nature portfolio

Peer Review File

Cost competitiveness of alternative heavy-duty truck technologies under real-world utilisation profiles

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This file contains all reviewer reports in order by version, followed by all author rebuttals in order by version.

Version 0:

Reviewer comments:

Reviewer #1

(Remarks to the Author)
This manuscript presents a comprehensive, bottom-up assessment of the economic and technical feasibility of alternative heavy-duty truck technologies in Europe, combining heterogeneous real-world utilization profiles with a scenario-based TCO framework. The integration of micro-level freight activity data with infrastructure-constrained feasibility filters is a notable strength and represents a meaningful advance over stylized average-duty-cycle analyses. Here are some comments on it.

-The manuscript does not explicitly model battery replacement for BEVs or fuel-cell stack replacement for FCETs as separate cost items. These costs are neither explicitly included in CAPEX nor represented as specific events over the vehicle lifetime. Given that the model assumes a service life of 10–12 years for heavy-duty trucks, this simplification may systematically affect the relative competitiveness between large-battery BEVs and FCETs, as well as their competitiveness relative to diesel vehicles. A sensitivity analysis addressing battery and fuel-cell stack replacement would therefore be recommended

-The manuscript appears to abstract from payload impacts of BETs/FCETs. In practice, higher curb weight from large battery packs or hydrogen storage can reduce available payload under regulatory gross-weight and axle-load limits, potentially lowering freight productivity and increasing cost per tonne-kilometre. By evaluating feasibility primarily against daily mileage and reporting substitution shares in terms of vehicle activity, the analysis may overestimate the operational and economic attractiveness of zero-emission trucks for payload-constrained missions. The authors should clarify whether payload penalties are embedded in the assumed energy-consumption parameters and, ideally, provide a sensitivity analysis translating results from vehicle-km to tonne-km (or modelling payload-adjusted duty cycles) to test the robustness of the reported replacement shares.

-The manuscript states that all input data for the TCO model are publicly available on GitHub; however, the provided repository link is not accessible at the time of review. Without access to the underlying input data, the model calculations cannot be independently verified. The authors should ensure that the data repository is functional and that the input datasets are publicly available.

-The assumption of at most one intermediate fast-charging event lacks quantitative justification or support from empirical operational studies. The authors are encouraged to provide a brief rationale, relevant empirical evidence, or a sensitivity analysis exploring alternative charging assumptions to strengthen the robustness of the feasibility assessment.

-The correspondence between the vehicle utilization profiles and the selected VECTO vehicle groups (4, 5, 9, and 10) is not immediately intuitive for readers unfamiliar with the VECTO classification framework. The authors are encouraged to provide a brief explanation or illustrative mapping (e.g., in the Methods or Supplementary Information) to clarify how utilization profiles are assigned to these vehicle groups.

(Remarks on code availability)

Reviewer #2

(Remarks to the Author)
This paper assesses the economic viabilitty of battery electric trucks and hydrogen fuel cell trucks using microdata from four million existing trucks across the Europe. Given the inherent uncertainty around future costs for these technologies, and their related fuel and infrastructure, the authors have adopted a scenario-based approach to assess viability under different prevailing conditions.

While some industry literature examining this issue exists, I agree with the authors proposition that this study provides a novel and useful contribution in terms of providing this analysis as peer-reviewed, academic literature.

Overall the paper is well written and structured. The authors have provided access to the model coding as part of their submission (although I have not reviewed in detail). This additional information, combined with the outline of the methodology, should largely allow for replication of results.

Some of the hydrogen (at the pump) cost components appear optimistic, and I would recommend further highlighting this to demonstrate that despite assumptions that should favour hydrogen fuel cell trucks, the use cases where this technology is economically viable, and competitive with alternatives, is narrow, and only likely to narrow further in time given mass deployment of hydrogen refuelling stations would require a relatively significant fleet size across europe to justify investment in the infrastructure.

Overall, this paper provides a sound analysis, that is well explained and justified. I recommend for publication.

