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Environmental impact of scrapping old cars ☆

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Abstract

Many countries introduced scrapping programs in the 90s, partly legitimated by environmental impact reductions. However, reducing the age of the current car fleet may result in an increase of life-cycle CO_2 emissions. This will probably also be true for cars to be produced in future unless fuel efficiency of new cars improves much faster than the historical trend indicates. Reducing the age of petrol-fuelled cars without a catalytic converter will reduce both life-cycle NO_x and VOC emissions but is less cost-effective than fitting catalytic converters on these cars. In any case, the influence of a car's lifetime on life-cycle NO_x and VOC emissions will be reduced in the near future.

Keywords: Scrapping; Life-cycle; Emissions; Energy use; Cars

1. Introduction

The performance of cars with regard to energy efficiency and detrimental emissions has shown continuous improvement. The development of more energy-efficient and cleaner car engines, the introduction of car designs with decreased drag resistance and the application of exhaust catalysts are some of the reasons behind this trend. So one should expect that, all things being equal, the shorter the average lifetime of cars, the lower the energy consumption of and emissions from the car fleet. An unpublished study of the Dutch National Institute of Public Health and the Environment (RIVM) underlines this expectation: if in the year 2000 all Dutch petrol cars without a three-way catalytic converter were to be replaced by new cars, NO_x emissions would be reduced by

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30%. So shortening the average lifetime of cars seems to be good for the environment. In the 90s several countries (Greece, Hungary, Denmark, Spain, France, Ireland, Norway and Italy: see Fontana (1999)) have introduced regulations to scrap old cars. Several studies on the impact of scrapping old cars have been carried out. Kavalec and Setiawan (1997) conclude that scrapping cars of 20 yr and older is cost-effective, particularly in the USA. The US Congress, Office of Technology Assessment (1992) concludes that a carefully designed early retirement program, targeted at areas that are out of compliance with air quality standards, can achieve environmental benefits at costs equal to or lower than those of other emission–reduction options already in use or scheduled to be used. Besides, some countries, such as Japan, Germany and Sweden, have other (fiscal) policies that reduce the average age of cars. For example, in Germany, yearly taxes on cars with relatively high emissions (no catalytic converter) are much higher than taxes on new cars. Three objections may be raised against the conclusion that regulations to scrap old cars are good for the environment.

1. Firstly, the RIVM analysis, as reported above, is solely based on the phase of car use. Since other phases in the life cycle of the car require energy, the result will be detrimental emissions. A shortening of the average lifetime will boost car production, requiring energy for car materials and assembly, and producing emissions. So an assessment encompassing the whole life cycle of the car may affect the conclusion.
2. Secondly, since new cars are larger and faster than the old cars they are replacing, with the 'other things being equal' assumption, the gains of more efficient technology are offset by a higher curb weight and acceleration. Besides, newer cars may differ from older cars in their use.
3. A third argument is that by retrofitting, high polluters may be dealt with more cost-effectively than by scrapping.

This article will focus on the relationship between the average lifetime of cars and their life-cycle energy requirements and emissions. The production, materials, uses and scrapping of cars, including recycling will all be considered. Also addressed will be the differences in performance and use between old and new cars. Finally, cost-effectiveness of scrapping will be compared to retrofitting programs for old cars. All data used are for the Netherlands car fleet.

2. Energy for car use

Table 1 shows CO_2 emissions of the Dutch car fleet for several years within the 1970–1997 period and the remarkable improvement in energy efficiency for this period.[1] This also happened

[1] Energy use of the car fleet not only depends on technical characteristics of cars. The fraction of all kilometres for each road type (e.g., motorways, urban roads) is also relevant. In the Netherlands the fraction of urban roads has decreased, resulting in a decrease in fuel use per kilometre. Besides, the average speed on motorways has increased, resulting in an increase in fuel use per kilometre. Since 1985, cars in the Netherlands older than 3 yr have been required to have an annual safety check (APK). This is similiar to the MoT in the UK and the TUV in Germany. The introduction of the APK might have improved overall level of maintenance of cars, resulting in a reduction of energy use per kilometre. Between 1970 and 1990 the average age of the car fleet increased, resulting in a reduction in the penetration speed of new techniques. All things being equal, this will reduce the improvement in fuel efficiency. Overall impact of these factors is small compared to the change in technical characteristics. For this reason, we use average fuel use per kilometre of the car fleet as an indicator for changes in the fuel efficiency of cars.

Table 1
CO_2 emission data for The Netherlands[a]

	CO_2 emission (gr/veh. km)	Number of cars	Number of car kilometres on Dutch territory	CO_2 emission of cars on Dutch territory
1970[b]	100	100	100	100
1975	98	137	132	130
1980	89	176	166	147
1985	85	191	186	157
1990	79	216	219	172
1992	79	220	231	182
1994	79	231	241	189
1995	79	234	243	193
1996	80	239	243	193
1997	79	244	252	198

[a] Source: Based on data from Statistics Netherlands.
[b] (Index 1970 = 100).

in several other countries. In the USA the improvement was even greater than in the Netherlands. On the other hand, fuel efficiency of the car fleet in the western part of Germany, the UK, Italy and France either did not improve at all or hardly improved, mainly due to an increase in vehicle power and weight (OECD, 1995). Because of the much stronger growth in car ownership and car use than the decrease in CO_2 emissions per kilometre, total CO_2 emissions increased between 1970 and 1997.

