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CO_2 labelling of passenger cars in Europe: Status, challenges, and future prospects

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HIGHLIGHTS

- Car labelling Directive 1999/94 implemented by all 28 EU Member States.
- National labelling schemes vary from each other in design and amount of information displayed to consumers.
- Future revisions should ensure labelling accurately reflects on-road energy use and CO_2 emissions of cars.
- Expansion of labelling scale toward zero CO_2 emissions would allow differentiating between hybrid and plug-in hybrid cars.

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ABSTRACT

Directive 1999/94/EC requires Member States of the European Union (EU) to ensure that consumers are informed about the fuel consumption and CO_2 emissions of new passenger cars. The European Commission is currently evaluating the directive. In support of this effort, we assess the status of car labelling in the EU. We find that all EU Member States have formally implemented national car labelling schemes. However, relevant information is not presented to consumers in a uniform manner. Only 13 Member States have implemented graphic labels that differ in their design, metrics, and classification of vehicles. The fuel consumption data displayed to consumers underrate yearly fuel costs in the order of several hundred Euros per car. We argue that car labelling can be made more effective if Member States adopt: (i) a uniform label that mirrors, as far as feasible, the design of the EU energy label, (ii) data and classification metrics that accurately reflect the fuel consumption and CO_2 emissions observed by consumers, and (iii) a labelling scale that allows differentiation between efficient hybrid and plug-in hybrid vehicles. By following these recommendations, the European car labelling can receive wider recognition and foster well-informed consumer choices.

1. Introduction

In 1999, the European Union (EU) introduced Directive 1999/94/EC (EC, 1999) to inform consumers about the fuel consumption and carbon dioxide (CO_2) emissions of new passenger cars. This so-called car labelling directive should enable informed consumer choices and contribute to achieving a 40% reduction in the economy-wide greenhouse gas (GHG) emissions by 2030 compared to 1990 levels (EC, 2010a, 2015). Recently, policy makers have taken a renewed interest in the car labelling directive for several reasons:

- The 250 million passenger cars in use account for 14% (6.4 EJ) of the final energy use and 12% (450 Mt) of the fuel-related CO_2 emissions of the EU (ACEA, 2014; EC, 2014a, 2014b); increasing the fuel efficiency of cars can reduce CO_2 emissions and fuel costs, thereby making passenger road transport more resilient to increasing oil prices.
- Passenger cars represent the single largest energy consumer and CO_2 emitter among all energy-demand technologies labelled in the EU.
- Member States have implemented labelling schemes by applying a range of designs and metrics. However, experience with the various schemes, specifically in view of their effectiveness remains limited (see, e.g., ADAC, 2005; AEA, 2011; Codagnone et al., 2013).

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In 2015, the European Commission (EC) initiated a comprehensive review of the car labelling Directive 1999/94/EC. In support of this effort, we assess and evaluate here the status of car labelling in the EU based on a scoping review of peer-refereed articles, research reports, and official policy documents, complemented by own analyses. In addition, we draw upon the experience gained from labelling of other energy-demand technologies and discuss the effectiveness of product labels in influencing consumer choices.

The article continues with a short description of our methods (Section 2) and principle considerations about environmental labelling (Section 3). Section 4 provides an overview of the regulatory provisions defined in the car labelling Directive 1999/94/EC (EC, 1999). We address the implementation of the car labelling directive by EU Member States in Section 5. The article ends with a discussion and conclusions for researchers and policy makers in Sections 7 and 8.

2. Methods

This paper focuses on the mandatory labelling scheme established with respect to CO_2 emissions and fuel consumption of new passenger cars within the EU. We refer to the relevant Directive 1999/94/EC (EC, 1999) as the car labelling directive. We seek to analyse the modalities of implementation and subsequently the effectiveness of car labelling across EU Member States based on a scoping review (Grant and Booth, 2009) of the English literature, including:

- peer-refereed articles identified through 'scopus' and 'researchgate';
- scientific reports, presentations, workshop documents, and working papers identified through a standard 'google' search;
- legal documents such as directives, regulations, and official communications that are publicly available through the web servers of EU Member States and the European Commission.

We search the internet for these documents by using the key words: "car labelling", "CO_2 labelling", "CO_2 labelling directive" in combination with the terms "passenger cars" "assessment", "European Union", and "European Commission". We identify a total of 86 relevant documents that were published before April 2015. Out of these, 36 constitute peer-refereed articles, 23 research reports, 13 legal documents of the European Commission or EU Member States, and 14 other sources of information such as websites, books, presentations, and data sheets. Out of the 86 documents, 7 specifically assess the EU car labelling scheme and its implementation (see Table A1 in the Appendix).

We complement our internet search on car labelling in two main areas. First, we survey key literature on product labelling in general to identify the strengths and limitations of labelling, specifically its effectiveness in affecting consumer choices and decreasing the environmental impacts of production and consumption. This survey does not aim at a comprehensive analysis of product labelling but rather seeks to add rationale to the literature on car labelling wherever this appeared necessary. Second, we conduct an analysis of the implementation status of car labelling in the various EU Member States. To this end, we verify with authorities whether and, if so, in what form information about the fuel consumption and CO_2 emissions of new cars is provided to consumers. For selected countries that apply a graphic label, we identify the assigned label class for twenty car models in ten segments, ranging from mini cars up to luxury cars and sport utility vehicles. This analysis can verify whether the labels applied in EU Member States diverge in the classification of car models. Based on the findings of both the literature review and our complementary analysis, we provide recommendations on how to increase the effectiveness of car labelling in the EU.

3. Environmental labelling

Environmental labelling intends to provide consumers with information on the environmental impact of products and services based on verifiable criteria. It represents a low-cost and often easily implementable policy option to overcome information asymmetry and market failure by 'nudging' consumers to informed pro-environmental choices (Sammer and Wüstenhagen, 2006; Amstel et al., 2008). The effect of environmental labels on consumers depends on the amount and manner in which information is provided and on the frequency with which consumers are exposed to the label (Teisl and Roe, 1998; Allcott and Mullainathan, 2010; Waechter et al., 2015). Moreover, the accuracy of information conveyed to consumers is of critical importance as inaccurate information can misdirect consumers away from environmentally optimal choices (Bougherara et al., 2005; Pedersen et al., 2006; Davis and Metcalf, 2014).

