried out by ifeu (2016). Ifeu modelled the impact of a vehicle mass reduction of 100 kg on vehicle fuel/energy use. The specific values used for this study refer to mixed vehicle use and include so-called secondary effects of primary mass reduction. Secondary effects account for any adjustment to the vehicle made possible by mass reduction. The secondary effects considered by ifeu (2016) are limited to adjusted power-to-weight ratios of the vehicles. Resulting estimates of secondary effects are therefore considered to be "conservative". Fuel savings are found to be higher for petrol vehicles than for diesel vehicles, which is mainly explained by the generally higher fuel consumption of petrol vehicles.

Since ifeu (2016) does not provide an assessment for all vehicle technologies considered in this study, several additional assumptions are required (see Table 6). The values provided translate to a 6% (or 7%) reduction in energy consumption when reducing the mass of petrol (or diesel) passenger cars by around 10%. This is, for example, in line with ICCT (2017) where these values are provided for mass reduction incl. related engine downsizing. Energy savings for BEVs and FCEVs are only relevant for cost assessments (as provided later in this report). For CO_2 emissions analysis they do not play a role in this study, given that only vehicle tailpipe (but no upstream, or well-to-tank) emissions are considered. Given that the mass reduction scenario looks at vehicle mass reductions in the range of around 400 to 600 kg, an assumption had to be made as to how to scale up energy savings observed for a 100 kg mass reduction. Relevant alternative literature sources that provide estimates of energy savings thanks to mass reductions above 10% for the different fuel types could not be identified. Our central hypothesis is that these energy savings could be linearly scaled (i.e. a 400 kg reduction brings four times the energy savings of a 100 kg reduction). The section on sensitivity analysis provides scenario results with a more conservative assumption concerning energy savings.

Table 6. **Assumed vehicle efficiency gains/energy savings for 100 kg mass reduction – PCs and LCVs**

	Petrol *(l/100km)*	Diesel *(l/100km)*	LPG *(l/100km)*	HEV	BEV *(kWh/100km)*	FCEV
PCs	0.32	0.23	(1)	(2)	0.64	(3)
LCVs	0.32	0.21	(1)	(2)	0.64	(3)

Source: ifeu (2016).

Notes: The used values include secondary mass reduction effects and refer to mixed vehicle use; (1) Assumed to be equal to petrol vehicles; (2) Assumed to be 80% of petrol/diesel (depending on the type of HEV) – in line with indicative result in ifeu (2016); (3) Assumed to be equal to BEVs.

Modelling results

The following paragraphs provide the scenario results. First, results for the baseline and mass reduction scenarios are provided. The second section provides an option for achieving the European Commission's transport decarbonisation target (i.e. -60% CO_2 by 2050, compared to the 1990 base year), i.e. the target achievement scenario. Results are provided in terms of the average new fleet emission values up to 2050 (in NEDC, WLTP and real-life emission estimates) and the change in total CO_2 emissions of the respective vehicle fleet compared to real-life CO_2 emission estimates of the respective vehicles in 1990 (also based on NEDC, WLTP and real-life emission estimates).

CO_2 emissions in the baseline and mass reduction scenarios

Table 7 provides the results of the baseline scenario. CO_2 emissions from the passenger car fleet are projected to reduce by 21% by 2050, compared to 1990, despite the projected vehicle activity increase (see Figure 6). This is due to the moderate vehicle efficiency improvements and, especially, the future uptake of alternative vehicle technologies (see Figure 10). New passenger cars are assumed to emit around 78 gCO_2/km (in real-life estimates) in 2050 (or 60 gCO_2/km in WLTP terms and 53 gCO_2/km NEDC terms). The 21% reduction equates to a reduction of around 100 MT CO_2 compared to 1990 levels. The CO_2 reduction of the total EU28 light-commercial vehicle fleet attains a similar value in 2050 (24%, or around 20 MT CO_2 reduction compared to 1990). Given the relatively small impact of light-commercial vehicles, the total projected CO_2 reduction in the baseline scenario for the total light-duty vehicle fleet (PCs and LCVs) amounts to around 21% (or around 120 MT CO_2) by 2050, compared to 1990.

Table 7. **Results for the baseline scenario – PCs and LCVs**

	2020	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
PCs							
Average new vehicle fleet CO_2 emissions (gCO_2/km) based on…							
Real-life estimates	143	132	119	106	94	84	78
WLTP	*116*	*100*	*92*	*82*	*73*	*65*	*60*
NEDC	*95*	*88*	*80*	*72*	*64*	*57*	*53*
Resulting change in total CO_2 emissions (%) compared to 1990 based on…							
Real-life estimates	9%	3%	-4%	-9%	-14%	-18%	-21%
WLTP	*-12%*	*-19%*	*-25%*	*-30%*	*-33%*	*-37%*	*-39%*
NEDC	*-21%*	*-29%*	*-35%*	*-39%*	*-41%*	*-44%*	*-46%*
LCVs							
Average new vehicle fleet CO_2 emissions (gCO_2/km) based on…							
Real-life estimates	201	193	172	148	128	117	107
WLTP	*164*	*148*	*131*	*113*	*98*	*90*	*82*
NEDC	*147*	*141*	*125*	*108*	*94*	*85*	*78*
Resulting change in total CO_2 emissions (%) compared to 1990 based on…							
Real-life estimates	37%	33%	24%	10%	-4%	-15%	-24%
WLTP	*11%*	*5%*	*-4%*	*-15%*	*-26%*	*-35%*	*-42%*
NEDC	*6%*	*-1%*	*-9%*	*-20%*	*-30%*	*-38%*	*-45%*

The vehicle mass reduction scenario results for passenger cars in a CO_2 reduction of 40% by 2050, compared to 1990 (see Table 8). This equates to an additional reduction of around 85 MT CO_2 compared to the baseline scenario. The average new passenger car fleet would attain an average emission value of 56 gCO_2/km (compared to 78 gCO_2/km in the baseline scenario; both in real-life estimates). Emissions from light-commercial vehicles emit 35% less in 2050 than in 1990. This equates to an additional CO_2 reduction of 5 MT compared to the baseline scenario. In total, the light-duty vehicle fleet (PCs and LCVs combined) would reduce its CO_2 emissions by around 39% in 2050 compared to 1990 (or by around 210 MT).

