

Assumptions and input data calculations

Circular economy

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Introduction

The tool estimates the CO₂-eq emissions of all passenger cars in Sweden based on input data (see below) and certain assumptions. Based on an estimation of how many cars there will be on the road in a certain year, what the age of the fleet is, what the mix in powertrain is (i.e. how many of these cars are fully electric, hybrid, diesel, petrol, etc.), how fuel efficient the cars are, how far they drive and how much CO₂ is associated with one liter fuel, the CO₂-eq emissions of passenger cars in the next 30 years is calculated. The tool is calibrated with data of the current Swedish car fleet. The input data and assumptions in the tool are further explained below.

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1. Input data and assumptions

1.1 Number of cars on the road and distance driven

The number of new cars on the road in the past 17 years is taken from Statistics Sweden (SCB)¹. To simplify the calculations, it is assumed that all cars registered on the road in Sweden will live for exactly 17 years (which is the average lifespan) and are then taken off the road. This means that the calculations, compared to the reality, underestimates the number of old vehicles on the road.

Following the prognosis made after the decision on the national plan for transport system in Sweden 2018-2029, the total travel distance of all Swedish registered passenger cars is assumed to increase from 61 200 million km in 2014, to 79 100 million km in 2040, and 86 500 million km in 2060². For 2014 to 2040, this corresponds to a yearly increase of 1%. For 2040 to 2060, this corresponds to 0.45% increase per year. Note that according to this prognosis, the total distance driven in 2019 should be almost 64 300 million km, while the reported distance driven in 2019 was 67 142 million km³. Recalculating the annual trend from the actual 67 142 million km in 2019 to the projected 79 100 million km in 2040, an 0.84% annual increase in total distance driven is included in the model from 2019 to 2040. From 2040 to 2050, a 0.45% increase is included.

The total distance is divided by 12 040 km (the average annual distance per car) to derive the number of cars on the road in the various years. The number of new cars coming on the road in a certain year equals the cars scrapped in a certain year plus the increase in the overall car fleet.

1.2 Split between different powertrains

Data on the split of different powertrains (i.e. petrol, diesel, hybrids, electric vehicles, etc.) of cars sold in previous years are taken from SCB⁴ and BIL Sweden⁵. An assumption regarding the share of hybrids on petrol versus diesel is based on Kvd bil internal data. The share of electric vehicles will increase in the future. BIL Sweden published a prognosis that electric vehicles will account for 24% in 2020 and 30% in 2021. After that, a stronger transition to electric vehicles is assumed following the prognosis made by 2030-sekretariatet, which means that electric vehicles are responsible for 76% of the new car sales in 2030. It is assumed that in the beginning (year 2020 to 2024) the majority (i.e. 70%) of electric vehicles are plug-in hybrids, while from year 2025 the majority (i.e. 70%) of the electric vehicles are full electric

¹ SCB, "Fordonsstatistik", <https://www.scb.se/hitta-statistik/statistik-efter-amne/transporter-och-kommunikationer/vagtrafik/fordonsstatistik/>

²

https://www.trafikverket.se/contentassets/7e1063efbcfd4b34a4591b0d4e00f855/2018/oversikt_prognosresultat_trv_basprognoser_20180401_ver-2018111....xlsx

³ Trafikanalys, "Körsträckor 2019",

https://www.trafa.se/globalassets/statistik/vagtrafik/korstrackor/2020/korstrackor_2019.pdf?

⁴ SCB, "Fordonsstatistik", <https://www.scb.se/hitta-statistik/statistik-efter-amne/transporter-och-kommunikationer/vagtrafik/fordonsstatistik/>

⁵ BIL Sweden, http://www.bilsweden.se/statistik/nyregistreringar_per_ar/arkiv_1997-2012/nyregistreringar_per_ar_2005/definitiva_nyregistreringar_2005

cars. It is further assumed that the share of ethanol and gas vehicles (both only a small percentage) remain constant over time. The remaining share of newly sold cars each year is divided between petrol, diesel, and electric hybrids following the same divide as in 2019. In 2019, petrol, diesel, and electric hybrids accounted together for 87%, which means that for petrol 46/87 is assumed, for diesel 32/87, and for electric hybrids 9/87.