A diversity of mandatory and voluntary environmental labels exists worldwide; these are also referred to as eco-labels, energy labels, green stickers, or product labels. Within the EU, the ecolabel, energy label, and car label are prominent examples of labels that provide consumers with information on the environmental impact of products and services (e.g., EC, 1992a, 1992b, 1999; Raimund, 1999; Thøgersen et al., 2002, 2009; Cohen and Vandenbergh, 2012). Two types of environmental labels can be distinguished: endorsement and comparison labels. *Endorsement labels* indicate that a product or service meets a pre-defined standard (BIS, 2011). The EU ecolabel represents an example of an endorsement label (EC, 1992b). Introduced in 1992, the ecolabel constitutes a voluntary labelling scheme of products and services with a reduced environmental impact relative to a predefined standard. To date, over 2000 ecolabel licences have been awarded in the EU, covering more than 44,000 products and services that range from tourist accommodation and all-purpose cleaners to (and beyond) tissue paper, textiles, and footwear (EC, 2016). *Comparison labels* tend to provide information on the quantitative performance of a product in view of one or multiple parameters, therefore allowing consumers to compare products. The EU car label (EC, 1999) and the EU energy label (EC, 1992a, 2010b) represent comparison labels, providing information on the energy efficiency of cars and household appliances.

The EU energy label has been successful in 'nudging' consumers to the purchase of energy efficient domestic appliances (e.g., refrigerators, freezers, dishwashers and washing machines) for approximately 90% of appliances sold in the EU are now labelled as class A (Allcott and Mullainathan, 2010; EC, 2010c). Although causality is difficult to establish, EC (2008a) estimates that the EU energy label has contributed to first-order CO_2 emission reductions of some 14 Mt annually between 1996 and 2004. Still, an estimated 10% of saving potentials are lost due to poor enforcement across EU Member States (Ecofys, 2014). Labelling products with an A-G scale thereby appears to be more effective than applying a label with an A+++ to D scale (LE/IPSOS, 2014). This observation may be explained by consumers relating the plus signs to extraordinary high efficiency that exceeds the standard for efficient products typically labelled as class A.

Moreover, Waechter et al. (2015) found that consumers judge the absolute energy consumption of appliances based on the coloured graphic efficiency label rather than the numerical information provided on the label sticker, and in turn, tend to choose larger appliances with a higher absolute energy consumption if these have received a high, e.g., A to A+++ rating. This observation points to rebound effects, that likely diminish and even off-set savings from efficiency improvements (see, e.g., Alcott, 2005, 2010; Sorrell, 2007; van den Bergh, 2011).

Focusing on the CO_2 labeling of cars, it is important to note that consumers choose a car model by considering a range of factors such as price, fuel consumption (thus implicitly fuel type), comfort, size, reliability, safety, engine power as well as brand and image (ADAC, 2005; Noblet et al., 2006; Anable et al., 2008; Coad et al., 2009; de Hann et al., 2009; Flamm, 2009; Achtnicht, 2012; Lane and Banks, 2010; Galarraga et al., 2014). Although consumers may consider environmental attributes, information about fuel consumption and environmental impacts appear to be less important than other factors (e.g., price or hauling capacity) in the choice of a car model (Grünig et al., 2010; Codagnone et al., 2013; Noblet et al., 2006; Teisl et al., 2004, 2008). Moreover, information on fuel consumption can be perceived by consumers in an ambiguous manner. As Larrick and Soll (2008) argue, expressing fuel consumption in terms of miles per gallon (MPG) as opposed to its inverse gallons per miles may lead consumers to underestimate the value of replacing old and inefficient cars.

Therefore, environmental labelling requires careful design to influence consumer behaviour in the intended manner. From current evidence, the energy labelling of domestic appliances has been effective in promoting energy efficient products (EC, 2008a). However, there is yet little evidence to suggest that the car labelling directive has had a positive impact on consumer awareness and choices (AEA, 2011). Although a consumer might enter a buying situation with the intention to choose an efficient car, their purchasing decision is influenced by a range of factors (Pedersen et al., 2006; Codagnone et al., 2013). The diversity in these influences may render labelling an ambiguous policy tool that can at best remove information asymmetries but may not necessarily result in the desired pro-environmental choice (Dolan et al., 2012; Haq, 2008; Teisl et al., 2008).

4. Car labelling in the European Union

In 1999, the EU expanded the labelling of energy-consuming products to passenger cars by adopting the so-called car labelling Directive 1999/94/EC (EC, 1999). Together with EC Regulations No 443/2009 (EC, 2009) and No 333/2014 (EC, 2014c), which define binding fleet-average CO_2 emission targets for passenger cars and light commercial vehicles, the car labelling directive constitutes a cornerstone of EU policy to reduce CO_2 emissions from light-duty vehicles. The car labelling directive requires EU Member States to enforce national legislation that obliges car manufacturers to inform consumers upon purchase or lease about the fuel consumption and CO_2 emissions of new passenger cars. More specifically, Member States have to ensure that:

- official type-approval data on fuel consumption and CO_2 emissions of each commercially available car model on their market are compiled and made publicly available (this compilation of data is also referred to as 'fuel-economy guide');
- a label containing information on the fuel consumption and CO_2 emissions (see examples in Fig. 1) for each new passenger car model is clearly displayed;
- car dealers display adequate information posters in the showroom;
- car manufacturers include information on fuel consumption and CO_2 emissions in their promotional materials.

The fuel-economy guide containing data on the official fuel consumption and CO_2 emissions of commercially available car models must be produced at least once a year including, for example, a list of the 10 most fuel-efficient new cars per fuel type. The fuel-economy guide must be compact, portable and free of charge. Consumers must be able to obtain it both at the point of sale at the car dealership and from a designated body within each Member State. More specific requirements set out in Annex I of the car labelling directive require Member States to ensure that the label:

- complies with a minimal standardised format to allow recognition by consumers;
- is of a size of 297 × 210 mm (A4);
- contains a reference to the model and fuel type of the car to which it is attached;
- contains the numerical value of the official fuel consumption [l/100 km, km/l, or miles/gallon] and the distance-specific CO_2 emissions [g CO_2/km];
- contains specific text on the availability of the fuel economy guide;