Table 8. **Results for the vehicle mass reduction scenario – PCs + LCVs**

	2020	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
PCs							
Average new vehicle fleet CO_2 emissions (gCO_2/km)] based on…							
Real-life estimates	143	126	109	92	77	64	56
WLTP	*116*	*96*	*84*	*71*	*59*	*50*	*43*
NEDC	*95*	*84*	*73*	*62*	*52*	*44*	*38*
Resulting change in total fleet CO_2 emissions compared to 1990 based on…							
Real-life estimates	9%	1%	-9%	-18%	-26%	-33%	-40%
WLTP	*-12%*	*-20%*	*-29%*	*-36%*	*-43%*	*-49%*	*-53%*
NEDC	*-21%*	*-30%*	*-38%*	*-44%*	*-50%*	*-55%*	*-59%*
LCVs							
Average new vehicle fleet CO_2 emissions (gCO_2/km) based on…							
Real-life estimates	201	188	162	136	114	102	91
WLTP	*164*	*144*	*124*	*104*	*88*	*78*	*69*
NEDC	*147*	*137*	*118*	*99*	*84*	*74*	*66*
Resulting change in total fleet CO_2 emissions compared to 1990 based on…							
Real-life estimates	37%	31%	20%	4%	-12%	-25%	-35%
WLTP	*11%*	*4%*	*-7%*	*-20%*	*-33%*	*-42%*	*-50%*
NEDC	*6%*	*-2%*	*-12%*	*-24%*	*-36%*	*-45%*	*-52%*

In summary, compared to the baseline scenario, the mass reduction scenario achieves an additional reduction of CO_2 emissions from the light-duty vehicle fleet of around 18% (39% compared 21% in the baseline scenario) in 2050, compared to 1990 levels. The projected total reduction of 39% is, however, insufficient to meet European Union transport decarbonisation targets by 2050, i.e. a 60% reduction compared to 1990.

Development of 2050 target achievement scenario

The purpose of the 2050 target achievement scenario is to show a possible pathway for meeting the EU 2050 transport decarbonisation target (i.e. a reduction of CO_2 emissions by 60% compared to 1990 levels). On top of the mass reduction scenario, an additional reduction of 21% is required. There are numerous options that would allow achieving such an additional reduction, assuming that the mass reduction levels assessed in this study remain in place. For example, compared to the assumptions of the baseline and mass reduction scenarios, any of the following measures could be taken:

- Incite further vehicle efficiency improvements (e.g. by enhancing the vehicles' rolling resistance, further powertrain efficiency improvements or improving aerodynamics).

- Enhance mode shift (e.g. to rail, walking or cycling) or optimise or reduce travel activity (e.g. thanks to land use planning to reduce trip lengths) that would both result in a reduction of the projected growth of vehicle activity.
- Further increase the share of alternative fuel vehicles in the total vehicle fleet (e.g. the share of local zero-emission vehicles, i.e. BEVs or FCEVs).

In the target achievement scenario, only the third option is considered: It assesses to what degree zero-emission vehicles need to enter the fleet to ensure that the 2050 EU transport CO_2 target is met (while still assuming that the vehicle mass reduction to an average of 1 000 kg for PCs and 1 100 for LCVs to 2050 remains in place). For this purpose, it was assumed that any increase in the BEV/FCEV share is drawn proportionately from all other technologies.

Figures 13 and 14 show the results for PCs and LCVs respectively. The 2050 target can be met in case vehicle mass reduction happens at the pace and to the extent of the mass reduction scenario, and the share of zero-emission passenger cars (and light-commercial vehicles) increases to 64% (and 68%) by 2050 (compared to 27% [and 40%] in the baseline scenario). This results in a reduction of CO_2 emissions of around 320 MT (or around 280 MT for PCs and 40 MT for LCVs) by 2050, compared to 1990 levels (all based on real-life emission estimates). The average CO_2 emission values of the new vehicle fleet are at 28 gCO_2/km for PCs and 49 gCO_2/km for LCVs (in real-life estimates; see Table 9).

Figure 13. **Required uptake of BEV/FCEVs to meet 2050 target (assuming mass reduction as per respective scenario) – PCs**

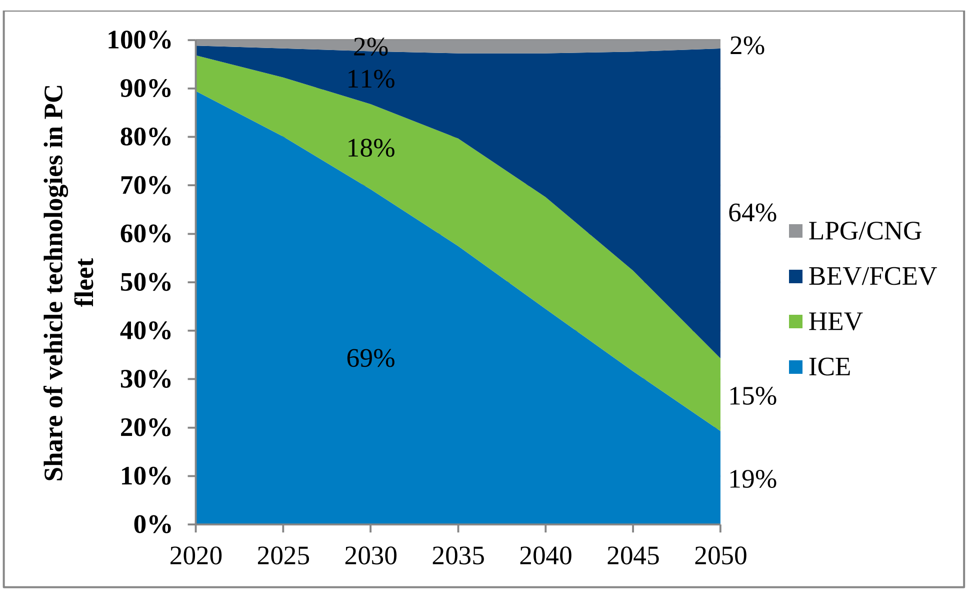


Figure 14. **Required uptake of BEV/FCEVs to meet 2050 target (assuming mass reduction as per respective scenario) – LCVs**