1.3 Fuel consumption

The average fuel consumption of newly registered cars in the previous years in liter per 100 km is taken from the Swedish Transport Administration⁶. According to some prognosis, the fuel consumption of the Swedish car fleet of both petrol and diesel cars is assumed to decrease to 6.1 l / 100 km in 2030 and to 4.9 l / 100 km in 2040⁷, which corresponds to a 2.2% annual decrease. This is based on the assumption that buyers will select a more fuel-efficient car when buying a new car. Recently the trend is that buyers select even more larger and heavier cars (more SUVs) than before. We included therefore a more conservative improvement rate of 1.65% for petrol and 1.44% for diesel cars based on the trend that we saw in the past 27 years. A similar extrapolation of fuel efficiency improvements of other powertrains is made based on the trend seen in the past year. Regarding ethanol and gas vehicles, the Swedish Transport Administration⁸ publishes the fuel consumption for driving on petrol. For ethanol cars, we assume a 10% increase in fuel consumption when fueled with ethanol compared to petrol. For gas vehicles, the CO₂ emissions in terms of g / km of gas vehicles driving on biogas are published for various years by Gröna Bilister⁹, which is used for the calculation. We assume that the CO₂ per km improvement is equal to the improvement expected for petrol vehicles. It is possible to select the share of petrol versus biofuel for ethanol and gas vehicles as well as for those petrol vehicles converted to ethanol vehicles (see below).

1.4 Distance driven per car

The average distance driven per car differs per powertrain (diesel cars driving the most per year) as well as age of the car. Data is taken from Transport Analysis¹⁰. From this, a correction factor is calculated which allows to vary the average distance per year per car (including all cars) but keeping the difference based on powertrain and age. For example, the average distance is multiplied with 1.18 for brand new cars and with 1.05 for plug-in hybrids. Note that there is a combined effect meaning that a brand-new plug-in hybrid is multiplied with both 1.05 and 1.18. The assumed

⁶ Trafikverket, <https://www.trafikverket.se/contentassets/07f80f01d92144eebf1a01fcb60ac923/pm-vagtrafikens-utslapp-200224.pdf>

⁷ Trafikverket, 2020-03, "Beskrivning av Scenarioverktyget", Table 5, https://www.trafikverket.se/contentassets/8a378cdce4f24e6cb2e2592e89e04632/beskrivning-av-scenarioverktyget_version-1.0.pdf

⁸ Trafikverket, <https://www.trafikverket.se/contentassets/07f80f01d92144eebf1a01fcb60ac923/pm-vagtrafikens-utslapp-200224.pdf>

⁹ Gröna Bilista, "Drivmedelsfakta", <http://www.gronabilister.se/rapporter>

¹⁰ Trafikanalys, "Körsträckor 2018", excel file, table PB4, <https://www.trafa.se/vagtrafik/korstrackor>

powertrain mix and average lifespan in the model influences the average annual driving distance.

1.5 CO2 value per liter fuel

The CO₂-equivalent emissions associated with one liter of fuel in Sweden in recent years is taken from the Swedish Energy Agency¹¹. The CO₂ reduction per liter fuel for petrol and diesel in the years 2018, 2019 and 2020 is calculated from the already decided share of biofuel that will be blended into petrol and diesel. After that, it is assumed that the government's new CO₂ reduction levels¹² for petrol and diesel will come into effect in 2021. The baseline of the tool has been adapted to those. It is calculated with a linear decrease of CO₂ per liter fuel until 2030 of 28% for petrol and 66% for diesel, starting in 2021 at 6% for petrol and 26% for diesel. For ethanol, we use 1.12 kg CO₂-eq/liter and HVO 0.3 kg CO₂-eq/liter¹³. We keep both factors constant over the years. Additionally, we assume that all cars drive in a certain year on fuel sold in that respective year.