Minor editorial comments:
- Capital 'i' in second sentence, Introduction.

(Remarks on code availability)
N/A

Reviewer #3

(Remarks to the Author)
This paper provides a thorough examination of the total cost of ICEV, FCEV, and BEV trucks in the EU. The paper is well-written, with clear explanations of the different inputs and parameters included in the model. It makes several important contributions, including the use of heterogenous real-world driving profiles. And it addresses an important topic, as both FCEVs and BEVs are considered important technologies for decarbonizing the transportation sector.
There are several modeling assumptions that I have questions about.

1. It seems insurance is not included in the total cost of ownership. Given that FCEVs and BEVs have higher purchase costs than ICEVs, they also may be more expensive to insure. I would recommend that the authors either a) add insurance to the modeling or b) justify their exclusion of insurance costs.

2. In some scenarios the authors include mid-day fast charging events for the BEVs. Even if this allows the BEV to meet the same daily VKT as the ICEV, the charging event would have associated time cost for the driver/fleet operator. Similar to the insurance, I would recommend either including this or adding further justification for its exclusion.

3. What are the assumptions regarding hydrogen production methods (steam methane reforming, electrolysis, etc.)? How does this impact the cost values? Figure 1 doesn't include a CO2 tax for the FCEV. Does this mean green hydrogen is used? Or is hydrogen excluded from this tax regardless of production method? Or is the tax for non-green hydrogen production methods already included in the cost?

4. In the SI discussion of hydrogen costs the authors mention that, "Further costs associated with the distribution from import terminals and from the central hydrogen hubs are not included in the figures shown here." Can this assumption be justified? What percentage of the retail hydrogen cost is from distribution and storage post import/hubs?

5. I don't believe battery replacement for the BEV is included in the TCO. This might be a fine assumption, depending on the vehicle's lifetime VKT, or this may need additional justification for long-lifetime/intensely driven vehicles.

As a more general comment, given that the utilization profiles, many of the TCO inputs, and the differential TCO results are country-specific, I expected some discussion of differences between countries (e.g., which are most or least favorable for different technologies, and why). Regional heterogeneity is mentioned in the methods (section 7.6), but it is not highlighted in the results. Alternatively, if there is not a significant difference between different countries included in the analysis, that might be worth stating.

A final minor note - if I am interpreting figure 5c correctly, the capital cost premium of the BEV and FCEV vs the ICEV gets smaller from 2030 to 2040 to 2050. This makes sense as battery and fuel cell prices decrease. However, I was surprised that the operating cost savings of the BEV vs the ICEV increases from 2030 to 2040, but then decreases from 2040 to 2050. Why does the BEV OPEX relative to ICEV OPEX increase from 2040 to 2050 (as shown in Fig. 5b)?

(Remarks on code availability)

Version 1:

Reviewer comments:

Reviewer #1

(Remarks to the Author)
I thank the authors for their careful and constructive responses to my previous comments. The revised manuscript has addressed the main issues I raised in the first round. In particular, the authors have added further discussion and sensitivity analysis regarding battery and fuel-cell stack lifetime uncertainties, clarified the treatment of payload-related assumptions, provided additional information on data and code availability, revised the charging feasibility assumption by using an effective range-extension framework, and improved the explanation of the mapping between utilization profiles and VECTO vehicle classes.
I find these revisions satisfactory. The manuscript is now clearer and more transparent regarding its key modelling assumptions and limitations. I have no further major concerns and recommend acceptance of the manuscript.

(Remarks on code availability)

Reviewer #2

(Remarks to the Author)
No further comments / suggestions for changes. The manuscript has been improved further and I recommend for publication.

(Remarks on code availability)

Reviewer #3

(Remarks to the Author)
The authors have addressed my concerns and made significant improvements to the paper. I think this will be a strong addition to the literature.

I only found one minor typo - please change "elevate" to "elevated" in the new text on page 10.

(Remarks on code availability)