Passenger light duty vehicles – Marginal abatement costs in WEO-2009

Methodology and sensitivity of results

For the analysis of marginal abatement costs in *WEO-2009* (IEA 2009a), a comprehensive and detailed review of the costs for reducing fuel consumption from passenger light duty vehicles (PLDVs) was conducted together with the Energy Technology Perspectives team of the IEA. The dataset comprised the following vehicle types:

- Gasoline internal combustion engine (ICE) vehicles
- Diesel internal combustion engine (ICE) vehicles
- Gasoline hybrid vehicles
- Diesel hybrid vehicles
- Gasoline plug-in hybrids
- Diesel plug-in hybrids
- Electric cars
- Hydrogen fuel cell cars

The data was peer-reviewed by representatives from industry and science.

The analysis of marginal abatement costs for PLDVs, however, found considerable differences between world regions because of underlying input parameters, in particular the annual mileage driven per vehicle and the average lifetime per vehicle. Moreover, distinct differences were observed with the choice of the discount rate. Therefore, this document aims at discussing the sensitivity of results in some detail for the case of EU27 with the objective of highlighting why marginal abatement costs for PLDVs are very uncertain and must be established for each country individually, with due attention and mention of the uncertainties associated with it.

Methodology

For this analysis, marginal abatement costs for any given year were estimated using the incremental costs of each PLDV type and CO_2 emissions saved relative to a reference vehicle -- a gasoline ICE vehicle in the given year. The analysis of incremental costs of PLDVs covers conventional ICE vehicles, hybrid vehicles, plug-in hybrids, electric cars and fuel cell vehicles. The method has been applied to each individual country/region of the World Energy Model (WEM). For the case of EU27, which will be subject to the sensitivity analysis in the remainder of this document, the reference car has an average on-road fuel consumption of 6.5 litres of gasoline equivalents per 100 kilometres (km). In mathematical terms, the Marginal Abatement Costs *MACs* for each PLDV *j* at any given time *t* relative to the reference PLDV were calculated as

$$MACs_{j,t} = \frac{\left(Annual\ Costs_{PLDV\ j,t,450\ Scenario} - Annual\ Costs_{Reference\ PLDV\ t}\right)}{\left(Annual\ CO_2\ Emissions_{Reference\ PLDV\ t} - Annual\ CO_2\ Emissions_{PLDV\ j,t,450\ Scenario}\right)} \quad (1)$$

Annual costs of each PLDV were derived from

$$Annual\ Costs = Investment\ Costs \times \frac{CRF}{AF} + O\&M + \frac{Annual\ Fuel\ Costs}{Efficiency} \times Annual\ Mileage \quad (2)$$

Where

$$CRF = Capital\ Recovery\ Factor = discount\ rate \times \frac{(1 + discount\ rate)^{vehicle\ lifetime}}{(1 + discount\ rate)^{vehicle\ lifetime} - 1}$$

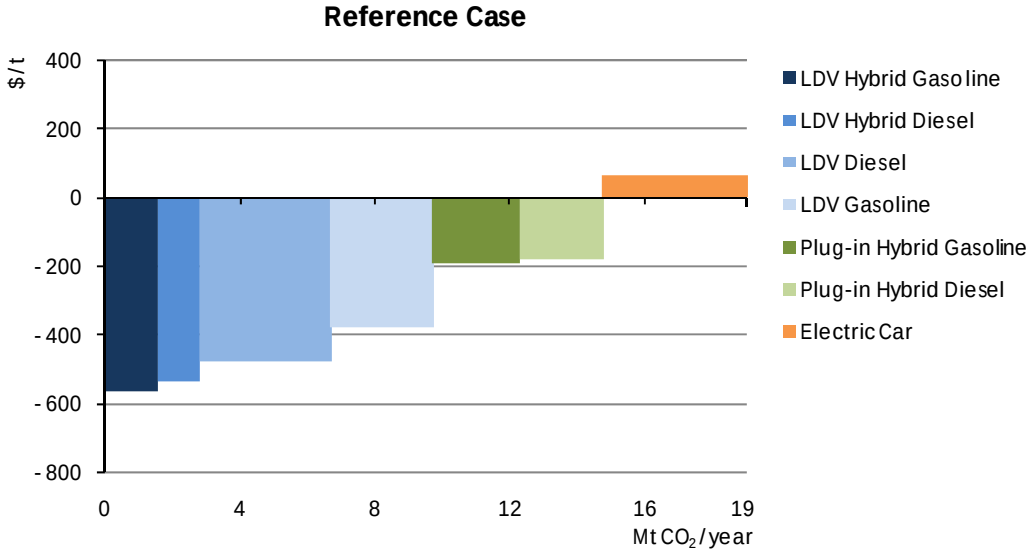
$$AF = Availability\ Factor = assumed\ 1\ across\ all\ technologies$$

$$O\&M = Annual\ O\&M\ Costs = assumed\ 2\%\ of\ investment\ across\ all\ technologies$$

The discount rate was set to 10% across all technologies and regions. Biofuels, electricity and hydrogen were treated as zero-emission fuels for this analysis.