1.6 Bonus for emission-efficient cars - and the extent of export

Cars with less emissions than 70 g CO₂/km receives a bonus from the Swedish government when bought new. It is assumed that the bonus accelerates the transformation to a fossil-free fleet of passenger vehicles in Sweden. At the moment, the bonus is maximal 60.000 SEK for electric vehicles and 10.000 SEK for gas vehicles¹⁴, but most likely will be increased from April 1st, 2021, to maximal 70.000 SEK electric vehicles and up to 45.000 SEK for hybrids with less emissions than 60 g CO₂/km¹⁵. However, the latest report from Transport Analysis¹⁶ shows that many new bonus-granted cars (between 0-5 years old) are deregistered in Sweden and exported (largely because the purchasing price in Sweden is low in international comparison which is made even cheaper considering the bonus upon first sale). Due to this lucrative business, the transformation to a fossil-free fleet of passenger vehicles in Sweden is not accelerating according to forecasts.

Statistics from Transport Analysis¹⁷ give a picture of how many cars by powertrain have been deregistered and exported between 2010 and 2019. These numbers have

¹¹ Swedish Energy Agency, <https://www.energimyndigheten.se/globalassets/statistik/drivmedel-2018.pdf>

¹² Regeringskansliet, 2020-09-11: "Bränslebytet förstärks med högre inblandning av förnybart i drivmedel" <https://www.regeringen.se/pressmeddelanden/2020/09/branslebytet-forstarks-med-hogre-inblandning-av-fornybart-i-drivmedel/>

¹³ Miljöfordon.se, 2020-03-24: "Miljöpåverkan", <https://www.miljofordon.se/bilar/miljoepaaverkan/>

¹⁴ Regeringskansliet, 2020-07-22: "Klimatbonusbilar ska vara registrerade i fem år", <https://www.regeringen.se/4a163e/contentassets/6034e994d00b4f11b481485590a0f711/promemor-ian-klimatbonusbilar-ska-vara-registrerade-i-fem-ar>

¹⁵ Regeringskansliet, 2020-09-18: "Förstärkt och förenklad miljöstyrning i bonus-malus-systemet", <https://www.regeringen.se/artiklar/2020/09/forstarkt-och-forenklad-miljostyrning-i-bonus-malus-systemet/>

¹⁶ Trafikanalys, "Begagnade miljöbilar lämnar landet", <https://www.trafa.se/vagtrafik/begagnade-miljobilar-lamnar-landet-7498/>

¹⁷ Trafikanalys, "Personbilar avregistrerade till utlandet", 2010-2019", <https://www.trafa.se/globalassets/statistik/vagtrafik/fordon/2020/personbilar-avregistrerade-till-utlandet.xlsx>

been used to forecast how many emission-efficient cars (between 0-5 years old) will be exported until 2050.

The prognosis for plug-in hybrids and electric vehicles is based on a linear forecast of the development from 2015-2019 in relation to new registered cars two years earlier, since data show these cars are in average two years old when exported. For electric hybrids, this forecast is based on a linear forecast of the development from 2015-2019 in relation to cars three years earlier because these cars are in average three years old when exported. For gas and ethanol vehicles, this forecast is based on the numbers from 2009-2019 in relation to new registered cars four years earlier because these cars are in average four years old when exported. For all vehicles, a linear trend of export is assumed until 2022. From 2022, the share between export to new registered cars plateaus and stays constant until 2050.

1.6.1 Kilometers are driven by petrol and diesel cars instead

Because of the export of those emission-efficient cars, which are not even yet 5 years old and would have contributed to lower CO₂ emissions, their kilometers on Swedish roads are instead driven by other cars in the model; assumed as a mix of petrol and diesel cars. For this, it was calculated with a fleet existing of petrol and diesel cars with an average fuel consumption of the last relevant set of years, based on the remaining assumed lifespan. In the baseline the assumed lifespan is 17 years.

The extra kilometers that are driven by petrol and diesel cars increase the CO₂ emissions.

1.6.2 Cost for bonus system for emission-efficient cars

A simple calculation, based on the bonus for the exported vehicles, shows that the bonus for emission-efficient cars has cost the Swedish government more than 920 million SEK between 2018-2020 and could cost, considering an increasing bonus, up to 45 billion SEK in 2030 if no actions are taken. In a study by the Swedish National Audit Office¹⁸, it is stated that the bonus system costs approximately 5 kronor per saved kg CO₂. However, that number is based on the assumption that an electric vehicle is driven in Sweden the cars entire life. In a different calculation, assuming export after 3 years, they estimate the cost per saved kg CO₂ to be approximately three times higher.

¹⁸ Riksrevisionen, (2020). Statliga åtgärder för fler miljöbilar, RIR 2020:1, https://www.riksrevisionen.se/download/18.69c381801700b3b6ecddccdb/1581431792786/RiR%202020_01%20Anpassad.pdf

Table 1. Bonus for emission-efficient vehicles

| Environmental bonus, 2012-2018 | |
|--|--|
| 20.000-40.000 SEK | Bonus for vehicles under 50g CO ₂ /km |
| (Until 2016, 40.000 SEK for all emission-efficient vehicles) | |
| Bonus system (bonus malus), from 2018 and forward | |
| 60.000 SEK | Bonus for full electric vehicles, 2018-2020 |
| 22.779 SEK | Bonus for plug-in hybrids (with an average emission of 52g CO ₂ /km and 714 SEK reduction per gCO ₂ /km) |
| 70.000 SEK | Bonus for full electric vehicles, 2021 and forward |
| 34.861 SEK | Bonus for plug-in hybrids (with an average emission of 49g CO ₂ /km and 714 SEK reduction per gCO ₂ /km) |

1.6.3 Electricity mix in Sweden

Emission-efficient cars that run on electricity (i.e. electric vehicles) or partly on electricity (i.e. electric hybrids and plug-in hybrids) and are exported, run on a different electricity mix than they would have if driven and charged in Sweden. The following figure shows that the GHG emissions of electricity at charging points is the lowest in Sweden.

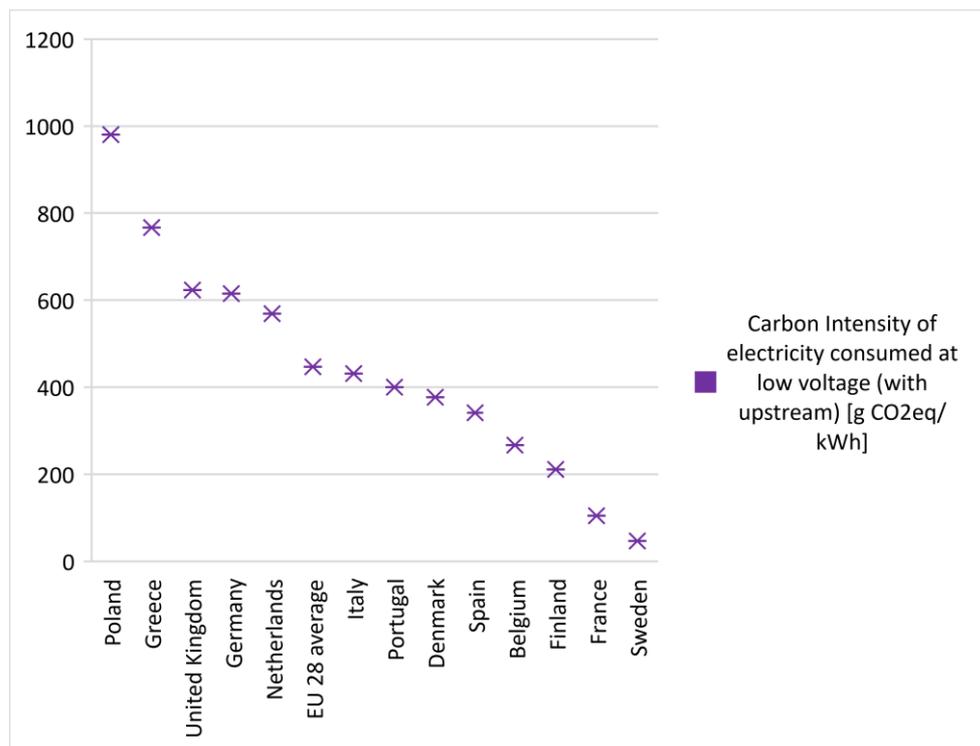


Figure 1. Carbon intensities of electricity for a selection of EU Member States¹⁹

1.6.4 Global increase in emissions from exported bonus vehicles

The global climate impact from exporting electric and plug-in hybrids from Sweden is calculated based on the following assumptions:

- 50% of the exported vehicles are exported to Norway. Norway is estimated to have the same electricity mix as Sweden, i.e. there is no increase in global climate impact for these vehicles.
- The other 50% is exported to the rest of European Union with an estimated life length of 150 000 km abroad.
- A plug-in hybrid is estimated to drive 50% on electricity and 50% on fossil fuels.²⁰
- Climate impact from fossil fuels is estimated to be the same, regardless which country the fuel is sold in.
- The energy efficiency of exported vehicles is estimated to be 18,4 kWh/100km.²¹
- In the calculation, we assume CO₂-eq intensity for electricity mixes to be constant over time.

2. Scenarios

2.1 Conversion to ethanol

If the option to conversion to ethanol is selected, it is assumed that from 2020 each year 20 000 petrol cars are converted to ethanol. The cars, at the moment of converting them to ethanol, are 5 years old. 20 000 is a maximum per year, if there are fewer 5-year old petrol cars in a certain year, those will all be converted to ethanol.

2.2 HVO for new diesel cars

If the option of HVO for new diesel cars is chosen, it is assumed that the new diesel cars coming on the market are gradually driving on HVO. In this scenario it is assumed that in 2020, no HVO is used while in 2030 all diesel cars drive on HVO, i.e. a linear trend is projected meaning each year 10% more of the new cars drive on HVO. If this HVO for new diesel cars option is not selected, it is assumed that all diesel cars will drive on conventional diesel.

¹⁹ Moro and Lonza (2018): Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles, Table 2,

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6358150/>

²⁰ The International Council on Clean Transport, 2020-09, Fact Sheet Europe: Real-world usage of plug-in hybrid electric vehicles, approximation made from Figure 1, <https://theicct.org/sites/default/files/PHEV-FS-EN-sept2020-0.pdf>

²¹ Energy efficiency based on Tesla Model S 2020 as being a common exported emission-efficient vehicle.

2.3 Lifespan of cars

The average lifespan of a car in Sweden is today 17 years. The tool allows to reduce the average lifespan to any number between 1 and 17 years to project the effect on the CO₂ emissions from passenger cars in the next 40 years. Reducing the lifespan to 1 year, will mean that all cars are scrapped after one year and replaced with new ones, i.e. only new cars drive the latest fuel efficiency drive on the road. Reducing the lifespan has an effect on both the acceleration to different powertrains (more electric cars on the road) but has as downside that more kilometers are driven (the annual driving distance for newer cars is higher than for older cars – see distance driven per car above). Note that the CO₂ emissions of the production and recycling of cars is not included in the tool.

2.4 Stop bonus for emission-efficient cars when exported within their first five years

A first scenario is based on a proposal²² that is being prepared and expected to come into effect January 1st, 2021. This proposal could reduce the numbers of exported emission-efficient cars within their first five years, because the bonus, which the first buyer of the new emission-efficient car received, has to be paid back if the car is deregistered and exported within the first five years after its first registration.

It is assumed, that from 2021 on all emission-efficient cars will stay in Sweden, because otherwise the bonus would have to be paid back. This assumption is based on the idea that most emission-efficient cars are leased by companies, so the owner are often leasing companies, and that they are not exporting these cars but keep them in Sweden, after their leasing period is over, to avoid paying back the bonus. Stopping the export will contribute to an acceleration of transforming the fleet of passenger vehicles in Sweden to a fossil-free fleet.

In a second scenario, the bonus for exported vehicles would need to be paid back in retrospect.

²² Regeringskansliet, 2020-07-22: "Klimatbonusbilar ska vara registrerade i fem år", <https://www.regeringen.se/4a163e/contentassets/6034e994d00b4f11b481485590a0f711/promemor-ian-klimatbonusbilar-ska-vara-registrerade-i-fem-ar>