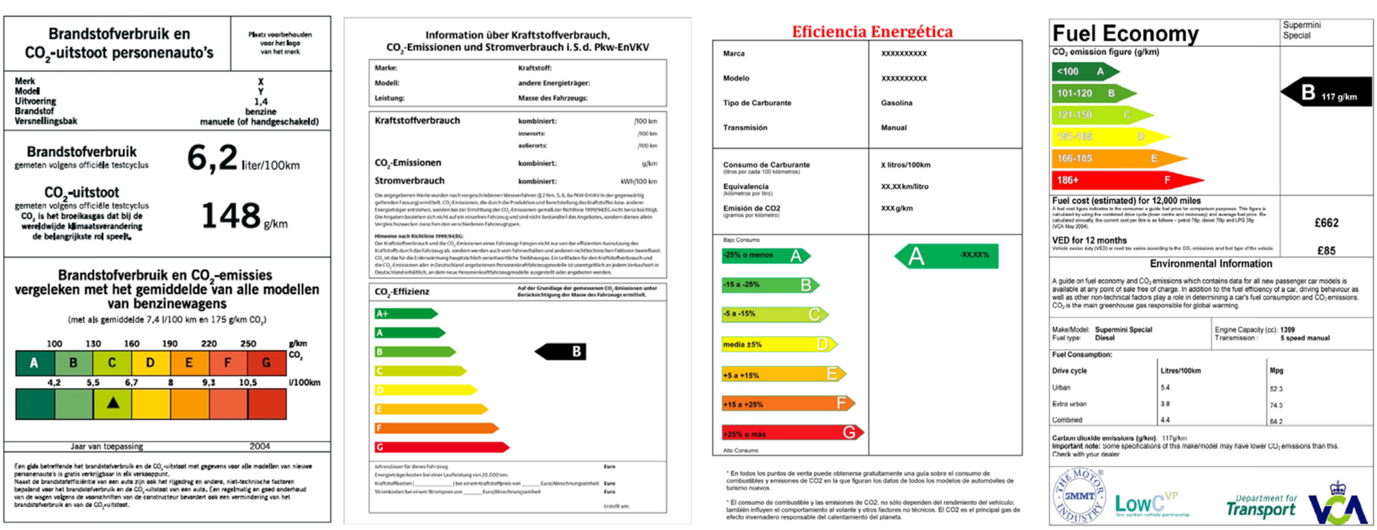

Fig. 1. Generic examples of car labels applied in Belgium, Germany, Spain (optional) and the UK (from left to right).

- contains specific text on other factors that affect fuel consumption (e.g., driver behaviour) and the information that CO_2 is the main GHG responsible for global warming.

The car labelling Directive (EC, 1999) requires EU Member States to introduce the necessary laws, regulations and administrative provisions by 2001. Since its adoption in 1999, there has been one recommendation and one amendment to the car labelling directive: Firstly, Directive 2003/73/EC (EC, 2003a) requires that in addition to, or instead of, displaying information on fuel consumption and CO_2 emissions on a label poster, such information could be displayed on an electronic screen. Secondly, Commission Recommendation 2003/217/EC (EC, 2003b) requires Member States to ensure that promotional material transmitted electronically or stored using electronic, magnetic or optic media should contain information on a car's fuel consumption and CO_2 emissions. In 2015, the European Commission launched a comprehensive review and evaluation of the car labelling directive.

5. Implementation of the car labelling directive

Our analysis confirms that the car labelling directive is implemented in all 28 EU Member States (Table S1 in the Supporting Information). The concrete implementation of the directive often differs between Member States in the amount of information presented to consumers, the design of the label, and the metrics and classification criteria chosen for graphic labelling (e.g., ADAC, 2005; Carroll et al., 2014).

Thirteen Member States have implemented a graphic label that uses colour coding in combination with capital letters to classify cars of high efficiency (dark green colour; letter A) to low efficiency (dark red colour; usually letter G). In most cases, the label applies a seven-level rating scale from A to G following the classification of the EU energy label for domestic appliances. However, the UK uses an A to M rating scale and Germany uses an A+[1] to G rating scale. The labels in Austria and Belgium use one continuous green-to-red colour band as a main graphical element; the other eleven countries use multiple parallel, coloured, and vertically-ordered bars that increase in size from class A to G (or M for the UK).

Austria, Belgium, Denmark, France, Portugal and the UK have opted for an absolute labelling metric that rates cars according to their distance-specific fuel consumption and CO_2 emissions as determined during type approval (EC, 2008b). The width of individual labelling classes varies between countries but is typically 10–30 g CO_2/km. Bulgaria, Germany, the Netherlands and Spain[2] have opted for a relative labelling metric, accounting directly or indirectly for additional utility parameters (e.g., vehicle segments, vehicle weight, and vehicle length and width; see Table A2 in the Appendix).

Our assessment based on twenty car models in ten segments suggests that the application of a relative instead of an absolute labelling metric can cause substantial discrepancies in the classification of a particular car in two given EU Member States. These discrepancies are typically small for cars with low distance-specific CO_2 emissions (such as mini- and small-cars or plug-in hybrids) but can be substantial for large and heavy cars equipped with high-efficient to medium-efficient engines (Fig. 2; Table A3 in the Appendix). As an example, the luxury car BMW 730d is labelled from A (Austria, Italy and Germany) to F (UK). This observation confirms the findings of Carroll et al. (2014) who likewise observed deviations in the classification of cars depending on the applied labelling metric.

Relative labelling as applied in Germany and the Netherlands can provide perverse incentives and lead to contradictory vehicle classifications. The Honda Accord and the BMW 328i xdrive, both emit 159 gCO_2/km (see Table A3 in the Appendix). However, the cars are labelled D and C in Germany but C and D, respectively in the Netherlands.

With the exception of Austria, labelling schemes are generally unable to discriminate between cars that emit less than 100 g CO_2/km. Mini cars, together with electric cars, plug-in hybrids, and hybrids, would typically receive the highest label class A or A+. The inability to discriminate between highly efficient cars may be explained by (i) the low market share of these vehicles at the time labelling schemes were designed and (ii) the fleet-average emissions target of 95 gCO_2/km (EC, 2009), which likely compelled label designers to use a value of 100 g/km as a benchmark to distinguish efficient from less efficient cars.