Sensitivity of Results

Estimates of the marginal abatement costs of PLDVs vary widely, depending on the assumptions used, such as the discount rate, but also dependent on region-specific conditions such as the average lifetime of a vehicle and the mileage driven per year. The results presented above for EU27 are based on the technology detail of the World Energy Model (WEM) of the IEA, but can vary considerably depending on assumptions and region-specific conditions. For illustration of the impact of varying key input parameters, this document will provide a sensitivity analysis using EU27 results as an example.

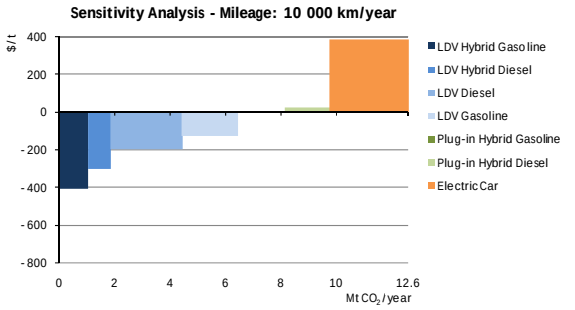


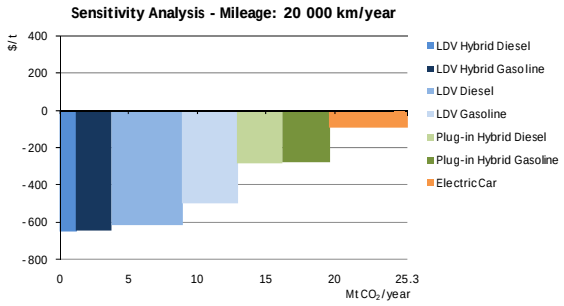
Key input assumptions in the above reference analysis:

- Mileage: 15 000 km/year
- Vehicle lifetime: 15 years
- Discount rate: 10%

Sensitivity 1: variation of the annual mileage

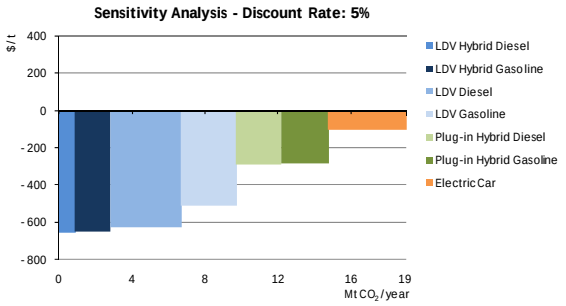
Varying the annual mileage has a distinct influence on the results, as it determines the relationship between annual discounted investment costs per kilometre driven and the fuel savings per year in the above equation 2. In summary, the higher is the annual mileage, the lower are the marginal costs of abatement, and results can differ anywhere from negative to positive costs. This observation enforces the argument that marginal abatement costs must be calculated region-by-region, as annual mileages vary considerably and data availability in many (if not most) cases is very weak.

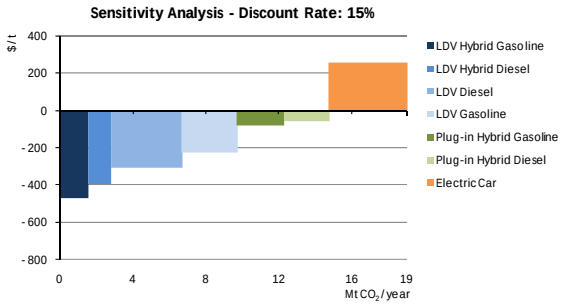




Sensitivity 2: variation of the discount rate

The discount rate is another key variable in the evaluation of marginal abatement costs, as it determines the relationship of higher upfront investment costs in purchasing a more efficient car to the value of annual fuel savings. This sensitivity analysis does not aim to enter discussions on likely appropriate choices of discount rates for the purpose of deriving marginal abatement costs, but it is still worth noting that there are good reasons for choosing either a societal perspective with low or very low discount rates, or the perspective of individuals which might choose higher discount rates in making monetary decisions. The discount rates chosen here are meant to illustrate only the impact of the choice of the discount rate on the marginal abatement costs.





