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Pilot study on determining the environmental impacts of conventional and alternatively fuelled vehicles through Life Cycle Assessment –

Critical Review Report

Zürcher Hochschule für Angewandte Wissenschaften (ZHAW)
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1 Introduction

This document is the concluding document of the accompanying critical review of the study "*Pilot study on determining the environmental impacts of conventional and alternatively fuelled vehicles through Life Cycle Assessment*" commissioned by the European Commission (DG Climate Action) and performed by a consortium comprising the consultancies and research institutions: Ricardo Energy & Environment, E4tech and the ifeu. This critical review was commissioned by the practitioners of the Life Cycle Assessment study (Ricardo Energy & Environment, E4tech and the ifeu).

2 Review process

Following ISO 14071, the aim of this review is to verify that:

- the methods used to carry out the LCA are consistent with the 14044 International Standard;
- the methods used to carry out the LCA are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretations reflect the limitations identified and the goal of the study; and
- the study report is transparent and consistent.

The review was performed by a single reviewer (Andrea Del Duce) as an accompanying review. The reviewer participated at:

- the kick-off meeting on the 18th of July 2018
- the first stakeholder consultation in Brussels on the 25th of February 2019, in which the first findings concerning literature review, methodological options and assumptions were presented,
- the second stakeholder consultation in Brussels on the 16th of January 2020, in which the first LCA results were presented,

and he provided written feedback and comments to:

- the "Task 1 and Task 2 Report" summarising the results from the literature review, methodological options and assumptions
- the interim report, summarising the proposed methodology
- the draft final LCA report and appendix, summarising the final proposed methodology and the main aspects of the LCI model, the database and the results
- the final LCA report and appendix.

Moreover, direct feedback was also given via email and various phone calls.

The project coordinator from Ricardo Energy & Environment also expressed the possibility of analysing specific data and modelling aspects in the calculation tool developed by the consortium. However, considering the documentation presented, this was not deemed necessary.

Finally, the consortium also implemented substantial changes in response to requests for clarification expressed by the European Commission.

3 Results of the review process

While some general indications are summarised in the following sections, a list of comments addressing specific statements in the main report is given in section 4.

3.1 Consistency with ISO 14044

The study builds up on the ISO 14040 and 14044 standards (as well as considering other relevant guidelines like the ILCD Handbook[1] or the PEFCR for high specific energy rechargeable batteries for mobile applications[2]), overall appropriately defines the functional unit and the goal and scope of the study and consistently developed the study along these. In terms of vehicle types, the consortium analysed medium passenger cars, sport utility vehicles (SUV), vans, small and large lorries, urban buses and coaches. Since one of the goals of the study is to inform the European Commission about future options in mobility, including small/city cars in the scope would have been beneficial, since this class of vehicles could play an important role in future transport systems. With respect to the allocation methods, due to the extremely broad spectrum of the study and the complex data basis behind, there are some situations in which the choice for solving multifunctionality situations seems driven by data availability rather than strictly following the hierarchy suggested by the ISO standard. Sufficient information is given by the authors to identify which allocational choices (and why) were taken within the various sub-systems of the study.

3.2 Methods used to carry out the LCA

Following the ILCD Handbook and stakeholder consultations, the aim of the consortium was to develop a hybrid methodology based on an overall attributional approach with consequential adjustments for aspects in which major changes can be expected in the future. Particularly, consequential modelling was foreseen for secondary feedstocks in the fuel chains, for part of the electricity chains and part of the material chains and processes in battery production. In the end, in order to maximise consistency in the modelling, it was decided to compute the final results following a complete attributional approach and then to test the impact of consequential modelling on secondary fuel chains in the form of additional results and sensitivity analyses, in order to understand the impacts of these methodological choices. Due to the broad spectrum of the project, it was decided to only include one counterfactual use scenario for each fuel in the analysis. The results show high fluctuations highlighting how the choice of the counterfactual has a dominant impact on the LCA of the fuel chains. Hence, using only one counterfactual scenario for a feedstock might not be sufficient to grasp the complexity in the assessment of secondary feedstocks. However, the authors also perform a sensitivity analysis which highlights the impact of the allocation and multi-functionality choices on the final results at the vehicle level. Overall, the methodology proposed together with the sensitivities performed to evaluate the impacts of the methodological choices are considered appropriate for the goal and scope of the study.