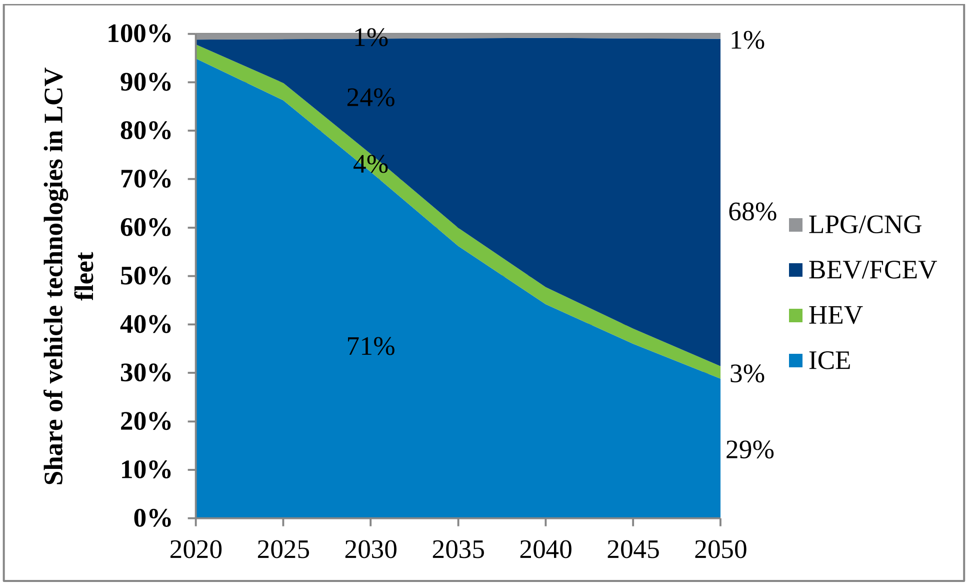


Table 9. **Results for the 2050 target achievement scenario – PCs + LCVs**

	2020	*2025*	*2030*	*2035*	*2040*	*2045*	*2050*
			PCs				
Average new vehicle fleet CO_2 emissions (gCO_2/km) based on…							
Real-life estimates	143	125	106	86	66	46	28
WLTP	*116*	*95*	*81*	*67*	*51*	*36*	*21*
NEDC	*95*	*83*	*71*	*59*	*45*	*31*	*19*
Resulting change in total fleet CO_2 emissions compared to 1990 based on…							
Real-life estimates	9%	0%	-10%	-21%	-32%	-45%	-60%
WLTP	*-12%*	*-21%*	*-30%*	*-39%*	*-48%*	*-58%*	*-69%*
NEDC	*-21%*	*-31%*	*-39%*	*-46%*	*-54%*	*-63%*	*-73%*
			LCVs				
Average new vehicle fleet CO_2 emissions (gCO_2/km)							
Real-life estimates	201	174	137	105	79	63	49
WLTP	*164*	*133*	*105*	*80*	*61*	*48*	*38*
NEDC	*147*	*127*	*100*	*76*	*58*	*46*	*36*
Resulting change in total fleet CO_2 emissions compared to 1990 based on…							
Real-life estimates	37%	27%	9%	-13%	-32%	-48%	-60%
WLTP	*11%*	*0%*	*-15%*	*-33%*	*-48%*	*-60%*	*-69%*
NEDC	*6%*	*-5%*	*-20%*	*-36%*	*-51%*	*-62%*	*-71%*

Sensitivity analysis

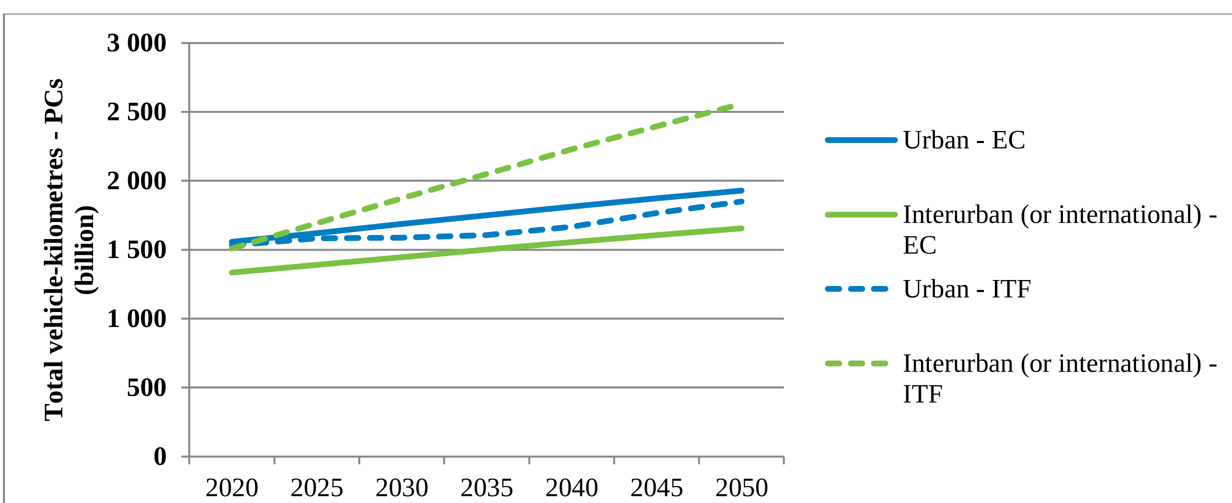
The baseline, mass reduction and target achievement scenarios are all based on a set of underlying assumptions described earlier. This section explores the impact of specific changes to some of the assumptions on scenario results. The first paragraph shows the impact of changing the assumption regarding future vehicle activity; the second paragraph then assesses a change to the degree of vehicle efficiency improvements coming with vehicle mass reduction.

Change in the underlying vehicle activity data

As described earlier (see Figures 6 and 7), projections for vehicle activity in this study stem from the ITF model suite (for PCs) and IEA's MoMo model (for LCVs). They are different for PCs and LCVs, and moreover for urban and non-urban vehicle activity. The European Commission (EC) 2016 reference scenario also provides transport demand forecasts (European Commission, 2016). However, the EC reference scenario does not differentiate between urban and non-urban transport; also, EC projections provide passenger-kilometres and tonne kilometres rather than vehicle-kilometres. As a result, certain assumptions had to be made to allow for comparisons with projections from the ITF/IEA models: vehicle load factors were assumed to be in line with ITF/IEA models; urban and non-urban growth in the EC scenario were assumed to be the same; and vehicle activity levels stemming from the EC and ITF/IEA models were put at the same level in year 2010 (the year for which the European Commission [2016] starts providing growth rates for the EC reference scenario).