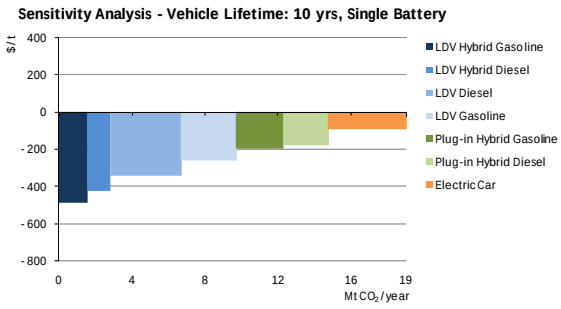
Sensitivity 3: variation of the vehicle lifetime

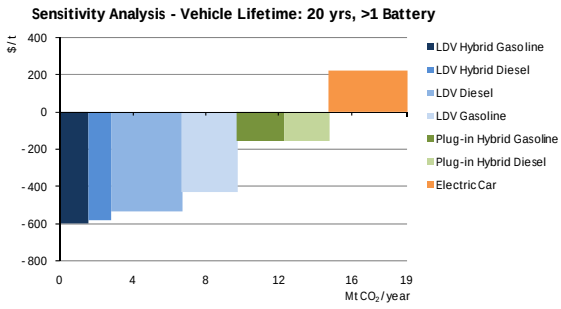
The vehicle lifetime has numerous implications on the cost of abatement. On a general level, the lifetime of a vehicle is again one important determinant for the relationship between annual discounted investment costs and fuel savings. Moreover, and particularly important for the analysis of electric cars and plug-in hybrids, the average vehicle lifetime determines the need for battery replacement.

Generally speaking, the development of batteries will be of high importance for the future of road transport electrification. The battery lifetime critically depends on numerous external influences such as regional climatic conditions, and also very importantly on the Depth of Discharge (DOD)[1]. The DOD is crucial in particular for their application in electric cars (as the battery-electric engine is the single drivetrain there), but less so for hybrid cars, where batteries do not undergo the same DOD because they are supported by an internal combustion engine. Manufacturers will certainly make strong efforts to design batteries that last the full lifetime of a vehicle, as failure to do so may hurt the marketability of plug-in hybrids as well as electric cars. But attaining very long lifetime may increase the cost of batteries substantially, so that vehicle designers may have to trade off costs with robustness and thus lifetime. In contrast, a replacement battery is likely to be less costly than the original one, as it probably does not need to meet the same lifetime requirements as the original one. Such factors are very hard to quantify at this stage.

The calculation of marginal abatement costs for electric cars gets further complicated if one additionally accounts for business models. The electrification of road transport is likely to come along with business models that depart from existing structure in the system of manufacturers and retailers. With the higher purchase costs of electric cars and the different requirements for recharging compared to conventional cars, it is likely that industry will need to seek alternative retail structures that allow e.g. the leasing of batteries or the swapping of batteries at service stations, or something entirely different with the development of smart grids. Many manufacturers are, thus, currently discussing the possibility of second hand markets for batteries, which could lower the overall investment for the consumer, even though it could come at the expense of lower robustness for the application in road transport.

For the analysis of the costs of PLDVs in EU27, an average vehicle lifetime of 15 years was assumed. The average battery lifetime of the year 2030 is likely to be in the order of 10 years at the given underlying battery DOD and durability assumptions (see IEA 2009b for details) and assuming further technological progress. Thus, one electric car of the year 2030 in EU27 would roughly require 1.5 batteries over its lifetime. With a lifetime of 10 or 20 years, however, an electric car would require 1 or 2 batteries respectively in this rather simplified analysis, neglecting the impact of additional second hand value of the battery. For plug-in hybrids, the lifetime of the battery would probably be somewhat higher as for electric cars, as the supporting internal combustion engine would reduce the DOD of the battery. For the purpose of this analysis, 1 battery was chosen for a plug-in hybrid vehicle lifetime of 10 years, 1.3 batteries for a lifetime of 15 years, and 1.6 for 20 years.





[1] The DOD essentially represents the charging level of the battery.

References

IEA (international Energy Agency) (2009a), World Energy Outlook 2009, OECD/IEA, Paris.

IEA (international Energy Agency) (2009b), Transport, Energy and CO_2: Moving toward Sustainability, OECD/IEA, Paris.