A further reduction of 14–17% in energy use per kilometre of the Dutch car fleet is expected between 1995 and 2020 (Geurs et al., 1998). However, the expected reduction was not realized in the period 1990–1994. The increase in average car weight, power and cylinder volume of new cars in the 1987–1990 period (Cornelissen, 1993) continued after 1990. For instance, in 1990–1994 the average weight of new cars increased by 68 kg or 7% (Moll and Kramer, 1996).

3. Energy in the manufacture and waste/recycle stage of cars

The literature shows a large variation in estimates of the energy needed to manufacture a car (Moll, 1993).[2] Evaluation of the life-cycle energy requirement of new cars in the Netherlands in the 1990–1994 period indicates that 15–20% of the life-cycle energy requirement is related to car production, maintenance and disposal; the remaining 80–85% is related to the fuel consumption for car driving (see Moll and Kramer, 1996).

Some of the energy becomes available again if the car is (partly) recycled: the re-used materials ‘contain’ energy. In the Netherlands about 70% of scrapped cars by weight are recycled (Vos and Meiling, 1991). Calculations by Moll (1993) and Moll and Kramer (1996) demonstrate that 50% of the net energy requirement for the car materials becomes available through recycling. Consequently, 35% of the net energy requirement of car materials in the Netherlands car is re-claimed. This percentage is expected to increase in future.

[2] In the literature, for example, the energy needed to produce a car varies between 33 and 77 GJ (Moll, 1993). This only refers to the energy to *produce* a car, not the energy needed to produce the materials.

4. Energy required for car use and car manufacture compared

Considering both the 'in-use' energy and the energy it takes to manufacture a car, the 'optimal' age of a car can be calculated once information on the energy it takes to operate and manufacture a car and information on fuel efficiency improvement (or better: decrease in energy use per kilometre) are available. Expressed in equation form:

$$n = \mathrm{Em}/[\mathrm{Eu} - \mathrm{Eu} * (1 - \alpha)^n],$$

where, n is the optimal number of years, Em the energy needed to manufacture a car (including the 'gain' at the recycling stage), Eu the energy for car use per year, and α is the decrease in energy for new car use per kilometre.

Key variables are the 'loss' in energy for manufacturing a new car as a result of scrapping (Em) and the 'gain' in energy from the use of new cars $[\mathrm{Eu} * (1 - \alpha)^n]$, which are more fuel efficient. The optimal lifetime is the number of years for which the 'loss' of energy from manufacture equals the 'gain' from the new, more fuel-efficient cars.

The energy use for operating a car in the Netherlands is calculated assuming the average lifetime of the present car fleet to be 12 yr. Using Moll's upper estimate that it takes four times as much energy to operate a car (total life of a car) than to manufacture it, annual energy use for operating a car comes to 4/12, or one-third, of the energy needed for manufacturing a car.

Consequently, an assumed decrease in energy use per year of 1% results in an 'optimal' car age of 19 yr. Moll's lower estimate (15% of the life-cycle requirement is related to car manufacture) results in an 'optimal' car lifetime of 15 yr. Note that the absolute figures for energy use are unimportant; only the relationship between energy required for manufacture and car use is relevant.

Table 2 presents the optimal lifetime for a car under different circumstances, which will depend on (a) the relationship between energy for manufacture and car use, and (b) the decrease in energy use by new cars per kilometre per year.

The calculated 'optimal' lifetimes that are found to exceed by far the current average lifetime (12 yr) of Dutch cars. Table 2 shows that scrapping old cars from a life-cycle-energy point of view is only favourable if the annual improvement in fuel efficiency is more than 1% and, at the same time, if the manufacture energy of a car is less than 15% of the energy required to operate a car.

The assumed *annual* efficiency increase of 1% does not show up in the energy efficiency figures of Table 1. However, when correcting these data for the increase of average car weight, this

Table 2
Optimal lifetime of a car

Decrease in energy use per kilometre per year (%)	Energy for manufacture as a percentage of operation (%)			
Age (yr)	10%	15%	25%	35%
0.25	23	28	36	43
0.50	16	20	26	31
0.75	13	16	21	25
1.00	12	14	19	22
1.25	11	13	17	20
1.50	10	12	15	18

estimate is likely to be accurate. Still, one should realize that real reductions in the fuel consumption per car will only occur in the future when the trend to buy bigger and more luxurious models than those scrapped ceases.

