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Swapping programs for accelerating vehicle fleet modernization – A Life Cycle perspective

Passenger vehicle fleet modernization has been stimulated by swapping programs subsidized by governments in several countries in the past. Such «cash-for-clunker» programs can be effective in supporting the car industry as well as in improving average fuel efficiency and local air quality, as new vehicles tend to consume less fuel and have lower air pollutant emissions. Today, battery electric vehicles could be subsidized in order to replace combustion engine vehicles and accelerate the electrification of the fleet. However, premature replacement of vehicles causes additional emissions related to vehicle production and end-of-life., These additional emissions must be more than compensated for by reduced operational fuel consumption and tailpipe emissions – otherwise, such scrappage programs are counterproductive from a life cycle perspective. We have evaluated actual past programs as well as potential programs taking place today – effects are ambiguous.

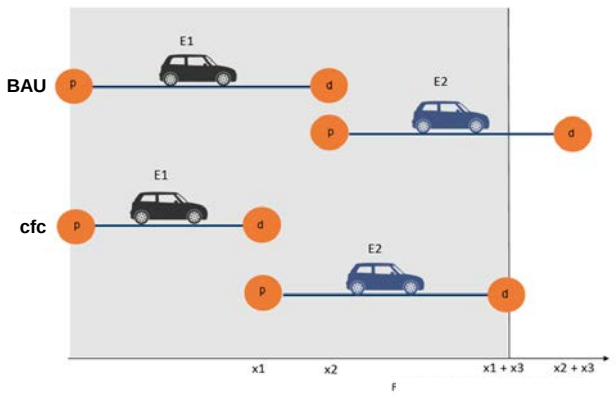
Andrea Nistad, Romain Sacchi, Chris Mutel, Christian Bauer*
Technology Assessment group, Paul Scherrer Institut (PSI), https://www.psi.ch/en/ta
* christian.bauer@psi.ch

Introduction

Past environmental assessments of scrappage programs are often limited to evaluating the reduction in direct air pollutant emissions. However, indirect emissions contribute considerably to the overall environmental impact of vehicles, especially in the case of battery electric vehicles (BEV). Accounting for these indirect emissions is essential to design programs providing benefits to air quality and climate change mitigation.
Our analysis focuses on the case of Germany, where a large scrappage program was implemented in 2009. First, this program is analyzed from a life-cycle perspective. Thereafter, a hypothetical current Program is assessed aiming at Replacing diesel cars with BEV in German cities where NO2 concentration limits are exceeded.

Method

The life cycle impacts of a business-as-usual (BAU) scenario are compared to those of a «cash-for-clunker» (cfc) or «Retire and Replace» (RaR) program.



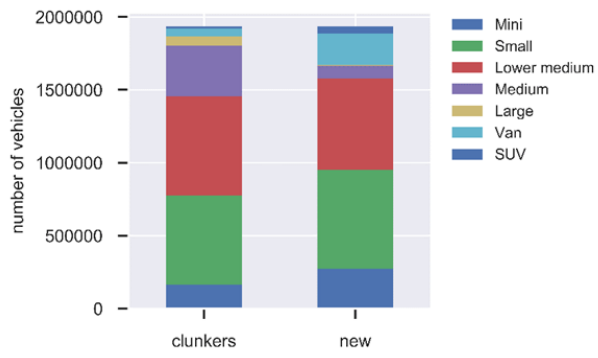
The net effect of the scrappage program is expressed as:

$$E_{net} = E_1(x_2 - x_1) - E_2(x_2 - x_1) - \frac{(p+d)}{x_3}(x_2 - x_1)$$

Effects on vehicle fleet

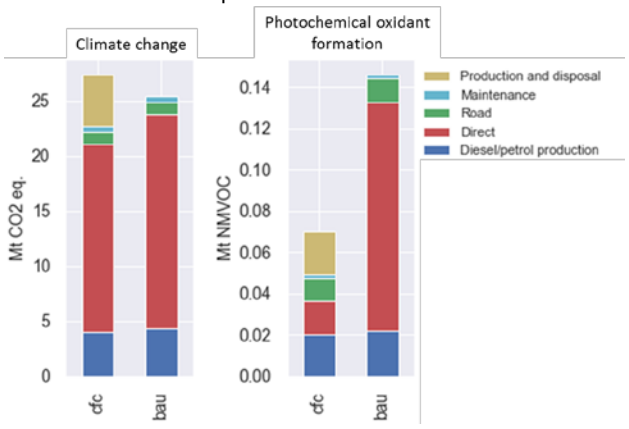
The 2009 program showed a substantial «downsizing effect», i.e. an increase in the small size segments could be observed. This effect as such already leads to an increased fuel efficiency. Further key parameters:

- Average age of the old vehicles: 14 years
- Estimated reduction in lifetime: 4 years
- Annual mileage: 14'000 km (old and new cars)

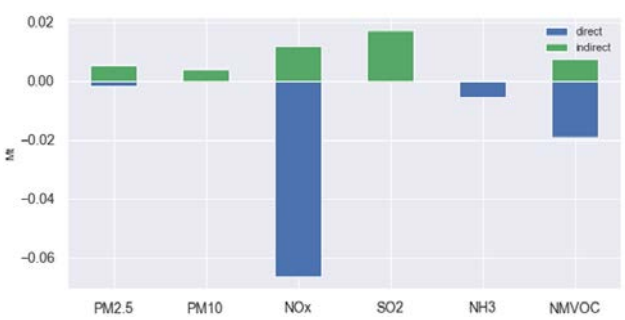


Life cycle impacts of the 2009 program

The life-cycle effect in 2009 was slightly negative regarding greenhouse gas emissions, but clearly positive in terms of photochemical oxidant formation (so-called «summers smog»). While additional GHG emissions of vehicle production and disposal are not compensated by increasing fuel efficiency, the reduction of (mainly) direct NO_x emissions due to new vehicles is much higher than the additional production related emissions.

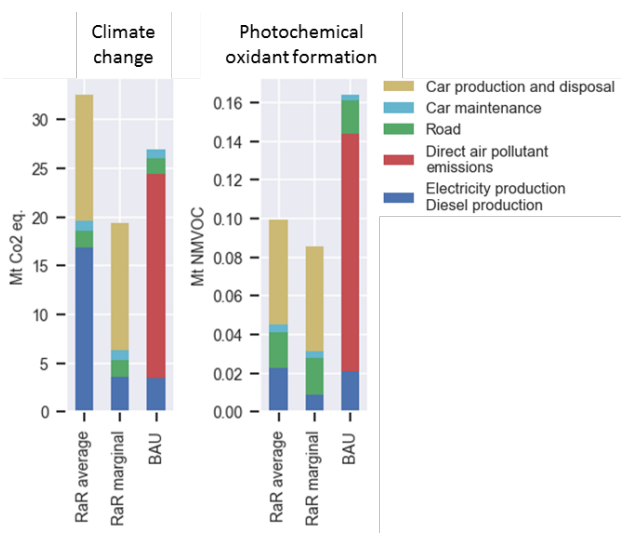


Direct NO_x emissions are most substantially reduced by the swapping program – PM2.5 only to a minor extent.



Impacts of introducing BEV

The impacts of a hypothetical «Retire and Replace» (RaR), taking place today and aiming at an early retirement of old diesel vehicles, to be substituted with new BEV in Germany very much depend on the assumed electricity mix used for BEV charging. With the current average mix, which contains substantial amounts of coal power, the impacts on climate change are negative; assuming a long-term marginal mix – in line with climate goals and containing high shares of renewables – leads to a positive effect of the program.
Substantial benefits in terms of photochemical oxidant formation as an effect of NO_x emission reduction can be observed independently of the electricity mix.
It is therefore important that stimulating vehicle fleet electrification goes hand in hand with the expansion of renewable power generation.



Conclusions

Past programs

- Neutral to moderate increase in GHG emissions, as the fuel economy improvement was modest
- Direct emissions of all air pollutants decreased, but only the decrease in NOx, NH3 and NMVOC emissions was large enough to compensate for increased production and disposal emissions
- Local air quality improved

Potential current programs with BEV

- Introducing electric vehicles today could lower NO_x emissions more substantially than the past program
- Benefits for local air quality would be substantial
- BEV programs can bring benefits to climate change mitigation and have larger potential to do so than scrappage programs limited to conventional vehicles; but only, if additional electricity demand for charging is met by a low-carbon electricity mix
- Incentives should encourage buying smaller cars – the downsizing effect observed in 2009 shows to be beneficial from the environmental perspective and would need to be in place today as well

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