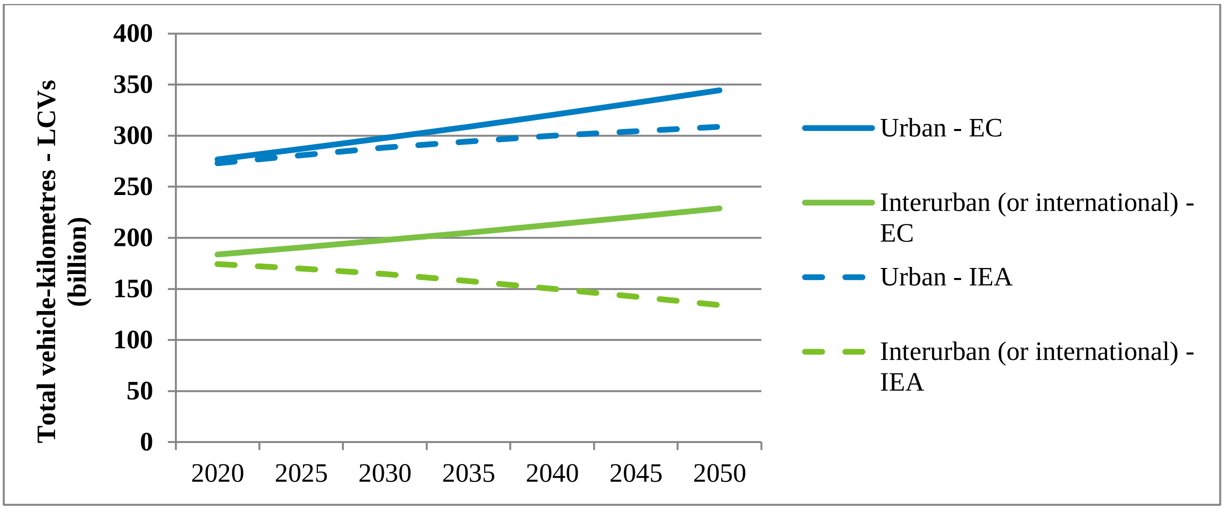
Figures 15 and 16 compare the projections from the EC and the ITF/IEA. The EC projects less growth in interurban passenger car activity than ITF; the growth in urban passenger car activity is similar. Concerning LCVs, the EC projects higher growth compared to IEA. Reasons for differences in projections could not be assessed based on the limited information provided in European Commission (2016).

Figure 15. **Vehicle activity projections – Comparison of ITF and European Commission projections - PCs**



Notes on EC projections: Due to lack of further information, urban and non-urban vehicle activity assumed to grow at the same rate.

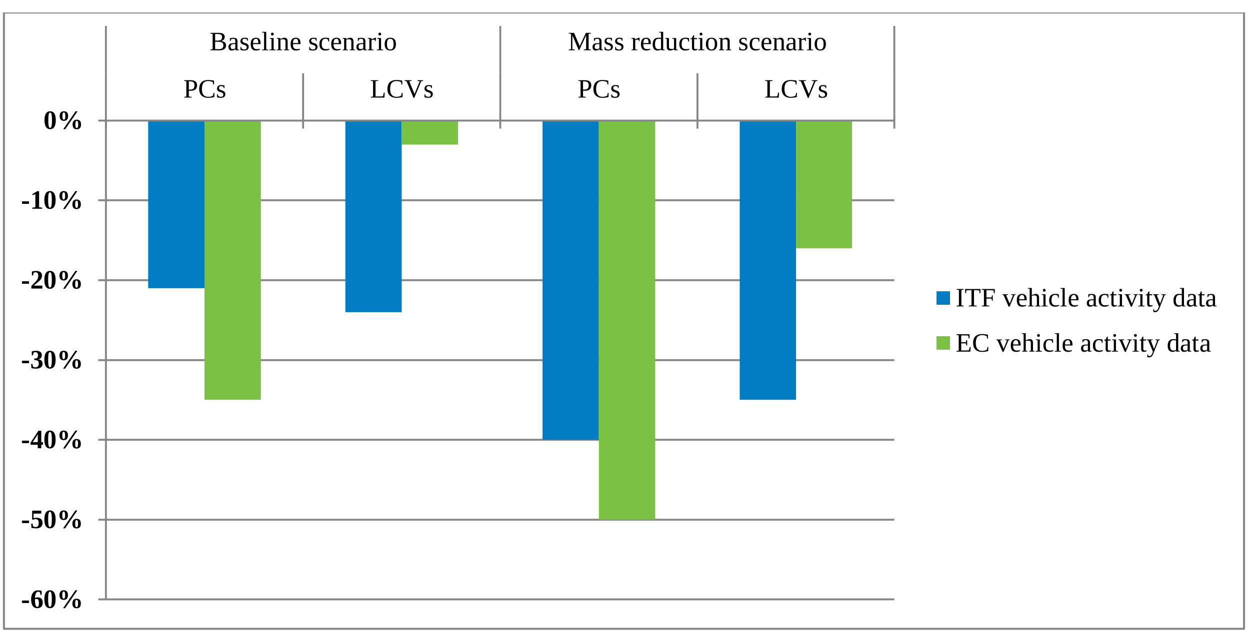
Figure 16. **Vehicle activity projections – Comparison of IEA and European Commission projections – LCVs**



Notes on EC projections: Due to lack of further information, urban and non-urban vehicle activity assumed to grow at the same rate.

Figure 17 provides results for the baseline and mass reduction scenarios based on the different vehicle activity projections. If based on EC projections, the baseline scenario results in a 34% CO_2 emission reduction by 2050 for passenger cars (compared to 21% if based on ITF projections). Inversely, for light-commercial vehicles, EC activity projections result in significantly less CO_2 reductions than IEA projections, given the EC's more pessimistic outlook on the development of LCV activity up to 2050 (i.e. projecting more growth). These differences are carried forward to the mass reduction scenario to a similar extent.

Figure 17. **Change in total fleet CO_2 emissions compared to 1990 for different vehicle activity data (based on real-life CO_2 estimates)**



As a result of the differences in vehicle activity projections, average vehicle CO_2 emissions (in gCO_2/km) for new vehicle sales also need to attain different levels to achieve a 60% reduction (as modeled in the target achievement scenario). They may be less stringent for passenger cars, but more stringent for LCVs by 2050 if projections are based on EC data rather than on projections from ITF/IEA (see Table 10).

Table 10. **Average 2050 emission values for new vehicles (in NEDC terms) for different vehicle activity data – PCs + LCVs, by scenario**

(in gCO_2/km)	ITF/IEA vehicle activity data			EC vehicle activity data		
	Baseline scenario	**Mass reduction scenario**	**Target achievement scenario**	**Baseline scenario**	**Mass reduction scenario**	**Target achievement scenario**
PCs	53	38	**19**	53	38	**27**
LCVs	78	66	**36**	78	66	**25**

Change in the assumed vehicle efficiency gains thanks to mass reduction

A critical assumption for the assessment of the mass reduction scenario is the degree to which vehicle mass reductions result in vehicle efficiency improvements. As described earlier, such assumptions are based on data obtained from ifeu (2016) that provides energy savings for a 100 kg vehicle mass reduction. These estimates were converted to CO_2 savings (in gCO_2/km) and scaled linearly, i.e. it was assumed that the same vehicle efficiency improvements can be achieved for the first 100 kg mass reduction as for the last 100 kg of mass reduction. For instance, if a vehicle efficiency improvement of 10 gCO_2/km for reducing mass from 1 200 to 1 100 kg can be obtained, then the same efficiency improvement can also be obtained for reducing this vehicle's mass further from 1 100 to 1 000 kg – exact values depending on the fuel type.