6. Effectiveness of the EU car labelling directive

The principal objective of the EU car labelling directive is to remove information asymmetry between car manufacturers and consumers related to the fuel consumption and CO_2 emissions of cars to foster well-informed consumer choices. Car labelling can therefore only address one element affecting the total amount of CO_2 emitted by passenger cars (namely awareness about fuel consumption) but may not be suitable to address complementary, yet important, factors such as the actual driving and car use pattern (see Fig. 3). We therefore focus our assessment on the effectiveness of the EU car labelling directive in raising consumer awareness and guiding consumer behaviour.

To this end, car labelling has to: (i) rely on accurate, verifiable, and homogenous data and metrics reflecting the distance-specific CO_2 emissions of cars; (ii) unambiguously translate data into label classes; (iii) ensure the label is recognized by consumers; and (iv) trigger a change in purchasing behaviour. We address each of these points below.

6.1. Accurate and verifiable data and metrics

All car labelling schemes implemented by EU Member States rely either directly or indirectly (i.e., as input for calculating the respective label class) on the distance-specific CO_2 emissions [g/km] determined during type approval conducted in the laboratory under standardized conditions with the New European Driving Cycle (NEDC; EC, 2008b). However, the NEDC conditions have been criticised for being unrepresentative of real-world driving, be it for the low accelerations of the cycle itself or the applied road loads (e.g., Kågeson, 1998; Mellios et al., 2011). Type approval therefore underestimates the actual on-road CO_2 emissions of cars (e.g., Weiss et al., 2012a; Mock et al., 2013, 2014; Tietge et al., 2015). The gap between the distance-specific CO_2 emissions measured at type approval and on the road has been widening in the past decade, reaching approximately $40 \pm 9\%$ in 2014 (Tietge et al., 2015). This observation suggests that the data underlying car labelling in the EU systematically under represent both fuel costs and environmental impacts.

To illustrate the case: the average European gasoline car is labelled with 129 g CO_2/km (EEA, 2014b) and a fuel consumption of 5.6 l/100 km. However, on the road this vehicle may actually emit

[1] A++ and A+++ classes may be introduced if at least 5% of the registered cars achieve the required CO_2 emission levels (BMWI, 2015).

[2] Graphic labelling is optional in Spain (ADAC, 2005).

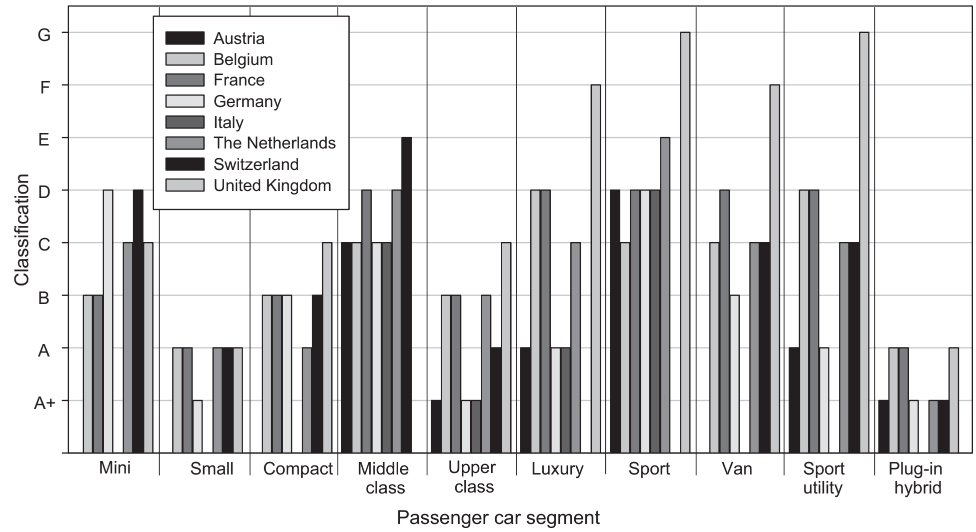

Fig. 2. Sample classification of passenger cars in selected EU Member States and Switzerland; the bars for each car segment represents the classification of one specific model; void spaces signify the absence of information; data based on Table A3 in the Appendix; car segments based on ICCT (2014a).

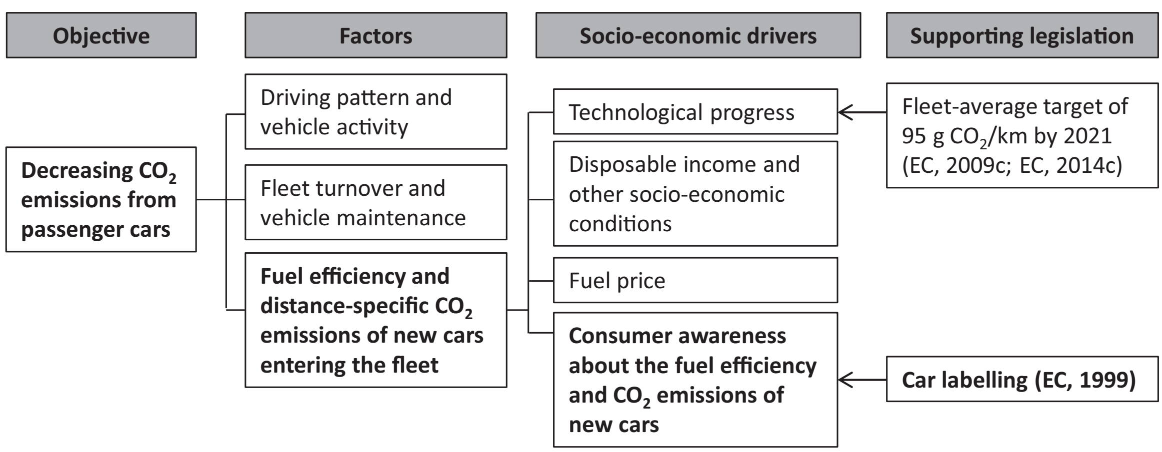

Fig. 3. Simplified scheme of CO_2 labelling within the overall policy objective to decrease CO_2 emissions from passenger cars.

181 ± 12 g CO_2/km and consume 7.8 ± 0.5 l/100 km of fuel (assuming a gap of $40 \pm 9\%$ between certified and actual on-road fuel consumption; Tietge et al., 2015). At a fuel price of 1.50 EUR/l and an assumed annual mileage of 20,000 km, the car label underestimates:

- yearly fuel costs for the car user by 670 ± 150 EUR (see Fig. 4 for results specific to a given annual mileage);
- yearly CO_2 emissions by 1030 ± 230 kg.

