Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

Motor vehicle demographics

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Demographic concepts and methods may help understand the dynamics of the motor vehicle population, or its inertia. Relying on a stock-flow cohort model of the Norwegian vehicle fleet, we generate, for seven different vehicle categories, age pyramids, survival curves, and life expectancy estimates, along with algorithms predicting vehicle stocks, aggregate annual mileage, energy consumption, emissions to air, and end-of-life scrapping. Distinguishing among eleven different powertrains, the model may serve as a decision support tool for long term energy and climate policy formulation.

Age pyramids

Demographers draw age pyramids as horizontal bar graphs with the two genders placed on either side of the vertical age axis. A more useful format is, however, obtained by rotating the graph 90 degrees to the right and placing one gender on top of the other. Indeed, when the population is made up by more than one 'gender' (read: powertrain technology), the vertically stacked bar graph is the convenient way to describe the population in a nutshell (Fig. E.1).[1]

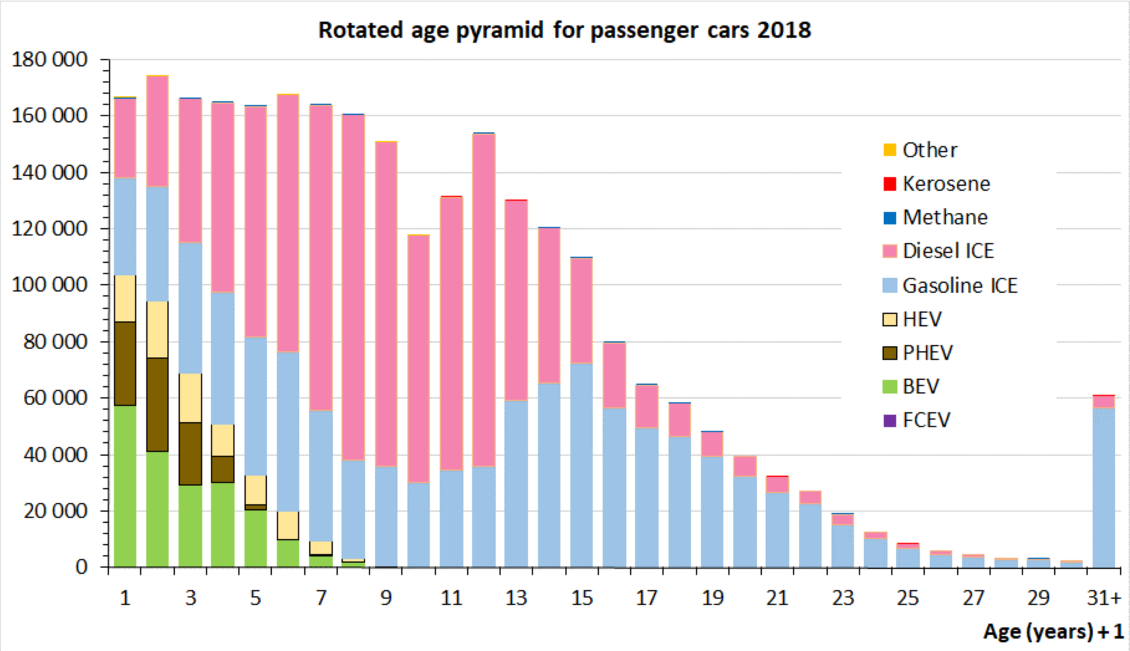

Fig. E.1: Norwegian registered passenger cars at year-end 2018, by age and powertrain technology.

[1] Note that in this and the following graphs, the age index runs from 1 to 31+, rather than from 0 to 30+. The real age of the vehicle is 1 year less than the index value.

In the BIG stock-flow cohort model of the Norwegian vehicle fleet (Fridstrøm 2017a), the following 11 powertrain technologies are specified:

a. gasoline internal combustion engine (ICE),
b. diesel ICE,
c. battery electric vehicle (BEV),
d. plug-in hybrid electric vehicle (PHEV) with gasoline ICE,
e. PHEV with diesel ICE,
f. non-plug-in hybrid electric vehicle (HEV) with gasoline ICE,
g. HEV with diesel ICE,
h. hydrogen fuel cell electric vehicle (FCEV)
i. biogas (methane) ICE
j. kerosene ICE
k. other

In Fig. E.1, gasoline and diesel hybrids have been grouped together.

Survival curves and life expectancy

In Figs. E.2 and E.3 we exhibit *net flow intensities*, defined as the relative change, from one year to the next, in the stock of vehicles of a given cohort, weight class and powertrain. The intensities have been calculated from data extracted from the Norwegian motor vehicle register for the years 2012 through 2018 – see Fridstrøm (2017a) for a detailed mathematical description.