This section provides scenario results with a more conservative assumption regarding such vehicle efficiency improvements. More specifically, we now assume that vehicle mass reductions that surpass 100 kg would achieve only 50% of the vehicle efficiency gains that can be achieved for the first 100 kg of mass reduction. Taking the same example as earlier, if efficiency improvements of 10 gCO_2/km for reducing from 1 200 to 1 100 kg can be achieved, then only 5g gCO_2/km for reducing the vehicle's mass further from 1 100 to 800 kg can be achieved – exact values depend on fuel type.

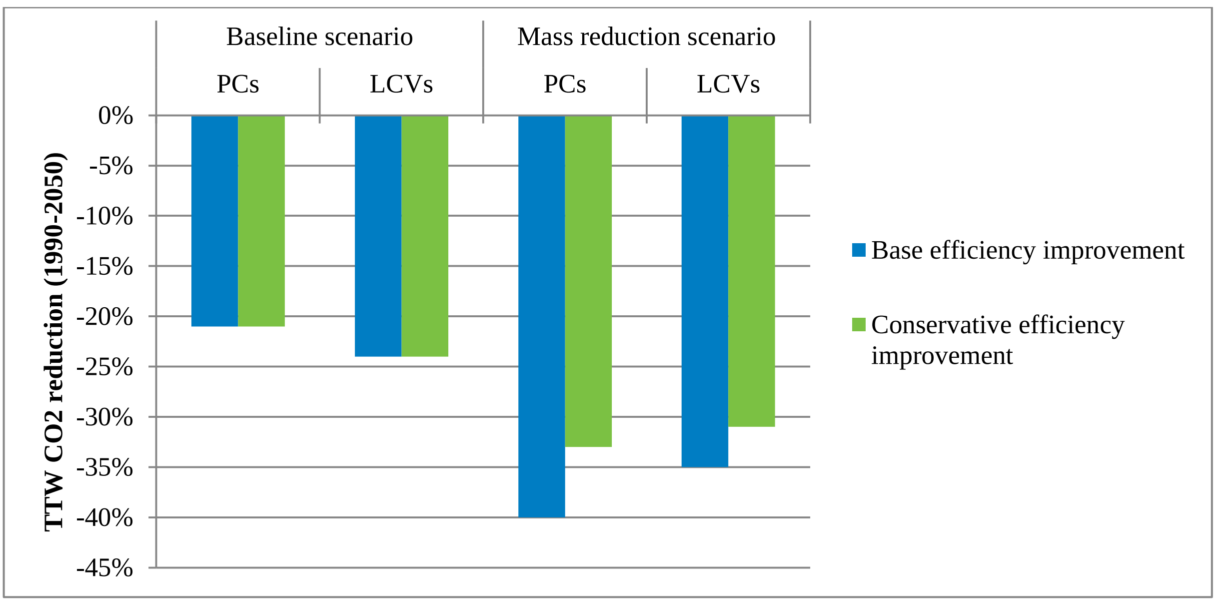
Table 11 shows the average CO_2 emissions of the new vehicle fleet in 2050 that result from the different assumptions regarding vehicle efficiency improvements thanks to vehicle mass reduction. With conservative efficiency improvements, the average CO_2 emissions from passenger cars increases to 44 gCO_2/km (in NEDC terms) compared to the 38 gCO_2/km in the base case of the mass reduction scenario. Meeting the 60% reduction in the target achievement scenario requires an increased share of zero-emission vehicles in the new fleet when assuming conservative vehicle efficiency improvements. In the base case, for passenger cars, a share of 64% is required; in the conservative case, an increase of this share to 71% is required. For light-commercial vehicles, the respective shares amount to 68% in the base case, and 70% in the conservative case.

Figure 18 provides the respective scenario results. Evidently, an impact on total CO_2 reductions can only be observed in the mass reduction scenario. For passenger cars, the total CO_2 reduction compared to 1990 reduces for the mass reduction scenario from 40% to 33%.

Table 11. **Average 2050 emission values for new vehicle fleet (in NEDC terms) for different vehicle efficiency improvement assumptions in the mass reduction scenario**

(in gCO_2/km)	Base efficiency improvements			Conservative efficiency improvements		
	Baseline scenario	**Mass reduction scenario**	**Target achievement scenario**	**Baseline scenario**	**Mass reduction scenario**	**Target achievement scenario**
PCs	53	**38**	19	53	**44**	19
LCVs	78	**66**	36	78	**71**	36

Figure 18. **Change in total fleet CO_2 emissions compared to 1990 for different vehicle efficiency improvement assumptions (based on real-life CO_2 estimates)**



Note: TTW – tank-to-wheel (tailpipe).

Cost assessment

All scenarios underwent a cost assessment. Given the constraints of this study, the scope of these assessments is limited to two cost categories: 1) environmental costs, considering only vehicle tailpipe CO_2 and pollutant emissions (NOx, PM, CO, HC), and 2) consumer costs, considering only monetary costs for vehicle refuelling/recharging and vehicle purchase. Any other costs or benefits, such as vehicle comfort or safety, or societal effects are not assessed. This section first describes the key input data and the main assumptions made to carry out the cost assessment; it then compares the costs of the different scenarios.

Methodology

All cost items are monetised, projected to 2050 in constant EUR2017 prices and discounted to the base year of 2020 at a rate of 4% (in line with the recommended social discount rate of the European Commission's better regulation guidelines (European Commission, 2017c).

Table 12 displays the assumed external costs of emissions and the sources. Table 13 provides the assumed consumer prices for fuel and electricity for the base year, as well as the cost growth factors and sources. Base year values are average retail prices including tax for the EU28.

Vehicle prices in the base year come from ICCT (2016a). They provide average vehicle prices including taxes by technology for the EU28 up to 2015. These values are inflation-adjusted to obtain values in EUR2017. It is further assumed that manufacturers' vehicle technology costs over time are directly passed on to the consumer. This means that possible pricing strategies of manufacturers are not accounted for. Costs other than vehicle technology costs that may arise for manufacturers, such as for marketing or training of employees to acquire new skills for changing technologies, are not considered. Vehicle technology cost projections are based on NAP (2013) that provide the incremental cost of the different technologies compared to a baseline 2010 ICE vehicle (see Figures 19 and 20 that retrace the graphs from NAP (2013) for PCs and LCVs respectively;). To be able to apply the NAP (2013) cost projections to this study, it is further assumed that:

- Cost projections for LPG vehicles are in line with those of CNG vehicles.
- The share of PHEVs (plug-in electric vehicles) within this study's larger category of HEVs (that comprises PHEVs and HEVs) increases from 10% in 2020 to 30% in 2050 (for both PCs and LCVs).

Finally, NAP (2013) values for FCEVs are adjusted upwards up to the year 2030 to be more coherent with estimates from ICCT (2016b).

Table 12. **Assumed external costs of emissions (in EUR2017/tonne)**

	2020	2025	2030	2035	2040	2045	2050
CO_2	56	75	100	125	155	194	241
				Pollutant emissions			
NOx				11 639			
PM (urban)				295 548			
PM (interurban)				53 801			
CO				2 328			
HC				1 713			

Notes: CO_2 costs based on Quinet (2013). Pollutant emission costs assumed to be constant over time; HC, NOx and PM in line with Ricardo-AEA (2014) (2010 values inflation-adjusted to 2017, values for HC assumed to be in line with NMVOC); CO assumed to be 20% of NOx (in line with Matthews et al., 2001).

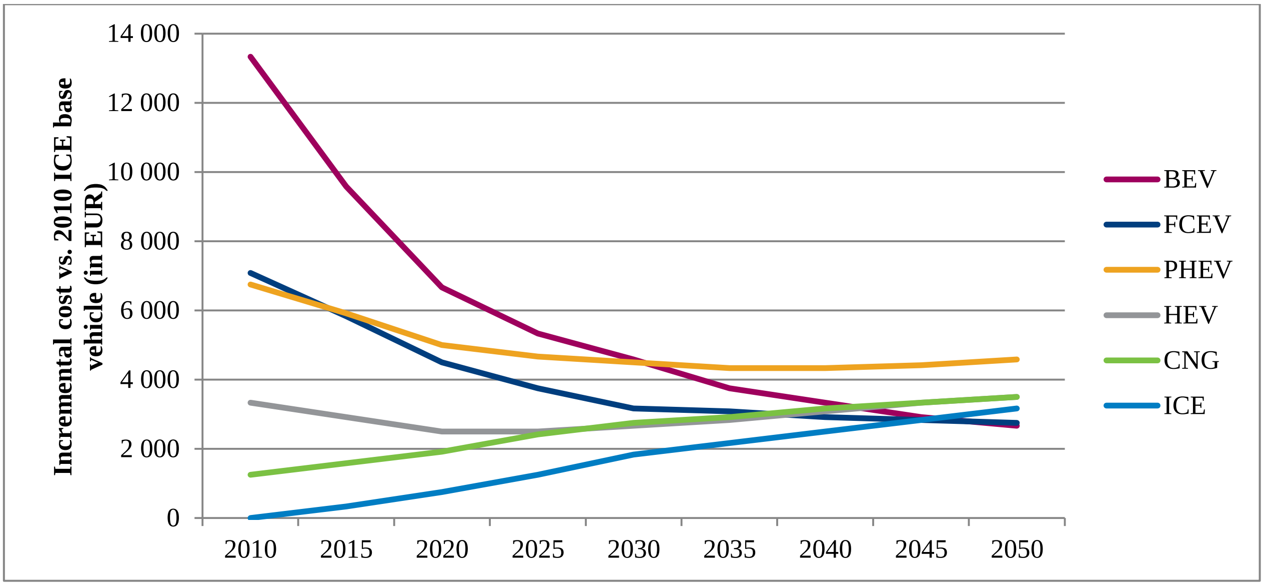
Table 13. **Assumed fuel and electricity price developments**

	2020	2025	2030	2035	2040	2045	2050
	Base value	Cost growth factors (compared to 2020)					
Petrol	**1.32** *EUR/l*	1.12	1.26	1.30	1.35	1.39	1.44
Diesel	**1.18** *EUR/l*	1.12	1.26	1.30	1.35	1.39	1.44
LPG	**0.53** *EUR/l*	1.03	1.07	1.11	1.14	1.18	1.22
Electricity	**0.21** *EUR/kWh*	1	1	1	1	1	1

Notes: 2020 base year values for petrol, diesel and LPG assumed to be equal to August 2017 averages of the EU28, retail prices including tax (European Commission, 2017d); 2020 base year values for electricity assumed to be equal to 2015 averages of the EU28, retail prices including tax (European Commission, 2016b); cost growth factors for petrol, diesel and LPG in line with oil price forecasts of European Commission (2016); cost growth factors for electricity assumed to be equal to one given significant uncertainty regarding uptake of alternative energy sources, related price developments (currently projected to significantly drop over time in European Commission [2016]), and related tax policies.

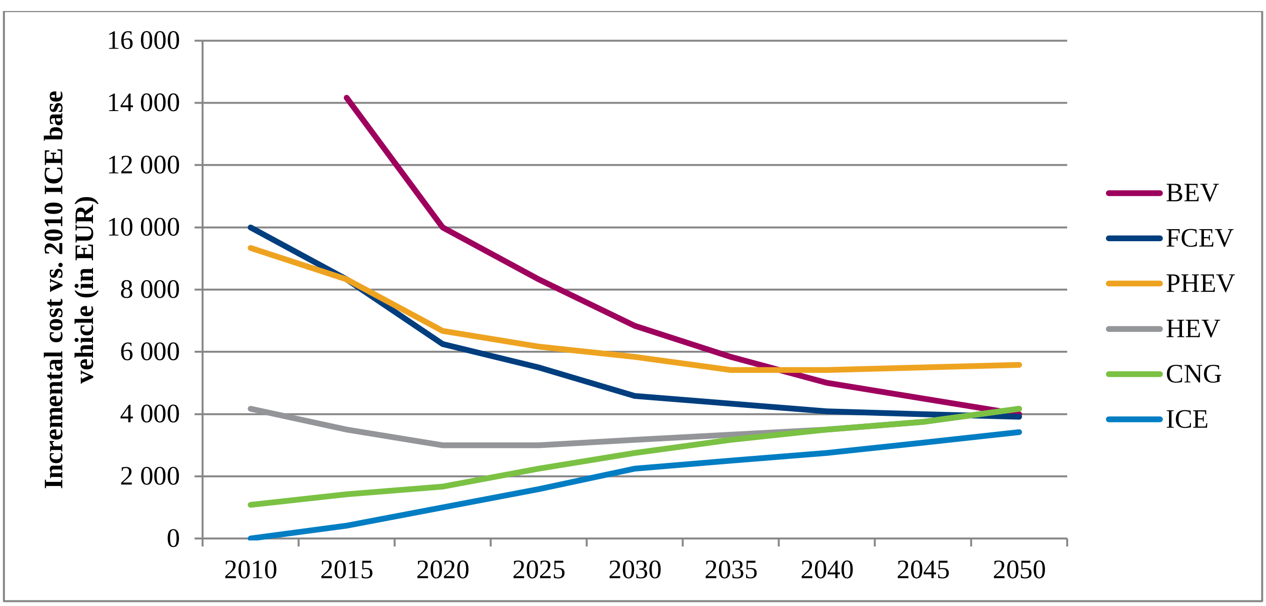
Assumptions regarding manufacturers' costs for vehicle mass reduction are based on Ricardo-AEA (2016) (see Table 14). Note that the estimates for LCVs are significantly higher due to the comparatively limited scope for mass reduction, mainly because of lower production volumes and longer model life-cycles. Furthermore, the range of available mass reduction techniques is smaller for LCVs as these vehicles are designed around providing the maximum possible payload. This means that even if the mass of the unladen vehicle is reduced, it still has to be designed to cope with the same payload (or preferably a greater payload) as a vehicle that does not have any mass-reducing measures applied. This is particularly the case with modern vehicles where legislative and market requirements for additional equipment in LCVs (e.g. emissions control equipment, safety systems, comfort features) have led to reductions in the available payloads for the latest version of many LCVs compared to their predecessors (Ricardo-AEA, 2016). The provided values are assumed to apply to all vehicle technologies.

