At what age does a car reach its environmental end of life?

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How is the environmental impact of cars assessed?

The environmental impact of cars is determined by 1) the production process of the vehicle including extraction of raw materials, 2) driving of the vehicle in the use phase, 3) maintenance and repair during use, and 4) end-of-life treatment. There is consensus that a life-cycle view is needed to determine the environmental impact of a car, especially when comparing different cars against each other (Hawkins et al., 2012; Messagie et al., 2014; van Loon et al., 2019). A distinction is made between embedded / embodied emissions and energy (related to the production of the vehicle) versus impacts coming from the use phase. In LCAs, the use phase impacts are often based on drive cycles. g

There is consensus that standard drive cycles do not perfectly represent the real performance of vehicles. The WLTC is assumed to be more realistic than the NEDC since it includes changes in velocity (Bauer et al., 2015), ambient temperature, more realistic weight categorization, and road load testing (Hooftman et al., 2016). However, it does not include driving behavior and conditions Canals Casals et al., 2016). The eco-invent database uses more realistic values to calculate the emissions per km driven, but some studies overwrite these values with NEDC values (van Loon et al., 2019). Deterioration of the operation efficiency of the engine over time is usually excluded. Finally, emissions associated with changing owner are assumed to be negligible and therefore mostly ignored.

Research around optimal lifespan of cars in terms of CO2-eq

Several researchers have explored what the optimal age is for passenger cars from an environmental point of view. Kagawa et al. (2008) assessed the consequence of extending the average lifetime by one year, assuming that the vehicles are not disposed when approximately 12 years old but instead 13 years. The study assumes the situation in Japan, for passenger vehicles (ordinary cars, small passenger vehicles, and light passenger vehicles) that are disposed between the year 1990 and 2000 (the lifespan of the vehicles is assumed to gradually increase with one year over the 10-year period). In this 10-year period, it is assumed that the fuel efficiency of the cars on the road changes. Due to lifetime extension, less people would use an ordinary new passenger vehicle that have a relatively low fuel economy and instead remain using a small passenger vehicle with a relatively high fuel economy. Lifetime extension leads therefore to an overall decrease in gasoline consumption. Further, due to less purchases of new vehicles in the lifetime extension scenario, less energy is needed to produce new cars. The authors conclude that lifetime extension which lead to old existing vehicles being used longer is more beneficial for the environment than buying new passenger vehicles with a relatively high fuel economy (Kagawa et al., 2008).

The results are however sensitive to the assumed fuel economy of the new replacement car. If an old gasoline passenger car is replaced by a new hybrid car, the optimal lifetime of the vehicle from an environmental point of view is much lower, i.e. 9 years (Kagawa et al., 2013). The authors calculated that the energy efficiency improvement in new models is then large enough to offset the embodied emissions of production and supply chain as well as the rebound effect of consumers driving more with more efficient and new vehicles. Similarly, Brand et al. (2013) and Nakamoto (2017) argue that if the assumed replacement vehicle is a ‘green’ vehicle, emission savings can be achieved but replacing older vehicles with ‘normal’ new vehicles will probably lead to the environmental benefit being offset by the higher environmental impact of producing more vehicles and the rebound effect of driving more with a newer car.

Rogers and Rodrigues (2015) argue that the greenhouse gas emissions of cars (both the embodied and tailpipe emissions) vary considerably between models and the answer on which age is optimally preferred from an environmentally point of view is therefore case specific. To give an example, a typical European car (VW golf) requires 21 year of use to meet its same CO2-eq emission than used for the manufacturing of the car (Danilecki et al., 2017), which is longer than the estimated average lifespan of passenger cars in most west and northern European countries, except for Finland (Oguchi and Fuse, 2015).

Complicating factors

Rebound effects

Switching from old to newer cars which are more fuel efficient can lead to increases in mileage, the so-called energy-rebound effect (Lenski et al., 2010; Small and Van Dender, 2007). In addition, because of users spending less money on fuel, they might spend their money on other activities that also has their own environmental footprint. It is estimated that this rebound effect can be 10% in developed countries, which results in that only 90% of the energy improvement can actually be translated to savings on the environment (Small and Van Dender, 2007; Sorrell, 2007). Keeping vehicles instead of buying a new one might improve the financial situation of consumers even further, potentially leading to higher rebound effect (Kagawa et al., 2008).

A study conducted in Sweden suggested that owners of energy-efficient vehicles drive on average 12% further than normal car owners (Whitehead et al., 2015). In general, the distance driven with a vehicle decreases when the vehicle ages (Lenski et al., 2010).

Lack of LCA data on vehicles

Most LCA studies on cars use data from the eco-invent inventory data, which is based on a Golf A4 from the year 2000 (Helmers et al., 2017). There is only one specific vehicle (the Golf A4) included in the database (Del Duce et al., 2016). Researchers use the data and adapt it to their need. However, only compact class vehicles should be considered if the eco-invent data is used since other cars with much more or much less weight have different glider / powertrain ratios (Del Duce et al., 2016). There is a clear need to improve and update the LCA inventory data with real data from actual cars driving on the road today (Helmers et al., 2017; Bickert et al., 2015; Del Duce et al., 2016), even more so for other powertrains technologies like electric vehicles (Lucas et al., 2012; Messagie et al., 2013).

This lack of data has led to many different assumptions and boundaries in the LCA studies, leading to divergence in the results (Nordelöf et al., 2014).

Technical innovation

The optimal lifetime of vehicles depends on the efficiency of the replacement car. Several studies assume that the energy efficiency in ICEVs will continuously improve. For example, Choma and Ugaya (2017) assume a 0.7% increase in efficiency per year. Batteries for electric vehicles are expected to improve significantly (Ellingsen et al., 2016: Helmers et al., 2017). Bauer et al. (2015) made an assessment of the environmental impacts of vehicles 15 years into the future (2030) and estimated the following innovation improvements:

- Vehicle glider mass reduced by 0.5% per year
- Aerodynamic drag and tire rolling resistance coefficient reduced by 0.5% per year
- Powertrain component efficiencies increased
- Energy and power of powertrain components (mainly batteries) improved
- Energy source changes
- Other materials used

Better production processes and content of a vehicle changes, the embedded emissions of vehicles will also decrease over time. It is estimated that the on average 5 t CO2-eq in 2001 is decreasing with about 1% annual improvement to 2.7 t CO2-eq in 2060[1].

A rough estimation

Optimal lifespan is determine on one hand by the lower emissions per km when driving the car when using a newer model and on the other hand by the higher emissions associated with the increase in number of cars produced if cars are retired before their normal end-of-life.

The calculations are based on the following input data:

- Average distance driven in Sweden is 12 040 km per year in 2018 for passenger vehicles[2] and is assumed to be constant over time.
- Average fuel usage in Sweden has declined from 6.6 liter per 100km to 5.5 liter for gasoline cars and from 5.6 to 5 liter per 100 km for diesel cars from 2010 to 2016[3]. We assume a steadily decline based on these numbers (see figure 1).
- The direct and indirect CO2 emissions associated with the fuel combustion is 2.68 kg CO2 per liter for diesel, 2.31 kg CO2 per liter for petrol[4].
- The direct and indirect CO2 emissions embodied in the vehicle is assumed to steadily decline from 5 t CO2 in 2001 to 2.7 t CO2-eq in 2060. Note that this might be optimistic, other numbers for the amount of embedded CO2-eq in personal cars are found to be 7.3 t CO2-eq for a 1.3 t petrol car (Wang, 2012 cited in Rogers and Rodrigues, 2015), 6.8 t CO2-eq for VW Golf mk4 (Schweimer, 2000 cited in Rogers and Rodrigues, 2015), 10 t CO2-eq for Ford

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[1] https://www.vcd.org/fileadmin/user_upload/Redaktion/Themen/Auto_Umwelt/CO2-Grenzwert/2018_04_CO2_emissions_cars_The_facts_report_final.pdf

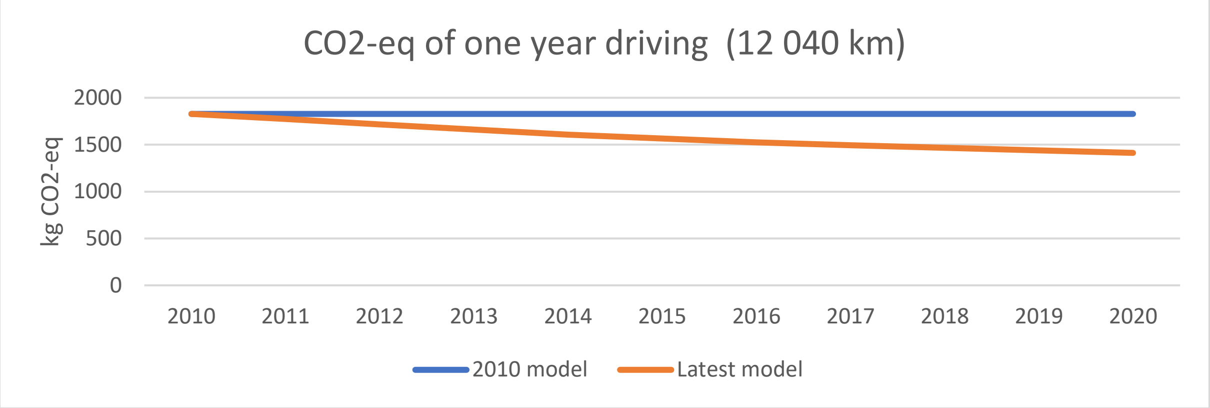
[2] https://www.trafa.se/globalassets/statistik/vagtrafik/korstrackor/2019/korstrackor_2018_blad_rev_sept.pdf?

[3] https://www.statista.com/statistics/792869/fuel-usage-of-gasoline-and-diesel-cars-in-sweden/

[4] https://people.exeter.ac.uk/TWDavies/energy_conversion/Calculation%20of%20CO2%20emissions%20from%20fuels.htm

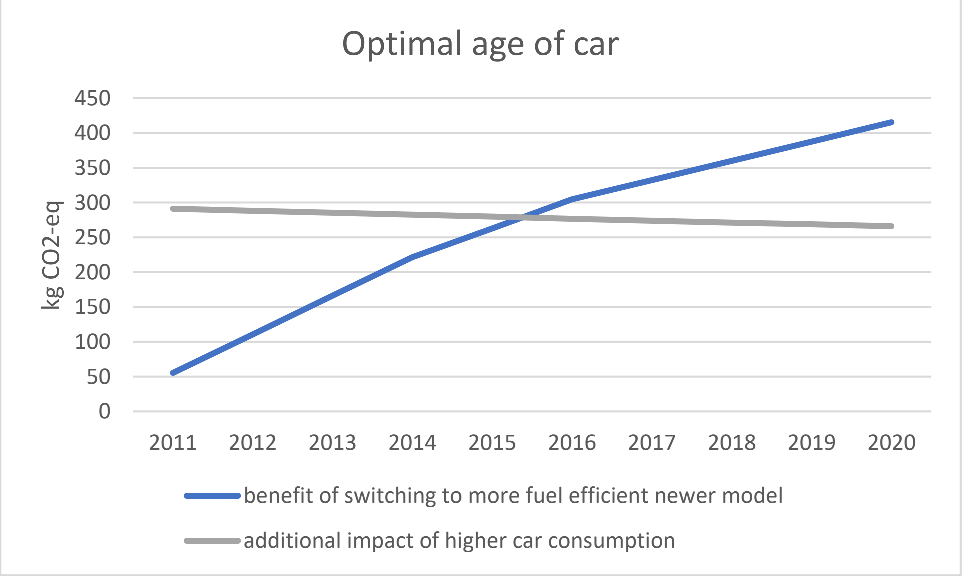
Taurus (MaxLean, 2003 cited in Rogers and Rodrigues, 2015), and 5.6 t CO2-eq for standard mid-size gasoline car[5].

Figure 1: CO2-eq emission of driving a car per year (excluding embedded emission). Blue line represents a car out of 2010, red line assumed the latest model each year.



Retiring a car earlier than initially planned does not make a change to the embedded emission, the car is already produced and need to be recycled in the end-of-life. It does however mean that a new car is produced that will have to be recycled earlier because it is taken on the road earlier. Assuming the average lifespan of cars (i.e. 17 years in Sweden and constant, Oguchi and Fuse, 2015), the embedded emissions of the newer model car is divided by this to include the impact of using the car earlier. Comparing the two against each other, we find that the 2010 car should be replaced in 2015.

Figure 2: optimal lifespan of vehicles in terms of CO2-eq emissions. Grey line represents the share of embedded emissions while blue line represents the difference in CO2-eq emission of driving a newer model compared to the 2010 model.



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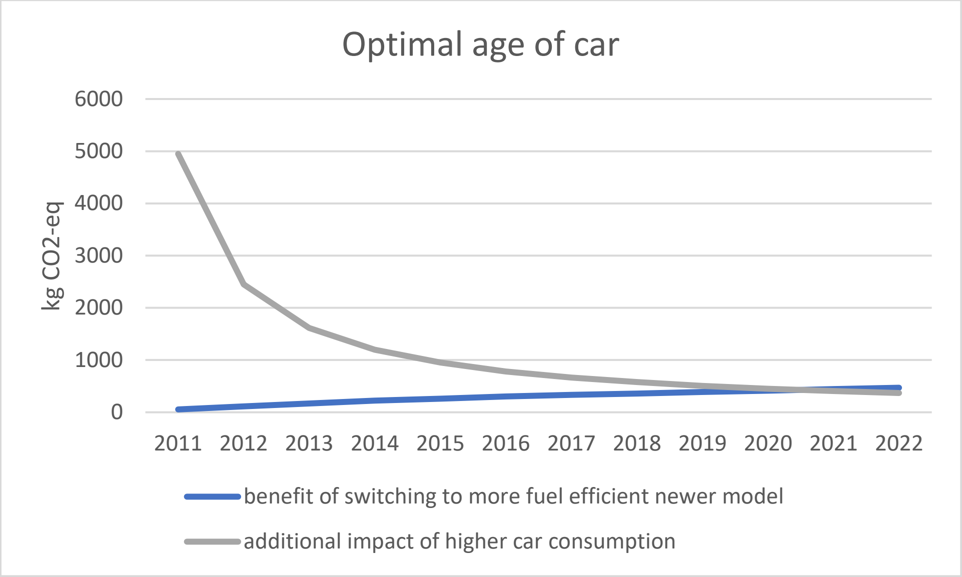
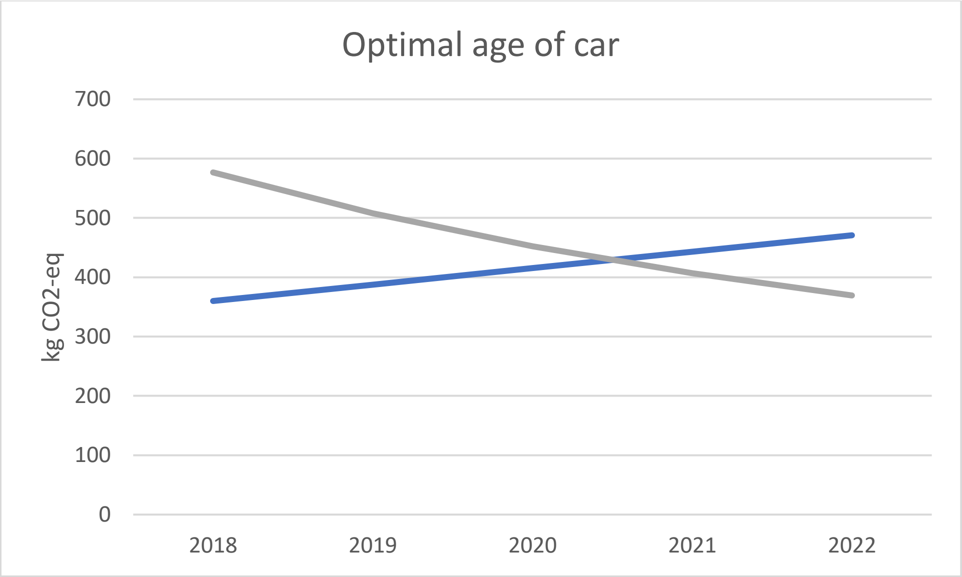
[5] https://www.lowcvp.org.uk/assets/workingdocuments/MC-P-11-15a%20Lifecycle%20emissions%20report.pdf

Obviously, assuming that the newer model car will also be replaced earlier, the embedded emission per year are higher. Correcting for this we get the following picture.



Zooming in on break-even point:



Optimal age is 10 to 11 years, but is highly dependent on input data and assumptions.

References

Bauer, C., Hofer, J., Althaus, H.-J., Del Duce, A., Simons, A. (2015). The environmental performance of current and future passenger vehicles: life cycle assessment based on a novel scenario analysis framework. *Applied Energy*, 157, 871-883.

Bickert, S., Kampker, A., Greger, D. (2015). Developments of CO_2-emissions and costs for small electric and combustion engine vehicles in Germany. *Transportation Research Part D*, 36, 138-151.

Brand, C., Anable, J., Tran, M. (2013). Accelerating the transformation to low carbon passenger transport system: the role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK. *Transportation Research Part A: Policy and Practice*, 49, 132-148.

Canals Casals, L., Martinez-Laserna, E., Garcia, B.A., Nieto, N. (2016). Sustainability analysis of electric vehicle use in Europe for CO2 emissions reduction. *Journal of Cleaner Production*, 127, 425-437.

Choma, E.F., Ugaya, C.M.L. (2017). Environmental impact assessment of increasing electric vehicles in the Brazilian fleet. *Journal of Cleaner Production*, 152, 497-507.

Danilecki, K., Mrozik, M., Smurawski, P. (2017). Changes in the environmental profile of a popular passenger car over the last 30 years – results of a simplified LCA study. *Journal of Cleaner Production*, 141, 208-218.

Del Duce, A., Gauch, M., Althaus, H.J., (2016). Electric passenger car transport and passenger car life cycle inventories in ecoinvent version 3. *International Journal of Life Cycle Assessment*, 21(9), 1314-1326.

Ellingsen, L. A.-W., Singh, B., Stromman, A.H. (2016). The size and range effect: lifecycle greenhouse gas emissions of electric vehicles. *Environmental Research Letters,* 11, 1-8.

Hawkins, T.R., Gausen, O.M., Hammer Stromman, A. (2012). Environmental impacts of hybrid and electric vehicles – a review. *International Journal of Life Cycle Assessment,* 17, 997-1014.

Helmers, E., Dietz, J., Hartard, S. (2017). Electric car life cycle assessment based on real-world mileage and the electric conversion scenario. International Journal of Life Cycle Assessment, 22(1), 15-30.

Hooftman, N., Oliveira, L., Messagie, M., Coosemans, T., Van Mierlo, J. (2016). Environmental analysis of petrol, diesel and electric passenger cars in a Belgian urban setting. *Energies*, 9, 1-24.

Kagawa, S., Kudoh, Y., Nansai, K., Tasaki, T. (2008). The economic and environmental consequences of automobile lifetime extension and fuel economy improvement: Japan's case. Economic Systems Research, 20(1), 3-28.

Kagawa, S., Hubacek, K., Nansai, K., Kataoka, M., Managi, S., Suh, S., Kudoh, Y., (2013). Better cars or older cars? Assessing CO2 emission reduction potential of passenger vehicle replacement programs. *Global Environmental Change*, 23(6), 1807-1818.

Lenski, S.M., Keoleian, G.A., Bolon, K., (2010). The impact of 'Cash for Clunkers' on greenhouse gas emissions: a life cycle perspective. *Environmental Research Letters,* 5, 1–8

Lucas, A., Silva, C.A., Neto, R.C. (2012). Life cycle analysis of energy supply infrastructure for conventional and electric vehicles. *Energy Policy*, 41, 537-547.

Messagie, M., Lebeau, K., Coosemans, T., Macharis, C., Van Mierlo, J. (2013). Environmental and financial evaluation of passenger vehicle technologies in Belgium. *Sustainability,* 5, 5020-5033.

Messagie, M., Boureima, F.-S., Coosemans, T., Macharis, C., Van Mierlo, J. (2014). A range-based vehicle life cycle assessment incorporating variability in the environmental assessment of different vehicle technologies and fuels. *Energies*, 7, 1467-1482.

Nakamoto, Y. (2017). CO2 reduction potentials through the market expansion and lifetime extension of used cars*. Journal of Economic Structures*, 6:17.

Nordelof, A., Messagie, M., Tillman, A-M., Ljunggren Soderman, M., Van Mierlo, J. (2014). Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles – what can we learn from life cycle assessment?. *International Journal of Life Cycle Assessment,* 19, 1866-1890.

Oguchi, M., Fuse, M. (2015). Regional and longitudinal estimation of product lifespan distribution: a case study for automobiles and a simplified estimation method. Environmental Science and Technology, 49, 1738-1743.

Rogers, J.G., Rodrigues, A. (2015). Product leasing – a strategy to allow manufacturers and customers to benefit from elongation of product life. PLATE conference, Nottingham Trent University, 17-19 June 2015.

Small, K.A., Van Dender, K., (2007). Fuel efficiency and motor vehicle travel: the declining rebound effect. *Energy Journal*, 28, 25–51.

Van Loon, P., Olsson, L., Klintbom, P. (2019) LCA guidelines for electric vehicles: how to determine the environmental impact of electric passenger cars and compare them against conventional internal-combustion vehicles. Available at: https://www.ri.se/sites/default/files/2019-06/Bilaga%202%2C%20LCA%20Guidelines%20for%20electric%20vehicles.pdf and https://www.ri.se/sites/default/files/2019-06/Bilaga%203%2C%20LCA%20guidelines%20for%20electric%20vehicles_Literature%20Review.pdf

Whitehead, J., Franklin, J. P., Washington, S. (2015). Transitioning to energy efficient vehicles: An analysis of the potential rebound effects and subsequent impact upon emissions. *Transportation Research Part A: Policy and Practice*, 74, 250-267.