One notes that for passenger cars and light commercial vehicles (LCVs), there is a biennial cyclical pattern of attrition among vehicles above a certain age – 10 years for LCVs, 16 years for passenger cars. More cars are scrapped or deregistered during years of EU mandated periodic vehicle inspection (year 4, 6, 8, … and so on).

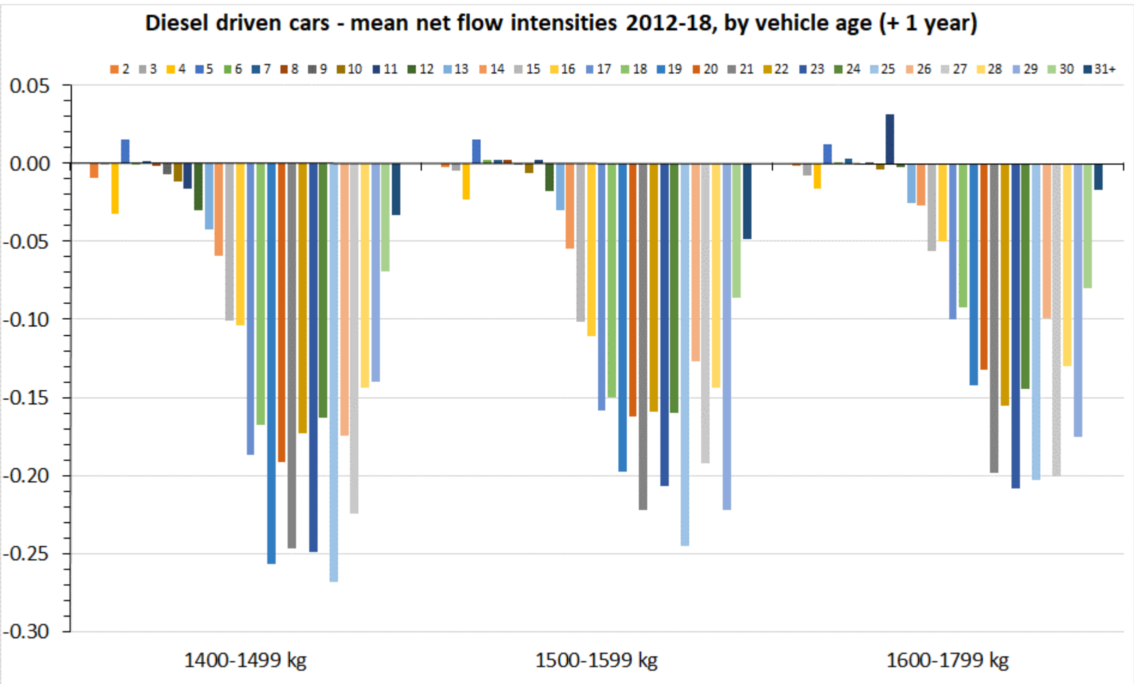

Fig. E.2: Mean net flow intensities 2012–2018 for certain diesel ICE passenger cars, by age and curb weight.

No such pattern is visible among heavy duty trucks (Fig. E.3). These are inspected every year.

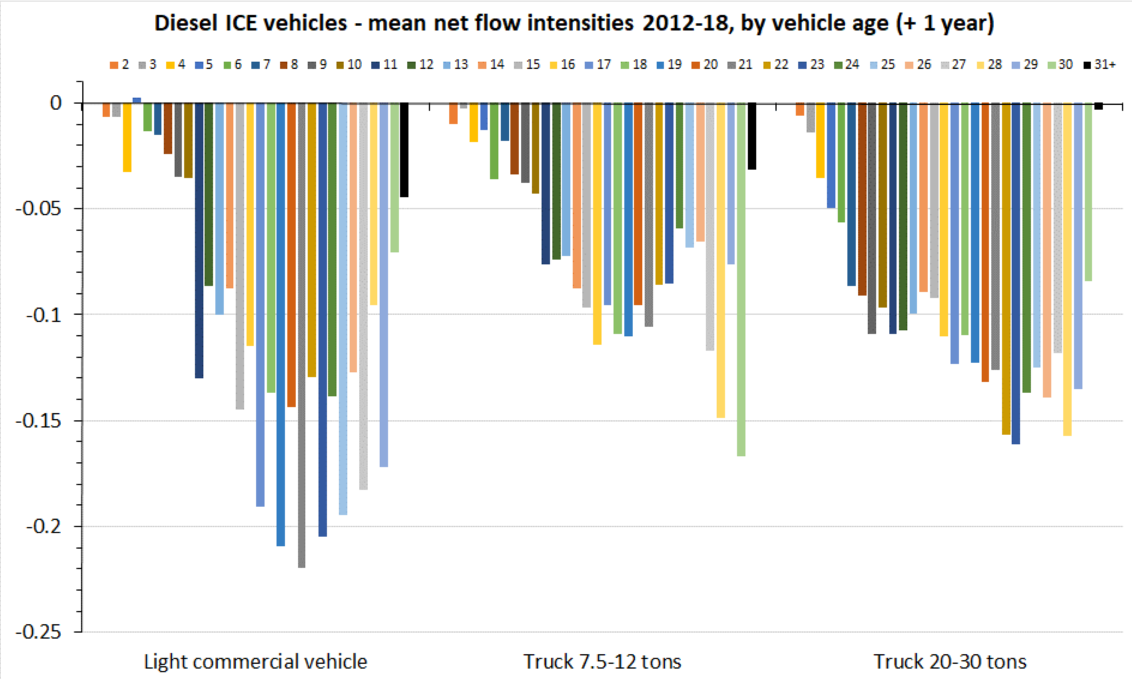

Fig. E.3: Mean net flow intensities 2012–2018 for certain diesel ICE freight vehicles, by age and maximal road train weight (metric tons).

Transition rates, given by one plus the net flow intensity, express how the respective cohorts of vehicles within each segment grow or shrink from one year to the next. By compounding the transition rates through the years, one can derive '*survival curves*'. Examples are shown in Figs. E.4 through E.8.

One notes from Fig. E.4 that just about half of all small passenger cars with a diesel ICE survive until their 17th year in Norway. The same applies to gasoline cars below 1300 kg. Small BEVs have considerably shorter lives. After 7 to 10 years, most of them are gone.

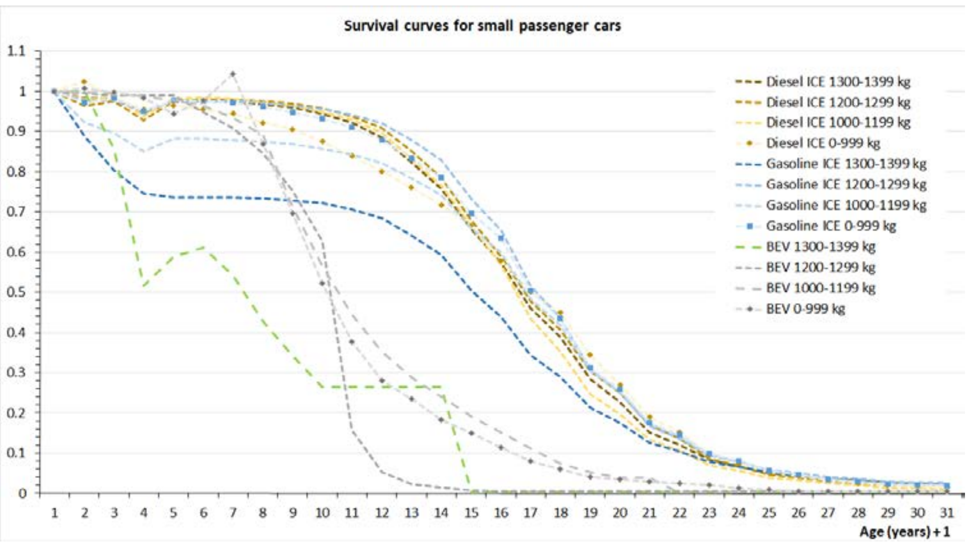

Fig. E.4: Survival curves for small passenger cars, by powertrain and curb weight.

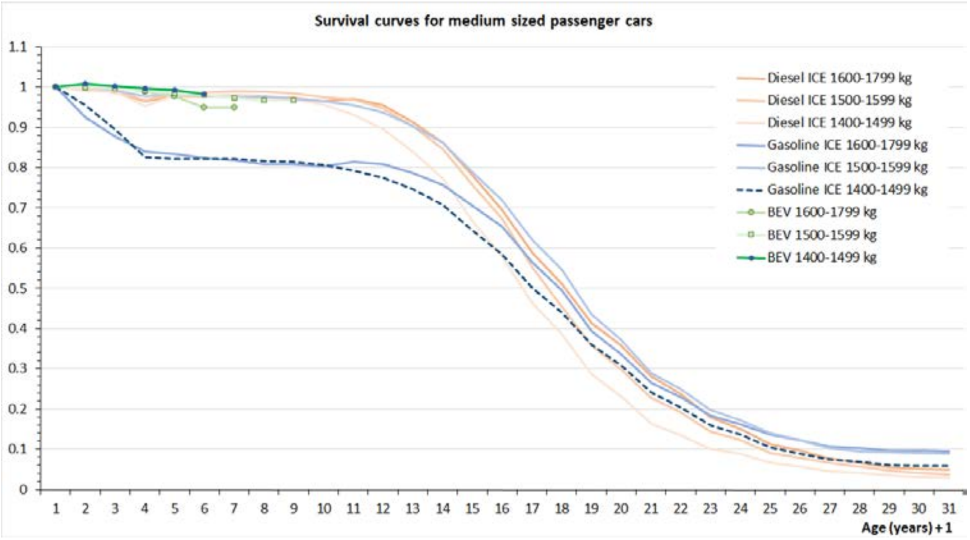

Fig. E.5: Survival curves for medium sized passenger cars, by powertrain and curb weight.

Medium sized automobiles roam the roads until their 17th to 19th year before half of them have succumbed (Fig. E.5). So far, BEVs of this size do not stand out against ICE cars in terms of survival. But our empirical data do not allow us to extend the BEV survival curves beyond 5 to 8 years of age.

Since our net flow intensity is a sum of positive and negative gross flows due to scrapping, de- or reregistration, or second hand import or export, 'survival' is to be understood as 'survival with Norwegian license plates'. In some cases, when a cohort is augmented through second hand import, 'survival' from one year to the next may exceed 100 percent. Indeed, in Fig. E.4 we note that the smallest type of BEVs are more numerous at age 6 than one year before. This is due to second hand import.

The larger diesel driven passenger cars, above 1800 kg curb weight, commonly become more numerous as they age. During their first ten years, the increase in number is due to second hand import, spurred by the age-graduated 'discount' granted on the Norwegian one-off automobile registration tax (Fig. E.6).

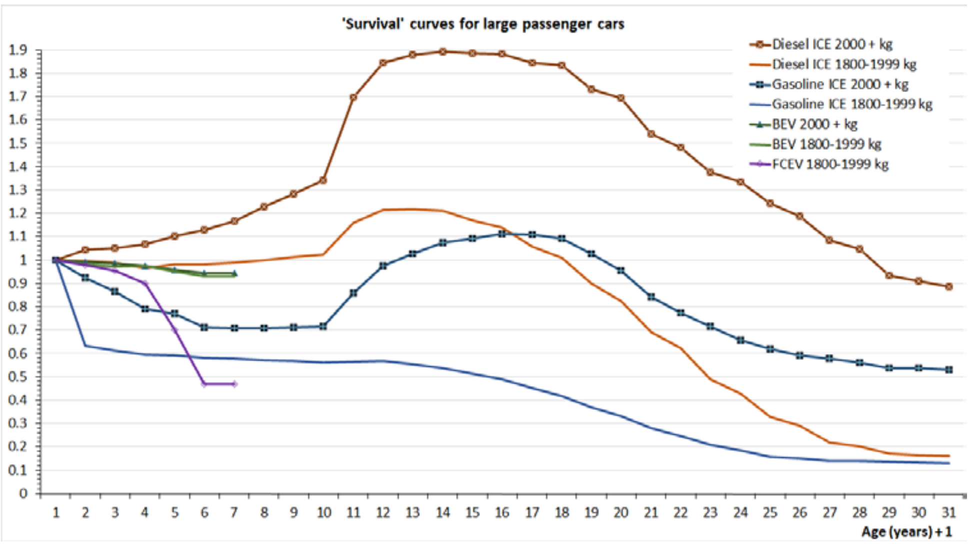

Fig. E.6: 'Survival' curves for large passenger cars, by powertrain and curb weight.

A spike in the 'survival' curve is seen after age 10, due to the fact that at this age, light commercial vehicles (LCVs, or vans) can be retrofitted as passenger cars without giving rise to any extra registration tax. Thus, in their 15th year, Norwegian registered diesel cars heavier than 2000 kg are almost 90 percent more numerous than they were as new.

Survival curves for light and heavy duty commercial vehicles are shown in Figs. E.7 and E.8. Trailer tractors exhibit much steeper curves than do ordinary truck and vans. Half of the tractors are scrapped or sold second hand abroad before they reach 7–8 years of age.

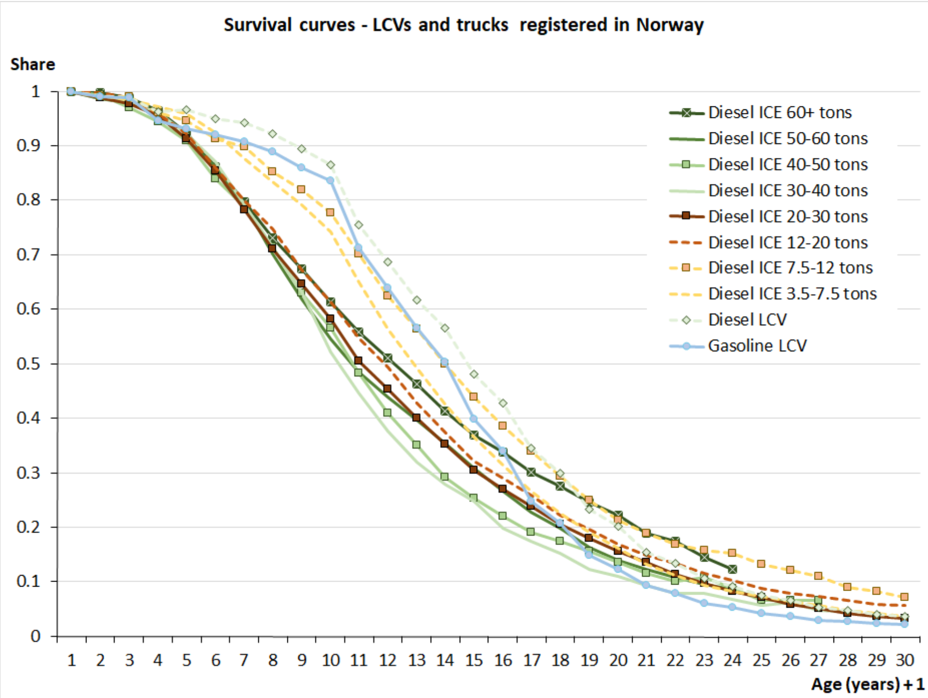

Fig. E.7: Survival curves for LCVs and heavy duty trucks, by maximal road train weight (metric tons).

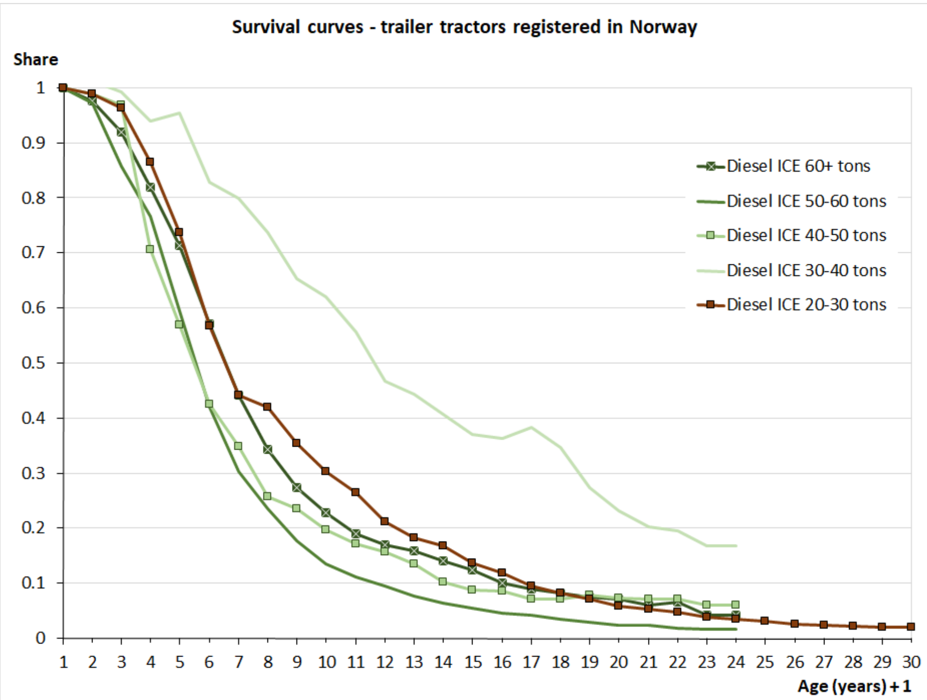

Fig. E.8: Survival curves for heavy duty trailer tractors, by maximal road train weight (metric tons).

Given the cumulative transition rates (survival rates), it is matter of simple algebra to compute the vehicles' domestic life expectancy. We estimate it at around 16 years for gasoline cars, 18 years for diesel cars, 13 years for trucks and LCVs, 8 years for trailer tractors, 11 years for buses, and 31 years for diesel driven recreational vehicles.

Second hand import of battery electric vehicles

Contrary to common belief, the record fast market uptake of battery electric vehicles (BEVs) in Norway (Fig. E.1) is due to taxation rather than subsidization. ICE passenger cars and their fuel and road use are taxed at a rate corresponding to a carbon price of at least € 1370 per ton of CO_2, before taking account of the roughly 15 percent biofuel blend-in (Fridstrøm 2021a). But no cash subsidies are being paid out to BEV buyers in Norway.

Such subsidies (or tax credits) have, however, been common practice in many other countries, among them Germany, Sweden, South Korea, and the USA. These subsidies give rise to a business opportunity (Amiot 2013, Doyle 2019). A clever businessman buys a BEV, cashes in the subsidy, and subsequently exports the car to a country without cash subsidies, where the market price is higher.

One such country is Norway. Figures from the foreign trade statistics reveal that 42 103 BEVs have been imported second hand to Norway from 2017 through 2021, most of them from Germany, many also from Sweden, South Korea and the USA (Fig. E.9). Taxpayers in these countries appear to have helped electrify the Norwegian automobile fleet. The second hand import has added around 13 percent to the total number of BEVs registered in Norway during 2017 through 2021.

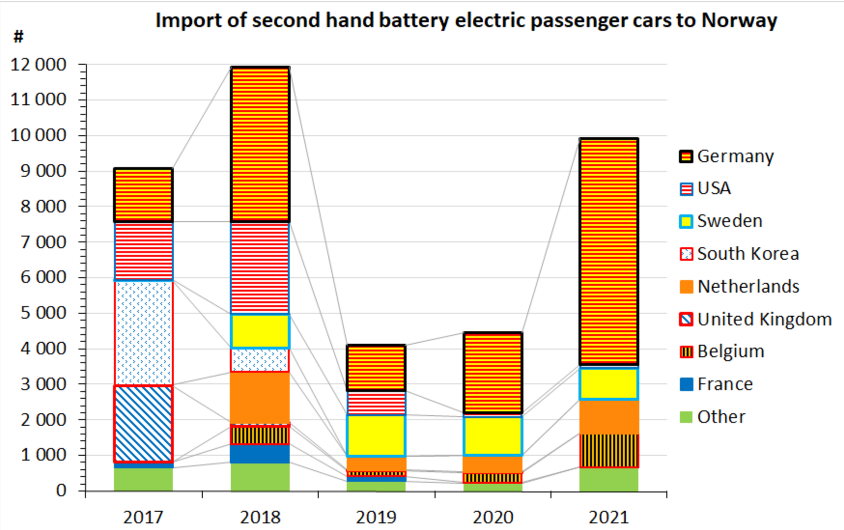

Fig. E.9: Annual import of second hand battery electric passenger cars to Norway 2017–2021, by exporting country. Source: Norwegian foreign trade statistics.

Emissions to air

The BIG stock-flow projection model provides information on the delay between innovation and penetration (Fridstrøm 2017a), i.e. on the time it takes before new technology affecting the *flow* of new vehicles has penetrated similarly into the *stock*. In Fig. E.10, we show the share of BEVs and FCEVs among *new* or *existing* passenger cars, LCVs and heavy duty freight vehicles, i.e. in the flows and stocks of these vehicles.

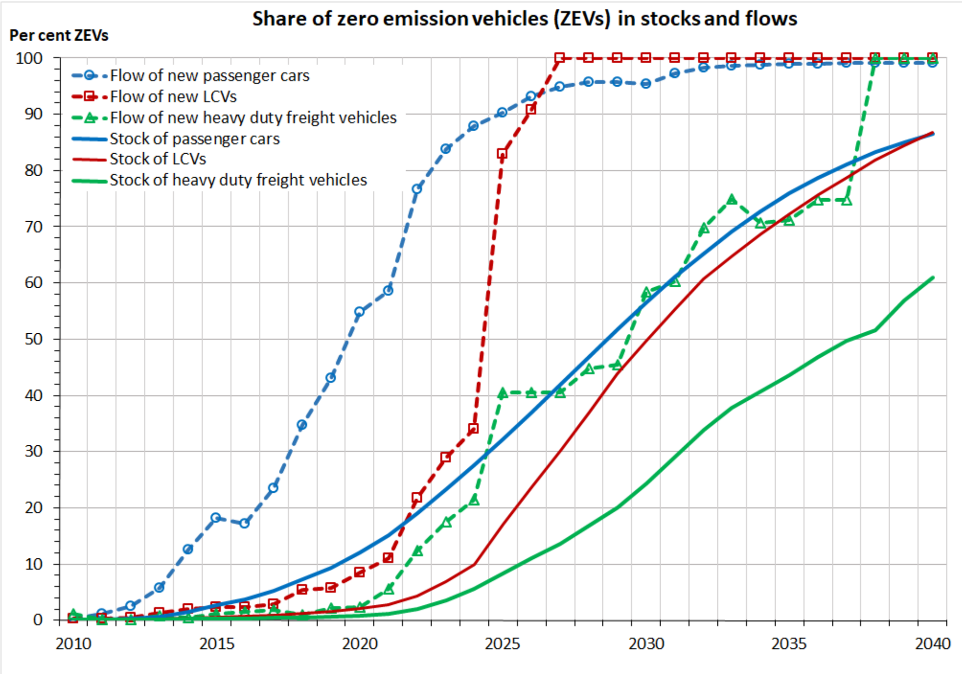

Fig. E.10: Observed and projected share of zero emission technology in vehicle flows and stocks 2010–2040, by vehicle class. Source: Fridstrøm mfl. (2022).

The solid lines in Figure E.10 represent the zero emission vehicle share of the *stock* of vehicles at the end of each year. The lag between new vehicle market uptake and the penetration into the stock can be read off as the horizontal distance between the two identically colored lines. At the 50 percent penetration level, the lag, as computed under this particular projection, is seen to be 9 years for passenger cars, 6 years for LCVs and 8 years for trucks (including trailer tractors). At the 90 percent penetration level, the lag is at least 15 years for all vehicle categories. The vehicle fleet is an inert matter.

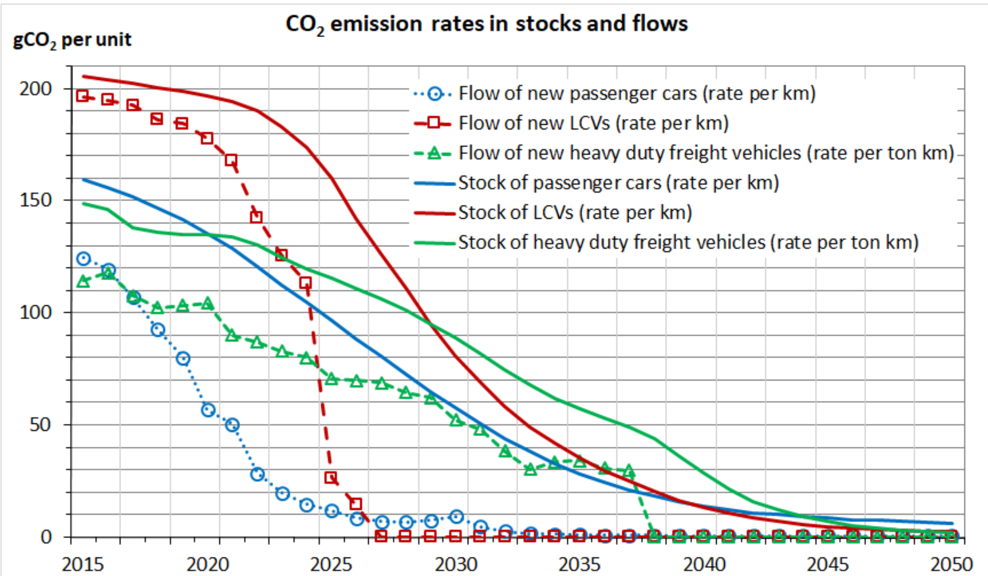

Figure E.11: Observed and projected mean CO_2 emission rates of new and existing vehicles 2015–2040.

Similarly, in Fig. E.11, we exhibit mean CO_2 emission rates characterizing the flows and stocks of vehicles, respectively. These rates are fast coming down, but not so fast for the stock of vehicles as for the flow of new ones. We observe a time lag of up to 15 years.

The motor vehicles' emissions to air also comprise local pollutants, such as nitrogen oxide (NO_X) and exhaust particulate matter (PM). In Norway, NO_X emissions on the road are down 53 percent between 1990 and 2020. Between 2015 and 2020 the cut is 32 percent, according to official statistics. Model projections show that NO_X emissions will continue to drop toward 2040 (Fig. E.12).

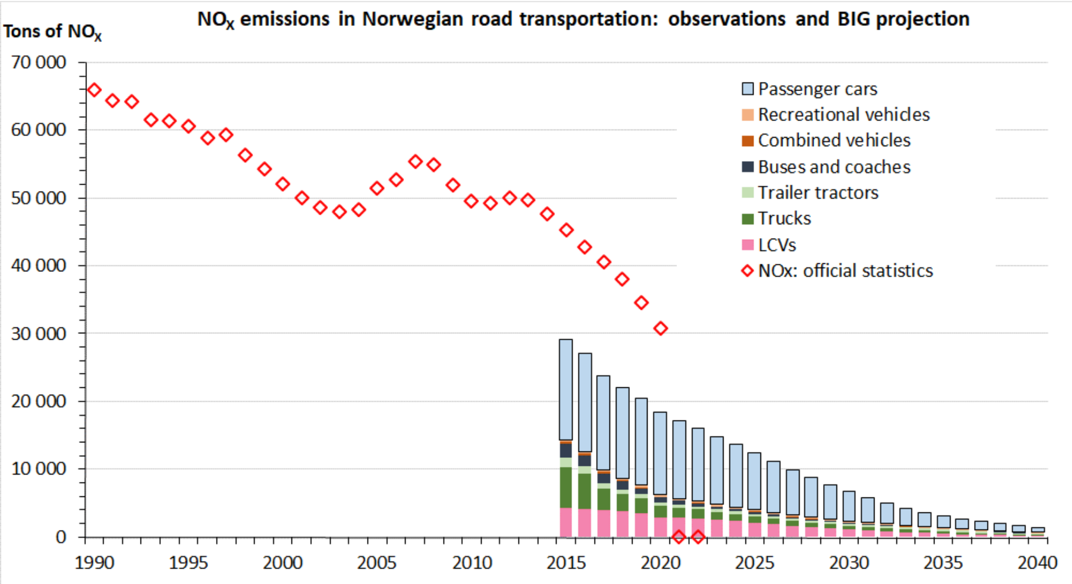

Fig. E.12: NO_X emissions in Norwegian road transportation 1990–2040. Observed and model projected values.

An even faster emissions cut applies to exhaust particles, shown in Fig. E.13. Between 1990 and 2020 the cut is 73 percent, whether one counts PM_{10} or $PM_{2.5}$. As shown by the graph, almost all the exhaust particles are of the smallest and most toxic kind ($PM_{2.5}$).

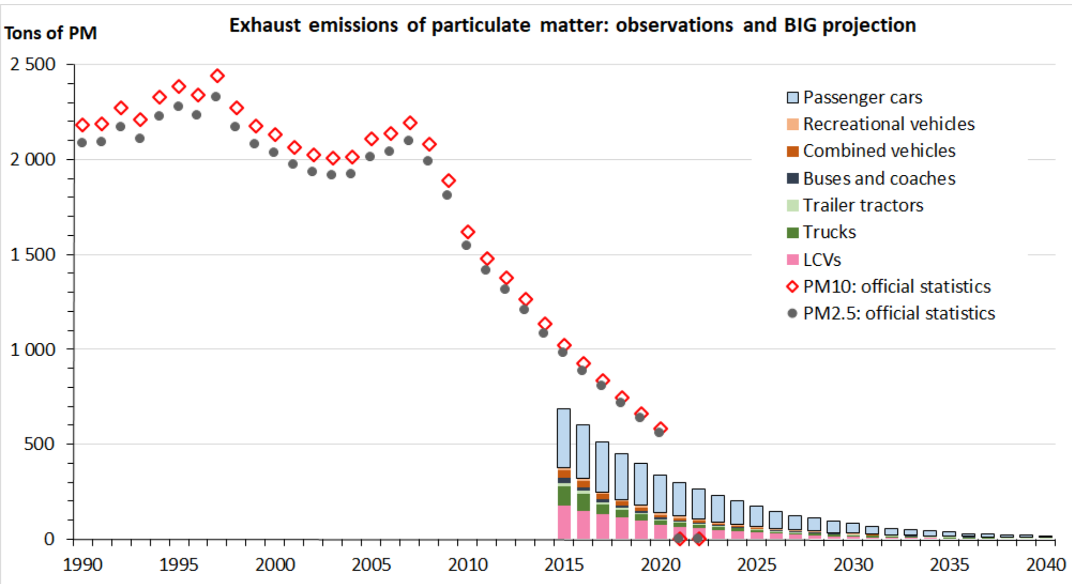

Fig. E.13: Exhaust emissions of particulate matter (PM_{10} and $PM_{2.5}$) in Norwegian road transportation 1990–2040. Observed and model projected values.

There are two main reasons why the NO_X and PM emissions on the road are coming down so fast. Diesel automobiles are being replaced by BEVs. Heavy duty trucks are becoming steadily cleaner, as the stock is being renewed and an ever larger share of these vehicles become subject to the latest environmental regulation (Euro VI).

End-of-life scrapping and recycling

A final output of interest from the BIG stock-flow projection model is the flow of scrapped or otherwise deregistered vehicles. This is shown in Fig. E.14.

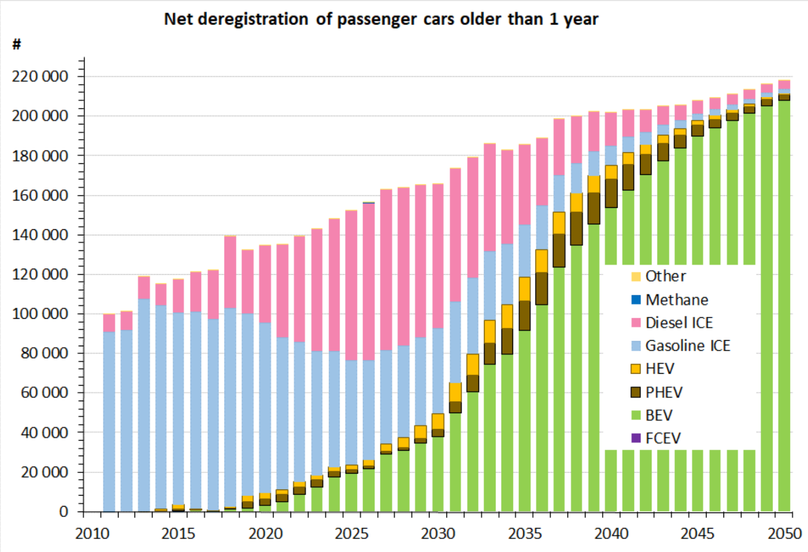

Fig. E.14: Projected net deregistration of passenger cars 2011–2050, by powertrain.

A more telling illustration of the inertia inherent in a vehicle population is hard to find. While the projection shown in Fig. E.14 assumes a 90 percent BEV market share already in 2025, it takes another 20–25 years before BEVs represent a 90 percent majority of all cars scrapped or deregistered.

A large amount of BEV batteries will sooner or later become available for reuse or recycling – more likely later than sooner.