The observed discrepancies risk consumers losing trust in the claims of the car label, which, in turn, could undermine the efforts to reduce CO_2 emissions from passenger cars.

6.2. Translation of emission values into label classes

Section 4 has revealed discrepancies between Member States in the translation of CO_2 emission values into label classes. These are small for low and high CO_2 emitters (e.g., see small cars and

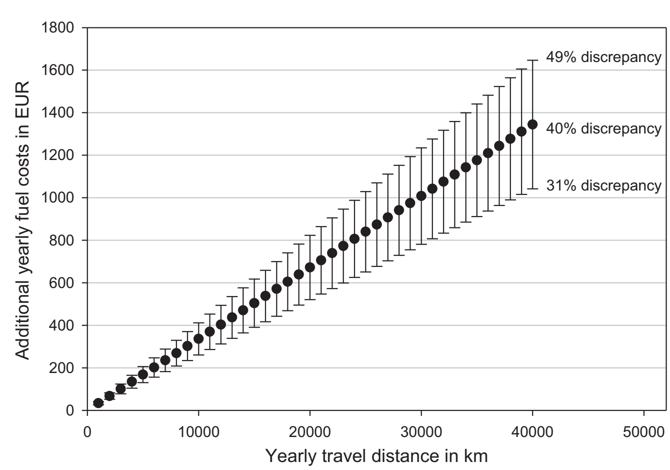

Fig. 4. Underestimation of fuel costs by the official type approval data on fuel consumption for the average EU gasoline car; uncertainty margins represent the standard deviation of discrepancies between type-approved and on-road fuel consumption (based on Tietge et al., 2015).

sports cars in Fig. 2) but can become large for relatively efficient medium size to luxury cars. The discrepancies result from the consideration of different utility parameters such as vehicle mass [kg] (Germany; see Table A3 in the Appendix) or vehicle footprint characterized by the product of length and width [m^2] (Spain; see Table A3 in the Appendix). Discrepancies in the labelling applied in Germany and Spain are especially pronounced for sport-utility vehicles (SUVs): A mass-based utility parameter can classify an SUV as relatively efficient as the increased vehicle mass compared to a passenger car is taken into account; a footprint-based utility parameter, by comparison, may label the SUV as relatively inefficient as the increased mass and air resistance at a given footprint tend to reduce the efficiency relative to a passenger car of a similar footprint. Essentially, Member States appear to disagree on two questions:

- Should the rating of cars be solely based on the distance-specific CO_2 emissions, or should additional utility parameters be taken into consideration?
- If the inclusion of additional utility parameters is deemed to be desirable, which parameter best reflects the utility of the car?

The car labelling directive does not answer these questions but gives Member States the freedom to find a solution that best fits their national situation. We argue that an unambiguous rating of cars across the EU can improve the effectiveness of car labelling. Moreover, labelling that *only* considers distance-specific CO_2 emissions may be more effective from an environmental point of view than labelling that considers additional utility parameters. The current application of utility parameters can provide perverse incentives and favour efficient large cars with comparatively high distance-specific CO_2 emissions over small cars with overall lower distance-specific emissions. However, the inclusion of additional utility parameters has also merits. First, utility parameters can take into account the actual use a vehicle. The current utility parameters do this implicitly; yet the explicit inclusion of, e.g., average occupancy rates in the car labelling could help express fuel consumption in terms of the actual vehicle utility experienced by consumers. Second, and related, utility parameters can take into account consumer preferences (Codagnone et al., 2013) and highlight best-in-segment vehicles. The application of utility parameters can therefore single out relatively efficient models that apply novel, yet expensive, technologies. With learning and economies of scale these technologies may eventually become cheaper (Weiss et al., 2010, 2012b) and diffuse into other car segments.

We mentioned earlier that the car labelling schemes applied by EU Member States are generally unable to differentiate vehicles that emit between zero and 95–100 g CO_2/km. This shortcoming will become important once hybrid, plug-in hybrid and electric cars penetrate the market. Although the EU market share of electric cars only represented 0.6% in 2014, sales may increase (Guardian, 2015) following technological learning (Weiss et al., 2012b), scarcity of conventional fuels and future climate change and air quality policies. The rising sales of hybrid, plug-in hybrid and electric cars may necessitate a label that can quantify the CO_2 emissions of such vehicles. We argue that a gradual expansion of the labelling scales down to zero grams of CO_2 per kilometre is necessary if car labelling is to guide consumer choices in the mid-term and accommodate post-2020 fleet-average CO_2 emission targets for passenger cars. Moreover, as the share of electricity in the total energy consumption of passenger cars will increase in the future, the provision of additional information (e.g., on the distance-specific electricity consumption or the entire well-to-tank or well-to-wheel emissions performance of cars should be considered.

6.3. *Recognition of the car label*

Consumers in the various EU Member States are generally informed about the fuel consumption and CO_2 emissions of new cars (Lane and Banks, 2010; Jung, 2012; Codagnone et al., 2013). A 2009 UK survey found that awareness of the CO_2 label had increased in new (49%) and prospective (29%) car owners compared to previous years (2006–2008) with the car label helping 71% of consumers to choose the make and model of their new car (Lane and Banks, 2010). Awareness about the car label among German car buyers had risen from 29% to 34% in the two years since the introduction of the newly designed label in 2012 (Jung, 2012). However, a survey of ten Member States found that 45% of the total sample of respondents was not familiar with the car label, while 40% felt that the label was not easily recognisable (Codagnone et al., 2013). These observations demonstrate awareness is probably hampered by the absence of a graphic coloured label in most EU Member States. Our internet search suggests that graphic labelling information is still not available (e.g., Spain) or only sporadically available (e.g., Austria, Italy) on the web page of car manufacturers, pointing to an inconsistent application of the national car labelling schemes (see Table A3 in the Appendix).

To increase the awareness of the car label, additional measures are warranted. These could include: (i) the application of a uniform and coloured labelling design that closely matches the design of the energy label on household appliances, (ii) increasing the size of the label, (iii) defining precise requirements for the placement of the label on the car and in the promotional materials online or in print, and (iv) conducting additional information and advertisement campaigns. Moreover, an expansion of the car labelling scheme to used cars may further contribute to widespread recognition of the car label and should be investigated during the official review process initiated by the European Commission.

6.4. *Changes in purchasing behaviour*

It is difficult to discern whether car labelling actively changes the purchasing behaviour of consumers. Codagnone et al. (2016) examined in ten EU Member States consumer understanding of the car label and the willingness-to-pay for efficient cars. They found labels that focused on fuel economy and running costs are better understood and more effectively support money-saving pro-environmental behaviour than labels that state only information on CO_2 emissions.

Evidence on household appliances suggest that consumers are willing to pay a premium for energy-efficient goods (Sammer and Wüstenhagen, 2006; Kieboom and Geurs, 2009; Scholl et al., 2010). Moreover, Min et al. (2014) found that providing information about energy costs lowers the implicit discount rate consumers apply when purchasing efficient, yet more expensive, energy technologies. This observation suggests that the provision of explicit information on annual fuel costs could increase the effectiveness of car labelling in influencing consumer choices. In line with the findings of LE/IPSOS (2014), a rating system ranging from A to G, as compared to a system expanding into A+ to A+++ classes, was the preferred choice of more than half of the participants in a survey among Austrian, German, Italian, Spanish and the British consumers (ADAC, 2005).

The macro trend in the average distance-specific CO_2 emissions of new passenger cars sold in the EU could provide an insight into consumer preferences. By 2014, passenger cars registered within the EU on average emitted 123 g CO_2/km, suggesting a decrease in the distance-specific CO_2 emissions of new cars by 28% since the year 2000 (Fig. 5). However, from the available time-series data it is not possible to determine whether the observed decrease is related to the introduction of the car labelling scheme. Anecdotal evidence suggests that the mandatory fleet-average CO_2 emissions target defined in Regulation 443/2009 (EC, 2009) may be the main driver behind both the substantially reduced CO_2 emissions of new cars at type approval and the increasing discrepancy between type approval and on-road CO_2 emissions. This hypothesis is supported by the observation that distance-specific CO_2 emissions of new cars at type approval have decreased annually by 1% between 2000 and 2007, a time period in which large EU Member States had already introduced car labelling. By contrast, initially high fuel prices in combination with the introduction of Regulation 443/2009 (EC, 2009) may have been the main driver behind the higher annual rate of 4% at which the distance-specific CO_2 emissions of new cars decreased between 2007 and 2014 (EEA, 2014b, 2015; ICCT, 2014b).

7. Discussion

This paper examines the status of car labelling in the EU based on a review of public information combined with own analyses. Our research presents the first peer-refereed survey on this topic in the academic literature. We find that car labelling is implemented in all EU Member States, but also identify shortcomings

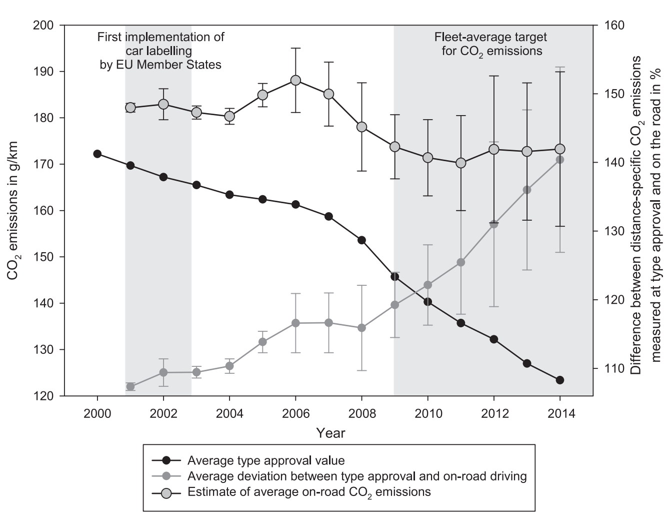

Fig. 5. Trend in the distance-specific CO_2 emissions of new passenger cars registered within the EU; error bars indicate the standard deviation of values (Principal data sources: Mock et al., 2013, 2014; EEA, 2014a, 2014b, 2015; Tietge et al., 2015).

that could be addressed by the European Commission. Yet, our research is subject to several limitations. First, focusing the literature search on publication written in English excludes potentially relevant sources of information published in other languages. The English study issued by the German Automobile Club (ADAC, 2005) suggests that stakeholder organizations in other European countries may have published relevant research that is disregarded here. Second, limited resources did not permit us to review in detail the more general literature on product labelling. The findings obtained from selected publications remain in part anecdotal and may need to be substantiated by rigorous hypothesis testing.

Although consumer knowledge about the car label has been investigated (Lane and Banks, 2010; Jung, 2012) for some Member States, we still lack this information for the EU-28 as a whole. Only one study investigates consumer perception of the car label (Codagnone et al., 2013). Further research is needed on consumer knowledge and perception, interpretation and ranking of the information presented by the car label as well as the extent to which information is perceived as untrustworthy or missing. The results from studies on the labelling of other consumer products can provide insight but may not always be transferable to car labelling as consumer behaviour, decision making, and pattern of use may differ between cars and, for example, household appliances.

The layout of the car label and the information present on the label differ among EU Member States. In line with Carroll et al. (2014), we see a need for standardisation across the EU to ensure consumers are provided with comprehensive, yet understandable, information that reflects the performance of a car and allows transparent comparisons across car models. With regard to the information provided to the consumer, the terms 'fuel' and 'economy' are seen as more effective 'nudges' (Codagnone et al., 2013; Thaler and Sunstein, 2008) than the term 'emissions' in the decision-making of new car buyers. This information should be given prominence in the label by applying the metric used in the respective Member State (e.g., miles per gallon in the UK as opposed to litres per hundred kilometres or kilometres per litre). Moreover, consumers could be provided with information on fuel costs based on national fuel prices (Carroll et al., 2014). To this end, the distance-specific fuel consumption and CO_2 emissions data used for labelling purposes have to reflect the actual values observed by consumers on the road. We regard this point as fundamentally important for car labelling. Consumer trust in both the label and the car manufacturers' claims about the fuel efficiency of vehicles may diminish in view of the increasing gap between type approval and actual on-road values. In the mid-term, EU policy makers are addressing this shortcoming by replacing the New European Driving Cycle that is used for the type approval of cars, with the Worldwide Harmonized Light-vehicles Test Cycle (WLTC) developed by the United Nations Economic Commission for Europe (UNECE, 2013). If gaps persist, two complementary solutions may be available; both require further elaboration: First, generic correction factors could be introduced and regularly updated based on the actual on-road fuel consumption (either reported by consumers or directly obtained via data loggers) of a representative sample of cars. This option may be subject to manipulation but could yield reliable first-order estimates if implemented and monitored by a public authority. Second, CO_2 emissions are recorded by the newly introduced Real-Driving Emissions (RDE) on-road test procedure. The results of this procedure, or parts of it, could be used to determine the distance-specific fuel consumption experienced by consumers under a wider range of normal driving conditions. In view of persisting air quality problems, policy makers may consider using the car label to signal to consumers cars with extra low pollutant emissions. For example, cars that are certified against a more stringent conformity factor than the one required by the RDE test procedure.

Our review has focused on the implementation status and effectiveness of car labelling in the EU but disregards further-reaching considerations about the limitations of product labelling as an environmental policy tool and the question whether efficiency improvements are effective measures to decrease the economy-wide energy use and CO_2 emissions. Compared to fiscal measures such as increasing fuel taxes, car labelling may be less effective in reducing the economy-wide CO_2 emissions. One observation supporting this argument stipulates that measures aimed at improving efficiency (as the car label does) are susceptible to rebound effects. An increased efficiency lowers the cost of driving a car and may result in more intense car use or fuel-consuming activities elsewhere in the economy (Brookes, 2000; van den Bergh, 2010). Despite those shortcomings, labelling has merits as an information tool, enabling informed consumer choices and thus market competition on a levelled playing field. Mandatory product labelling may also present the 'smallest common environmental denominator' policy stakeholders might agree upon, thereby presenting a practical and implementable policy option. In fact, the effectiveness of product labelling could be increased if complemented with additional policies, such as fuel taxation or environmental taxation in general. We therefore consider the objective to influencing consumer behaviour to purchase more fuel efficient cars through a mandatory labelling as a valid strategy to reduce transport-related CO_2 emissions and increase societal well-being.

8. Conclusions and policy recommendations

Based on our assessment, we identify a number areas where the EU car labelling directive could be more effective with respect to its objective to increase awareness about the distance-specific fuel consumption and CO_2 emissions of cars (Table 1). By implementing these recommendations and addressing the persisting knowledge deficits identified in Section 6, policy makers can ensure the car label is fit-for-purpose and compatible with post-2020 EU climate policy initiatives for the transport sector.

Table 1
Key recommendations for increasing the effectiveness of car labelling in the EU.

Area	Recommendation
Implementation	• Member States should be obliged to implement a graphic and coloured label (complementing information on fuel consumption and CO_2 emissions). • The feasibility to extend car labelling to second-hand cars should be investigated.
Design	• One standardized label design should be introduced, mirroring the EU energy label. • The dimensions of the graphic label and the font size of the information displayed should be increased.
Placement	• Labels should be placed at prominent and pre-defined places on the car, in the car show room, and in any online or printed materials should be considered.
Labelling metric	• The distance-specific fuel consumption and CO_2 emissions presented on the label should match those experienced by the average consumer; the introduction of the WLTC marks an important step towards achieving this objective. • If applicable, the introduction of generic correction factors or the use of on-road emissions data obtained from RDE testing could be considered for the purpose of car labeling. • A pre-defined schedule for redefining the labelling classification to differentiate vehicles that emit between zero and 100 g CO_2/km should be agreed upon. To do so would accommodate novel powertrain technologies in the car label. • If vehicle utility is to be considered by the labeling metric, the actual utility parameter should be chosen with care to avoid perverse incentives; additional analyses are warranted.
Labelling scale	• A 7-scale labelling denoted by the letters A-G should be implemented uniformly. • The rating of cars should be updated regularly. • The introduction of 'A+' or 'A++' categories denoting high efficiency should be avoided.
Auxiliary information	• Fuel costs should be presented based on a well-known and easily scalable metric (e.g., EUR per 10,000 km). • The presentation of distance-specific electricity consumption, information on well-to-wheel emissions, and emissions of pollutants should be considered.
Monitoring	• Mandatory and regular monitoring of the effectiveness of car labelling and exchange of information among Member States should be supported.

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Appendix

See Tables A1–A3 is here.

Table A1
Overview of literature on car labelling in the EU as identified by our scoping review.

Reference	Type of publication	Scope	Key finding
Raimund (1999)	Conference paper	Energy efficiency from passenger cars: labelling and its impact on fuel efficiency and CO_2 reduction.	Different labels were designed and tested among representative samples of consumers. A label showing a comparison of a specific car's fuel consumption to the average fuel consumption of cars of the same size was clearly preferred to a comparison among the whole fleet of new cars. Recommendation of (i) accompanying measures to enhance the effect of the label as well as (ii) a suitable framework to fit the labelling strategy into the overall strategy to reduce CO_2 emissions of passenger cars.
ADAC (2005)	Research report	Study on the effectiveness of Directive 1999/94/EC.	Directive 1999/94/EC does not yet show the desired effectiveness, neither regarding informing and influencing consumers nor the reduction of the CO_2 emissions of passenger cars. In order to increase the effectiveness it is recommended to increase the awareness of consumers and dealers and revise the provisions of the Directive.
Grünig et al. (2010)	Research report	Study on consumer information regarding fuel consumption and CO_2 emissions of new cars.	There is need for consumer-based market research in order to have a scientific foundation for decisions about, e.g., absolute vs. relative, dynamic vs. static, and continuous vs. graded labelling and the inclusion of running costs.
AEA (2011)	Research report	Review of the implementation of the car labelling Directive 1999/94/EC.	Directive 1999/94/EC might have a positive impact on consumer awareness. However, very few studies or surveys have rigidly investigated consumer awareness or the effectiveness of this directive.
Cardagnone et al. (2013)	Research report	Testing CO_2/car labelling options and consumer information.	Recommendation of easier to understand labels to improve comprehension, familiarity and trust.
Gibson (2013)	Presentation	Car CO_2 labelling in Europe – format and comparative ratings.	Recommendation of a composite label which shows absolute ratings and provides a "best and worst in class" evaluation.
Carroll et al. (2014)	Research report	Empowering EU consumers through visible and clear labelling information on CO_2 emissions from new passenger cars.	A revision of the car labelling Directive by standardising and optimising the format of the label is proposed to provide consumers with intuitive and user-friendly information allowing simple and accurate comparisons between cars.

Table A2
Overview of relative labelling schemes.