Unless the improvement in fuel efficiency in the future is much greater than in the past, scrapping old cars will very likely result in increased life-cycle-energy use and CO_2 emissions. A much greater improvement may result from much higher fuel prices, as the higher the fuel price, the more fuel-efficient cars are sold (see, for example, Goodwin, 1992) or by government regulation of fuel efficiency.

The energy used to manufacture a car as a percentage of the energy to operate it has increased (Moll, 1993). A further increase is expected. The better the improvement in fuel efficiency e.g., as a result of using light (but 'energy-intensive') materials, the greater – ceteris paribus – the increase.

5. Relationship between age of the car and distance driven per year

Up to now we have implicitly assumed that there is no relationship between distance driven per year and age of the car. In other words, it is assumed implicitly that people who scrap their old car will immediately buy another, new(er) car and exhibit a similar driving behaviour. However, statistics show that the average yearly distance driven decreases with car age. Table 3 shows figures for the Netherlands.

Table 3 shows that the average yearly distance driven by cars older than 10 yr is less than half the distance driven by cars only several years old. New cars are often more reliable, comfortable and energy-efficient than old cars. People who intend to drive more in the near future will therefore show anticipative behaviour by purchasing a new(er) car. In addition, a new(er) car will probably generate more kilometres by itself, since the variable costs decrease, the newer car may be more reliable and/or because of the pleasure of driving increases.

If the new(er) car is substantially more energy-efficient, it will cause a decline in the cost price per kilometre, which leads to an increase in petrol consumption (Goodwin, 1992). Moreover, incentives will be absent to perform energy-efficient journeys, driving styles and speed, as proved by Rouwendal (1996). In other words, the energy savings due to an improvement in energy

Table 3
Relationship between yearly distance driven and year of manufacture; 1997[a]

Age of cars (in years)	Average yearly distance
0–1	26,340
1–2	23,100
2–3	22,520
3–4	22,420
4–5	18,950
5–6	17,200
6–7	15,620
7–8	15,780
8–9	14,800
9–10	13,500
> 10	11,290

[a] Source: Statistics Netherlands (CBS).

efficiency of new cars compared to scrapped old cars will – at least partly – be undone by rebound effects.

6. Other emissions

The average lifetime NO_x emissions per kilometre of a new car (Euro 2) with a regulated three-way catalytic converter are at least 80% lower than NO_x emissions from a car without a catalytic converter. CO and VOC emissions reductions are even higher. We did not investigate life-cycle emissions of these pollutants. However, because of the much lower emission factors from cars with a catalytic converter, and because of the dominant contribution of car emissions to total national emissions, it is clear that scrapping petrol-fuelled cars without a catalytic converter will not only reduce emissions caused by using cars, but also life-cycle emissions. This raises the question of whether or not scrapping these cars is cost-effective. An alternative may be fitting three-way (unregulated or, in future, also regulated) catalytic converters. Unregulated converters can be purchased in Germany for US$125. With fitting included, the total cost of these converters will likely amount to (much) less than US$300.[3] According to an Environmental Protection Agency (EPA) remnant report provided by a company selling these converters, reductions in CO, NO_x and VOC per kilometre are between 55% and 80%.

These figures seem optimistic. Let us assume that emission reductions are about 40%. This reduction is half the reduction obtained by scrapping a car. Both alternatives, scrapping cars and retrofitting a converter, have the same cost-effectiveness if the average value of a car to be scrapped is twice the cost of a retrofit. For example, if the average value of a car to be scrapped is US$600, and the average retrofit costs are assumed to be US$300 (a maximum estimate) with scrapping, retrofitting will be competitive. In the Netherlands most of the cars without a converter were manufactured between 1984 and 1992. The average value of these cars will highly exceed the 'break-even-value' of US$600. Fitting catalytic converters on cars without them therefore would seem to be more cost-effective than scrapping them.

A possible complication of the regulation to stimulate the scrapping of old cars might be that it will prove difficult to prevent people being paid for having their cars scrapped, while they would have had them scrapped anyway (see also Fontana (1999)). People can be stimulated to have their cars retrofitted by allowing retrofitted cars to drive in cities in smog periods. This has proven to be possible in Germany. In this way people who have cars that are likely to last relatively long get the best benefit from the retrofit.

7. The use of raw materials

As long as less than 100% of the materials from scrapped cars is not recycled, scrapping old cars will reduce the volume of raw materials available.

[3] According to the information of Unifit (a company selling converters in Germany), fitting a catalytic converter to a used car takes about 1–1.5 h (maximum).

8. Conclusions

Reducing the average age of the existing car fleet seems to result in an increase of life-cycle energy use and CO_2 emissions. This will also probably apply to cars to be manufactured in the future unless the yearly improvement in fuel efficiency is much better than in the past. The largest uncertainty related to this subject is the relationship between the energy it takes to operate a car and the energy to manufacture it (including the energy 'gain' as a result of re-using materials from scrapped cars). Further research on this subject is recommended. Scrapping petrol-fuelled cars without a catalytic converter reduces life-cycle emission of NO_x, VOC and CO but seems to be less cost-effective than fitting catalytic converters to these cars.

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