3.3 Data used in relation to the goal of the study

In parallel to modelling the vehicle foreground system, the project also modelled a large variety of fuel chains and electricity chains. To do so, data from a broad spectrum of sources was used in the analysis. Sources include data from the GREET model, from various projects of Ricardo Energy & Environment, from the ifeu electricity model or from ecoinvent. For the latter, while mostly ecoinvent v3.4 was used, older versions (v2) were used for natural gas production and nuclear fuels. Hence, there is a certain heterogeneity in the data basis utilised. There are clear indications in the final reports concerning what data sources were used for which topics. Moreover, the authors also provide specific indications on the robustness and limitations of the data used for each fuel chain considered. Overall, bearing in mind the aspect of taking into

[1] https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf

[2] https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_Batteries.pdf

consideration only one counterfactual use for secondary fuels as discussed above, the data used is considered appropriate and reasonable for the goal and scope of the study.

3.4 Interpretation and limitations within the goal of the study

The authors present a large variety of results addressing various aspects of the study and, particularly, the fuel chains, the electricity chains and the results at the vehicle level. The chosen results help to understand the complexity of the system and the derived interpretation. Moreover, a sensitivity analysis further investigates the impact of methodological and data choices and, therefore, of the overall limitations of the results. The authors then sum-up the key methodological and data limitations identified giving a clear overview on aspects and topics within the study which need to be taken with particular care. Overall, the interpretation and the limitations discussed in the report are considered appropriate for the goal of the study. Since the authors have developed a new methodology and data basis, a comparison highlighting the impact of their methodological and data choices with key studies from the past, would have been helpful to better understand the influence and order of magnitude of these choices.

3.5 Transparency and consistency of the final report

The consortium provided an extensive report and annex with a broad and detailed spectrum of information concerning the data and methodology used. The main report focuses mostly on the project framework and development process, the key aspects of the methodology derived, the goal and scope, key aspects of the data used and the results for, both, the electricity and fuel chains as well as for the vehicles life cycle impacts. The annex contains details of the literature consulted, explanations on methodological choices and details on the final data basis used. Overall, the information given in the documentation is considered appropriate for understanding the methodology and data basis for most topics. Nevertheless, following aspects for optimisation on the reporting side are highlighted:

- The executive summary gives a good overview of what was done during the project and the limitations to consider. Less emphasis was placed on concluding recommendations on the vehicle level. Starting from the hotspots and environmental challenges identified in the analysis, more indications on resulting potentials for enhancing the sustainability of transports in Europe would have been a valuable addition to the executive summary considering the relevance of this part for interested stakeholders.
- The authors decided to split relevant data and modelling information on some specific topics in different sections. The idea behind is to provide various levels of detail to make sure readers with different level of interest do not have to read parts which do not interest them. While for some topics this works well (e.g. the electricity chains) for other topics like vehicle manufacturing or the energy consumption model, the result is less effective.
- A detailed literature review was made at the beginning of the project which identified, amongst various things, typical methodological choices in the LCA of vehicles. A critical review of choices in past studies linked to the proposed methodology is missing to some degree. It would have been helpful to have a more detailed explanation about why certain methodological choices were taken as opposed to past best practices.
- A relevant part of the project addressed the modelling of fuel and electricity chains as well as potential developments on future material chains. A considerable part of the results chapter is dedicated to these aspects. This shifts the focus away from the vehicle level. Shortening this part to only include results necessary to understand the results at the vehicle level and moving the remaining discussion to the appendix would have further strengthened the readability of the document.

4 List of specific comments to statements in the report

A list of comments, embedded in the draft version of the report and appendix, was forwarded to the consortium. Most of these were addressed in the final version of the report. The following is the list of remaining open comments:

Location	Comment	Response from the authors[3]	Additional response by the reviewer
Executive Summary – Overall conclusions and recommendations for future work	This part mostly focuses on the methodological part. The executive summary should contain a broader discussion addressing recommendations from the general conclusions at the vehicle level.	N/A. No change; we already provide a significant table of recommendations.	The table mostly focuses on methodological and data aspects. A broader discussion and conclusions addressing future mobility aspects based on the LCA findings would have been an important addition to the executive summary.
3.1.2 Functional units and reference flows	The authors provide the reference flows and describe what was considered conceptually in the definition of the functional unit. The exact definition of the functional units for the various vehicle bodies should be stated.	Now provided in a new table to be more explicit.	A list of reference flows is now provided, but not the specific definition of the functional units used for the various vehicle types.
3.1.4 General LCA methodological approaches	The authors state *"This hybrid LCA approach is not only in line with the ILCD handbook, but was also largely confirmed as appropriate by the stakeholder consultation."* Based on the stakeholder consultation and documentation, the impression arises that originally the hybrid approach was meant to address the attributional and consequential aspects simultaneously. The consortium then decided to provide overall attributional results and to add separate consequential analyses in the sensitivities. The sentence above does not exactly reflect the process in the methodological choice.	I have added a sentence clarifying that the approach has been further refined in the application stage. The chapter summarises the approach developed, and clearly indicates this approach was derived as a result of our and stakeholder views.	Solved.
3.1.4 General LCA methodological approaches	The authors state that consequential aspects were considered for electricity and material chains. For electricity and material chains, the documentation provided suggests that future developments are considered in	N/A	

[3] Response written by Nikolas Hill (Ricardo Energy & Environment) on behalf of the project consortium

Location	Comment	Response from the authors[3]	Additional response by the reviewer
	scenarios, but not a proper consequential approach.		
3.4.1. Scope and system boundaries – Multifunctionality: Substitution	The authors state that substitution is used and that an alternative methodology for multi-functionality is used (energy allocation). This seems in contrast with what is previously stated in the "General LCA methodological approaches" or in other parts of the report where energy allocation appears to be the default scenario.	I have amended the text here to indicated these are provided as alternative options/sensitivities, with the energy allocation option being the default.	Solved.
3.4.1. Scope and system boundaries – Elements of consequential LCA	The authors description of the consequential modelling for fuel chains gives the impression that this is the default model. It should be stated that this was done as an alternative option in addition to the energy allocation calculation.	As above, amended.	Solved.
3.4.2 Key LCA methodological choices, Table 3.8	It is specified that for various chains the energy allocation was calculated as an additional alternative. This seems in contrast with other indications where it is stated that the energy allocation models give a consistent reference and the other approaches were analysed to investigate the impact of methodological choices.	Amended to better reflect the final prioritisation here – i.e. indicating the default energy allocation with no counterfactual, and the alternative analyses.	Solved.
4.7.2 Assumptions for a selection of key vehicle parameters – Table 4.8	Specific indications on the energy consumption in terms of fuel/energy quantity (e.g. kWh/km for BEVs or litres/km for liquid fuels) for the various drivetrain technologies would have increased comparability with other studies.	The energy consumption of different vehicle powertrains are calculated dynamically in our LCA model based on specific input settings. A worked example of the methodology is provided in Appendix A3.13.3.1, Table A26. The dataset corresponding to the different scenarios and sensitivities presented is therefore very large and not easily summarised in the report. The baseline data/assumptions for 2020 can be calculated from the input data provided in the report and standard unit conversions, fuel properties.	The information provided in the reply will allow the interested reader to more easily identify the key sources for understanding the fuel and energy consumption estimation methodology. Still, an extended version of Table 4.8 in 4.7.2 for the various drivetrain technologies, at least for the passenger cars discussed, for example, in Figure 5.58, would have been a valuable addition and important for comparisons with other studies.

Location	Comment	Response from the authors[3]	Additional response by the reviewer
		(i) In the body of the report is provided the specifications for the reference powertrain, in Section 4.7.2, Table 4.8. (ii) In the Appendix (Table A34) we also provide the 2020 powertrain relative energy consumption assumptions by vehicle type, defined relative to the relevant reference powertrain (=100%). (ii) Test-cycle to real-world conversion factors are also provided in Appendix Table A49.	
5.5.1.1 Lifecycle GHG emissions, discussion after Figure 5.64	The authors state "This chart illustrates the relatively high impacts of both aluminium and textiles per unit mass. Whilst aluminium is a light-weight structural material that can offset its increased impact through fuel savings, this is not the case for textiles. As noted earlier in Section 5.2, textile manufacturing is highly energy intensive. Actions taken by OEMs to use more sustainably sourced /manufactured textile materials in vehicles are therefore likely to produce notable benefits." The partial results for the impacts from textiles are not shown and even though previously results on the general impacts of textiles have been shown, the amount of textiles in the model is not given. The reader cannot make an informed judgement on this statement.		
5.5.1.1 Lifecycle GHG emissions, discussion after Figure 5.66	The authors state "Figure 5.66 provides an illustration of the impacts on the result for different fuel blends, electricity mixes and for the lowest/highest 2020 GWP/ fuel/electricity production chains." This figure provides useful information on the potentials which may be obtained for the various technologies. A larger discussion on what it would require to exploit these potentials or how realistic some		