Country	Approach
Bulgaria	Relative performance: The percentage difference between the distance-specific CO_2 emissions [g/km]of a car compared to the average CO_2 emissions of all new registered passenger cars is calculated. The rating ranges from class A for cars that show at most a 25% less emissions than the average passenger car to class G for cars that show at least 25% more emissions than the average passenger car.
Germany	Mass-based weighing: First, the distance-specific reference CO_2 emissions *R* are determined based on the mass *M* of the respective car as: R [g CO_2/km]=36,59079+0,08987 × M [kg] The car is then classified based on the percentage deviation *D* between the distance-specific CO_2 emissions measured at type approval *E* [g/km] and the reference CO_2 emissions *R* as: $D[\%] = \frac{E-R}{R}\times 100$
Netherlands	Relative performance: The percentage difference between the distance-specific CO_2 emissions [g/km] of a car at type approval and the average distance-specific CO_2 emissions of all cars in the same segment is calculated. The rating ranges from class A for cars that emit at most 20% less than the segment average to class G for cars that emit at least 30% more CO_2 than the segment average.
Spain	Optional footprint-based weighing: First, the reference fuel consumption R [l/100 km] is calculated as an average for all cars on the Spanish market as: $R = a\times 2.7183^{b\times s}$ Where *a* and *b* represent fuel-specific coefficients and s the product of the average length and width of all cars on the Spanish market. The percentage deviation between the distance-specific reference fuel consumption of a car at type approval [l/100 km] and the reference fuel consumption R determines the rating of the car in the range of A (at most 25% lower fuel consumption than the reference) to G (at least 25% higher fuel consumption than the reference).

Table A3
CO_2 labelling of passenger cars in various EU Member States as of 1 February 2015 (Data source: online information provided by individual car manufacturers); numbers in parentheses indicate the CO_2 emissions value at type approval; ratings depicted in normal type setting are provided by the vehicle manufacturer; underlined ratings are included by the authors based on the design specifications of the respective car labelling scheme (see, e.g., Gibson, 2013); D - Diesel; SI – Spark ignition; MT – Manual transmission; BM6 – Blue Motion technology with 6-gear MT; - no classification provided by the respective car manufacturer; n.o. – model not offered.

Category	Vehicle	Austria	Belgium	France	Germany	Italy	The Netherlands[b]	Spain	Switzerland[c]	UK
Mini	Toyota Aygo, SI, MT (51 kW)	- (95)	A (95)	A (88)	B (95)	- (88)	A (88)	- (95)	B (95)	A (88–95)
	Fiat Panda 1.2, SI, MT (51 kW)[d]	- (117)	B (120)	B (120)	D (120)	- (120)	C (118)	- (120)	D (117)	C (120)
Small	Toyota Yaris hybrid, SI (74 kW[d]	- (79)	A (85)	A (75–82)	A+(82)	- (75)	A (75–82)	- (79)	A (75–82)	A (82)
	Honda Jazz 1.2, SI, MT (66 kW)	- (123)	B (123)	C (123)	C (123)	- (123)	C (123)	- (120)	C (123)	D (123)
Lower medium	VW Golf 1.4, SI, MT, BM6 (81 kW)[a,d]	- (114)	B (114)	B (114)	B (114)	- (114)	A (114)	- (114)	B (114)	C (114)
	Honda Civic 1.4, SI, MT (73 kW)	- (128)	B (128)	C (129)	C (128)	- (129)	B (128)	- (129)	C (131)	D (129)
Medium	Honda Accord S 2.0 i-VTEC, SI, MT (115 kW)	- (159)	C (159)	n.o.	D (159)	- (159)	C (159)	- (159)	F (162)	G (159)
	BMW 328i xdrive, SI, MT (180 kW)[d]	C (159)	C (159)	D (159)	C (159)	C (159)	D (159)	- (159)	E (159)	n.o.
Upper medium	BMW 520d, D, MT (140 kW)	A+(114–124)	B (114–124)	B-C (114–124)	A+(114–124)	A+(114–124)	B (114–124)	-(114–124)	A (114–124)	C-D (114–124)
	BMW M5, SI (412 kW)	F (231)	F (231)	F (231)	F (231)	F (231)	G (231)	- (231)	G (231)	L (231)
Luxury	BMW 730d, D (190 kW)[d]	A (148)	D (148)	D (148)	A (148)	A (148)	C (148)	- (148)	n.o.	F (148)
	Lexus LS 600 h, SI (290 kW)	- (199)	E (199)	E (199)	C (199)	- (199)	D (199)	- (199)	F (199)	J (199)
Sport	Porsche 911 Turbo, SI (383 kW)	- (227)	F (227)	F (227)	G (227)	- (227)	G (227)	- (227)	G (227)	L (227)
	BMW Z4 sDrive18i, SI (115 kW)[d]	D (159)	C (159)	D (159)	D (159)	D (159)	E (159)	- (159)	n.o.	G (159)
Van	VW Sharan 2.0, D, MT, BM6 (103 kW)[d]	- (143)	C (143)	D (143)	B (143)	- (143)	C (143)	- (146)	C (143)	F (146)
	Ford Galaxy 2,0-l-TDCi, D, MT (103 kW)	- (139)	C (139)	C (139)	B (139)	- (139)	C (139)	- (139)	C (139)	E (139)
Sport utility-off road	Porsche Cayenne, D (193 kW)	- (173–179)	D (173–179)	E (173–179)	B (173–179)	-(173–179)	-(173–179)	-(173–179)	D (173–179)	H-I (173–179)
	BMW X5 xDrive25d, D (160 kW)[d]	A (154–156)	D (154–156)	D (154–156)	A (154–156)	-(154–156)	C (154–156)	-(154–156)	C (154–156)	G (154–156)
Plug-in hybrid vehicles	Toyota Prius Plug-in, SI (100 kW)	A (49)	A (49)	A (49)	A+(49)	- (49)	A (49)	- (49)	A (49)	A (49)
	BMW i3, SI (range extender)[d]	A+(13)	A (13)	A (13)	A+(13)	- (13)	A (13)	- (13)	A (13)	A (13)

[a] sold in France and the UK with 77 kW but in Germany with 81 kW
[b] complementary data source: RDW (2014)
[c] complementary data source: BFE (2014)
[d] rating of vehicle depicted in Fig. 2

Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.enpol.2016.04.043.

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