Figure 19. **Passenger car incremental cost projections versus ICE 2010 baseline**



Source: NAP (2013); USD converted to EUR using an exchange rate of 0.83.

Figure 20. **Light-commercial vehicle incremental cost projections versus ICE 2010 baseline**



Source: NAP (2013); USD converted to EUR using an exchange rate of 0.83.

Table 14. **Cost estimates of vehicle mass reduction**

Passenger cars		Light-commercial vehicles	
Reduction in total vehicle mass	**Unit cost (EUR/kg)**	**Reduction in total vehicle mass**	**Unit cost (EUR/kg)**
10%	0.3	**3%**	2.2
20%	0.9	**12%**	5.4
30%	2.2	**25%**	37.4

Source: Ricardo-AEA (2015).

Results for the cost assessment

Results for the cost assessment by scenario are presented in Figure 21 for PCs and Figure 22 for LCVs. They detail the magnitude of the different cost categories: environmental costs (for CO_2 and the assessed pollutant emissions) represent less than 10% of the total costs assessed; vehicle purchase costs dominate the cost categories at around 60% of the total costs. The figures also show that as vehicle purchase prices increase (either due to mass reduction or an increasing penetration of alternative powertrains, depending on the scenario), vehicle refuelling/recharging costs as well as costs for emissions decrease.

Tables 15 and 16 compare the mass reduction and target achievement scenarios with the baseline scenario. In the case of the passenger cars (Table 15), and keeping in mind the limited scope of the cost assessment, both scenarios are beneficial from the environmental and consumer perspective. As a result, the consumer saves EUR 215 per tonne CO_2 saved thanks to reduced vehicle refueling/recharging costs in the mass reduction scenario, and EUR 122 per tonne CO_2 saved in the target achievement scenario. Savings in recharging/refueling costs outweigh the increased costs for vehicle purchase. In the case of light-commercial vehicles (Table 16), the picture looks different. Given the relatively high costs of reducing vehicle mass, energy savings for the consumer do not outweigh the increased costs of vehicle purchase. As a result, the consumer bears a cost for saving CO_2 emissions (and the benefits per tonne CO_2 saved are negative).

Figure 21. **Costs per scenario – PCs**

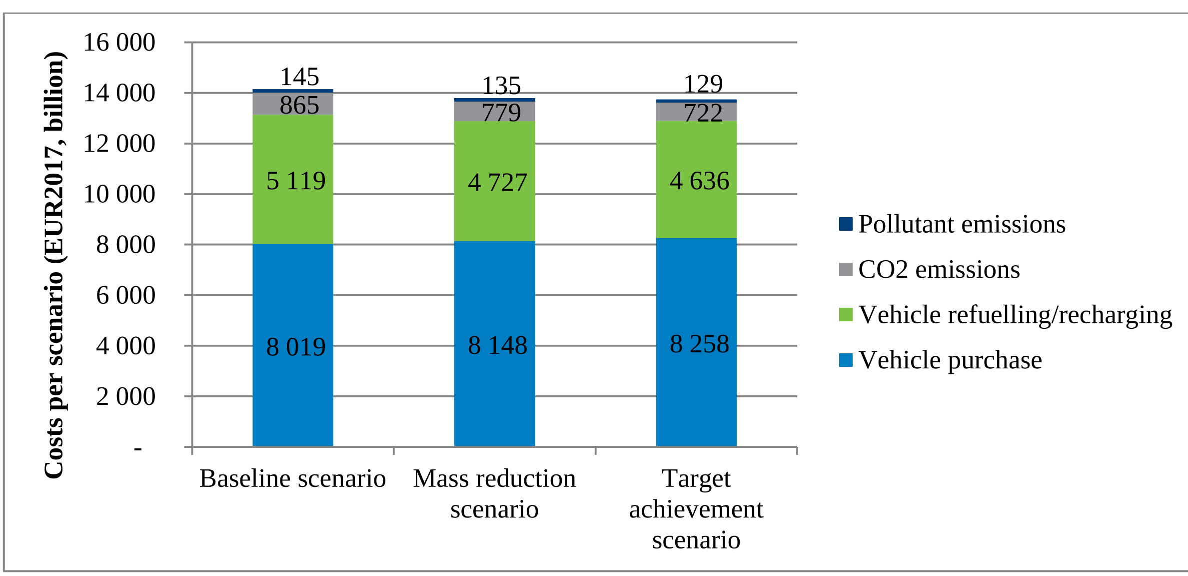


Figure 22. **Costs per scenario – LCVs**

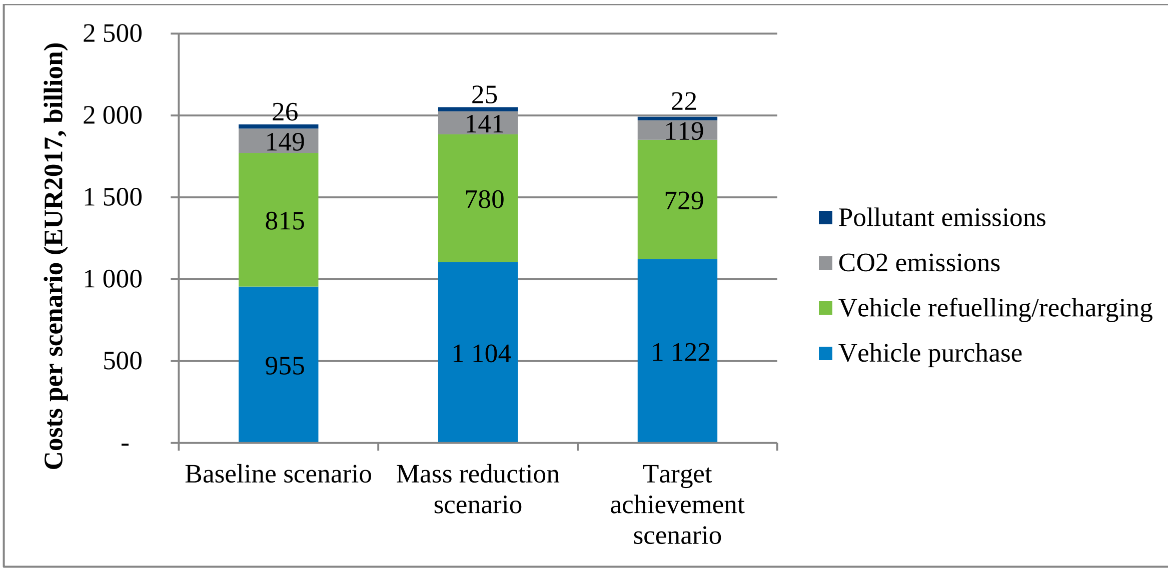


Table 15. **Scenario benefits compared to baseline scenario - PCs**

Benefits compared to baseline scenario	Mass reduction scenario	Target achievement scenario
Total benefits (billion EUR)	**359**	**402**
Environmental benefits (billion EUR)	97	159
Monetary consumer benefits (billion EUR)	262	243
CO_2 saved (MT)	**1 219**	**1 999**
Monetary consumer benefits per tCO_2 saved (EUR)	**215**	**122**

Table 16. **Scenario benefits compared to baseline scenario - LCVs**

Benefits compared to baseline scenario	Mass reduction scenario	Target achievement scenario
Total benefits (billion EUR)	**-105**	**-47**
Environmental benefits (billion EUR)	9	33
Monetary consumer benefits (billion EUR)	-114	-80
CO_2 saved (MT)	**117**	**417**
Monetary consumer benefits per tCO_2 saved (EUR)	**-977**	**-192**

Summary and conclusions

In the EU28, the average mass of passenger cars has increased by around 40% over the past four decades, with an average vehicle now weighing around 1 400 kg. This study assessed the impact of decreasing vehicle mass to levels observed in the mid-1970s on reducing CO_2 emissions from road transport. The baseline scenario projects tailpipe CO_2 emissions from the passenger car and light-commercial vehicle fleet up to 2050. In the mass reduction scenario, gradual vehicle mass reductions down to 1 000kg for passenger cars, and 1 100kg for light-commercial vehicles, allow for reductions of CO_2 emissions. In both cases, most relevant assumptions, such as future vehicle activity, vehicle lifetimes and uptake rates of alternative fuel vehicles, come from projections of the ITF modeling framework or the European Commission 2016 reference scenario.

The baseline scenario finds CO_2 reductions of 21% (or 120 MT CO_2) of the light-duty vehicle fleet (passenger cars and light-commercial vehicles combined) in 2050 compared to 1990 levels. Given the comparatively high vehicle activity of passenger cars, around 85% of overall reductions are due to passenger cars alone. Average CO_2 emission of new passenger cars attain around 78 gCO_2/km (in real-life estimates; or around 60 gCO_2/km in WLTP terms and 53 gCO_2/km in NEDC terms) in 2050; those of light-commercial vehicles around 107 (or 82 and 78 in WLTP and NEDC terms respectively).

The mass reduction scenario results in an additional reduction of around 18%, or 90 MT CO_2, compared to the baseline scenario. Overall CO_2 reduction in this scenario amounts to 39%, or 210 MT CO_2, by 2050 compared to the 1990 base year. In this scenario, average CO_2 emission of new passenger cars attain around 56 gCO_2/km (in real-life estimates; or 43 gCO_2/km in WLTP terms and 38 gCO_2/km in NEDC terms) in 2050; those of light-commercial vehicles around 91 (or 69 and 66 in WLTP and NEDC terms respectively).

Emission reductions of the mass reduction scenario are, however, insufficient for meeting the EU transport decarbonisation target – a 60% CO_2 reduction by 2050 compared to 1990 levels. In an EU target achievement scenario, it is assumed that the gap will be closed by solely increasing the share of zero-emission vehicles. It shows that having a 64% share of zero-emission passenger cars in new vehicle sales by 2050, compared to 27% in the baseline scenario, is required to close the gap with the EU target. In the case of light-commercial vehicles, 68% of zero-emission vehicle in sales is required. The average CO_2 emission values of the new 2050 vehicle fleet is 28 gCO_2/km for passenger cars and 49 gCO_2/km for light-commercial vehicles, both in real-life estimates. The corresponding numbers are 21 and 38 gCO_2/km when looking at WLTP-based CO_2 estimates, or 19 and 36 gCO_2/km when looking at NEDC-based CO_2 estimates.

The cost assessment of the different scenarios reveals that, in case of passenger cars, both the mass reduction and target achievement scenario are beneficial from the environmental and the financial perspective of consumers. Savings outweigh the increased cost of purchasing more fuel efficient vehicles in both scenarios. Consumers save EUR 213 per tCO_2 saved due to reduced vehicle refueling/recharging costs in the mass reduction scenario, and EUR 121 per tCO_2 saved in the target achievement scenario.

For light-commercial vehicles, the picture is less favorable because of the higher costs related to vehicle mass reduction. Notably, the consumer pays EUR 977 for each tCO_2 saved in the mass reduction scenario, and EUR 192 in the target achievement scenario. In both scenarios, monetised environmental benefits do not outweigh the increased financial costs for the consumer due to higher prices.

Overall, the results of this study show that vehicle mass reduction is an effective measure for reducing CO_2 emissions from road transport and can contribute to meeting EU transport decarbonisation targets. In the case of passenger cars, they also come to the financial benefit of the vehicle user. However, CO_2 reductions thanks to vehicle mass reductions to the levels proposed in this study (an average of 1 000kg for passenger cars and 1 100kg for light-commercial vehicles) are insufficient for meeting EU 2050 transport CO_2 targets.

All results are based on a set of input assumptions and projections up to 2050 that are subject of considerable uncertainty; the cost assessment has a limited scope given the constraints of this study; and finally emission estimates relate to vehicle tailpipe emissions only. Comparisons of the mass reduction and target achievement scenarios were furthermore drawn to a baseline scenario, which is not a “do-nothing” scenario. For example, it assumes significant uptake of zero-emission vehicles in the new vehicle fleet by 2050.

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International Transport Forum

Lightening Up: How Less Heavy Vehicles Can Help Cut CO_2 Emissions

This report examines how lowering vehicle mass can reduce CO_2 emissions from road transport. The average mass of new passenger cars in the European Union has increased by around 40% over the past four decades. Lowering vehicle mass to levels observed in the mid-1970s could reduce vehicle emissions substantially and help meet European Union targets such as the 60% reduction in transport CO_2 emissions by 2050. Based on different scenarios, this study shows that mass reduction across all vehicle technologies has potential to reduce the gap between such ambitions and the current trend and would financially benefit the vehicle user.

This report was developed in the context of the International Transport Forum's Decarbonising Transport project. It is part of the International Transport Forum's Case-Specific Policy Analysis series. These are topical studies on specific issues carried out by the ITF in agreement with local institutions.

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