Location	Comment	Response from the authors[3]	Additional response by the reviewer
	of these scenarios are for a mass market would have been an important addition.		
5.5.1.2 Other lifecycle impacts	The authors state "However, it should be noted that (a) health impacts from most of these pollutants are highly location-specific (i.e. depending on exposure levels – highest in urban areas) and (b) some of the lifecycle emissions presented here will have occurred outside of the EU (i.e. mainly from fuel and materials production, battery manufacturing), so will not be directly regulated or accounted for within the national/EU inventories." This project looks at potential impacts including its development in the future. Such an observation on the relevance of impacts occurring outside the EU could have been expanded into a policy suggestion.		
5.6.2 Sensitivity on variations in driving conditions within the EU, Figure 5.78	The figure highlights the overall variations in GWP impact due to the combined effect of road mileage share, electricity mix and ambient temperature in various countries. The chosen representation does not allow to identify the weight of the three aspects (mileage share, electricity mix and ambient temperature) on the results. Highlighting this would have helped to prioritise areas of interventions.	No action.	
5.6.12 Sensitivity on battery production and EoL; 5.6.13 Sensitivity on vehicle production and EoL	The GWP results presented seem to highlight little differences from optimising the production processes for the battery and vehicle and the recycling rates. These results are critical as they seem to suggest that efforts in optimisation and higher recycling might not be effective. A broader discussion with the analysis of other indicators would have been useful to shed more light on this relevant topic.		
6.1.4 Conclusions for the overall findings from the vehicle cycle	The authors develop their results under specific decarbonisation scenarios which reflect expected decarbonisation policies and	Added to section 6.2.4 "Key limitations and uncertainties for the analysis".	Solved.

Location	Comment	Response from the authors[3]	Additional response by the reviewer
	trends. Moreover, because of these decarbonisation scenarios, a reduction in the spread of the results (particularly for GWP) can be observed. It would be important to stress that the observed trends in the results at the vehicle level can only be obtained if the decarbonisation targets in the power and manufacturing sector are achieved.		
6.1.4 Conclusions for the overall findings from the vehicle cycle	A discussion on the influence of size on the environmental impacts of passenger vehicles would have been a valuable addition.	Added text to the conclusions section – section 6.2.2.1 (Environmental hotspots). The benefits are greater for BEVs for Large SUVs due to higher lifetime mileage.	A broader discussion, and particularly one also addressing the policy options on the size of vehicles would have been a valuable addition.
6.1.4 Conclusions for the overall findings from the vehicle cycle	A summarising discussion on the appropriate and efficient use of renewable electricity for e-fuels, BEVs and FCEVs would have been a valuable addition. Relevant comments on this topic are made in various sections of the documentation, but final recommendations would have been helpful.	Further elaborated more clearly now in the conclusions. For example, there is discussion of the importance of CED in relation to limited renewable resources in Section 6.2.2.1 (Environmental hotspots).	The point mentioned in the reply is a good example of a relevant comment on the topic. However, a broader, summarising discussion and recommendations would have been a valuable addition.
A.4.3.1 Vehicle specification, Table A34	The term “relative power efficiency” is confusing here. With this formulation, the numbers given suggest, for example, that ICEVs are more efficient than xEVs.	Title of Table A34 amended to *“2020 powertrain relative energy consumption assumptions by vehicle type, defined relative to the relevant reference powertrain (=100%)”*, plus a clearer indication on the reference powertrains is now provided in the footnotes.	Solved.

5 Self-declaration of independence

I, the signatory, hereby declare that:

- I am not a full-time or part-time employee of the commissioner or practitioner of the LCA study
- I have not been involved in defining the scope or carrying out any of the work to conduct the LCA study at hand, i.e. I have not been part of the commissioner's or practitioner's project team(s)
- I do not have vested financial, political or other interests in the outcome of the study

I declare that the above statements are truthful and complete.

Date: 5.8.2020

Name: Andrea Del Duce

Signature: