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Alexander Wanitschke

Are battery electric vehicles the future?

An uncertainty and robustness comparison with hydrogen fuel cell and internal combustion engine vehicles in Germany

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vorgelegt von
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I hereby declare that I have written the present work independently and I have not used any sources or resources other than those specified.

Berlin, June 11, 2021

Notes on language use

Conventions about acceptable style in academic writing differ across languages. For example, German academic writing routinely uses and prefers the passive voice, while English-speaking academics increasingly frown upon it and prefer the active voice and the first person, both singular and plural, as it results in more comprehensible language and encourages scientists to be explicit [1, 2]. For the sake of maximum clarity of thought and vigorous expression I use the active voice (i.e. first person in singular) where possible and the passive voice where appropriate. I also strive for specific but plain language for it is better to be clear and possibly wrong than to hide behind obscurity and not be understood at all. As Stuart Hampshire described Bertrand Russell's writing style (as cited in [3]): "It's a question of not obfuscating – of leaving no blurred edges; of the duty to be entirely clear, so that one's mistakes can be seen; of never being pompous or evasive. It's a question of never fudging the results, never using rhetoric to fill a gap, never using a phrase which conveniently straddles, as it were, two or three notes and leaves it ambiguous which one you're hitting."

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What began with a ten-page exposé ends today - five years, two babies and 144 pages later. And even though words can hardly describe the range of my emotions I know that above all I feel enormous gratitude for all the support I have received over the years and along this journey.

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Abstract

The passenger vehicle sector in Germany is under increasing pressure to reduce its GHG emissions. As a scalable remedy three distinct technology options are available: (1) internal combustion engine vehicles (ICEV) supplied with non-fossil, hydrocarbon fuels, (2) fuel cell electric vehicles (FCEV) supplied with hydrogen, and (3) battery electric vehicles (BEV) supplied with electric energy. Public disagreement about the "best" option persist to this day. While uncertainty (i.e., lack of knowledge) arguably plays a major role in this disagreement, past research has touched only superficially on what we do and *do not* know in order to assess how robust the feasibility of any of the technology options is with regards to possible future states of the world.

In order to address this issue I conducted both a systematic uncertainty analysis and a consecutive robustness analysis. The results show that even though all three drive technology options are affected by a similar number and quality of uncertainties, the uncertainty landscape translates into significant differences of robustness regarding the different vehicle technology's total cost of ownership (TCO) and life cycle GHG emissions (LCE). According to a tipping point analysis none of the three technologies can be demonstrated to reliably outperform their competitors in all conceivable future states of the world. Each of the three technologies still has distinct vulnerabilities and associated risks. However, it can be argued that today's reality is closer to the point of clear superiority for BEV than for FCEV or ICEV. Broadly speaking my research contributes further arguments of why BEVs should be considered the most reliable option for decarbonizing passenger vehicles in Germany.

Zusammenfassung

Der deutsche PKW-Verkehr steht unter zunehmendem Druck, seine Treibhausgasemissionen zu reduzieren. Als skalierbare Lösung stehen drei unterschiedliche Technologieoptionen zur Verfügung: (1) verbrennungsmotorische PKW mit nicht-fossilen Kraftstoffen, (2) Brennstoffzellen-PKW mit Wasserstoff und (3) batterieelektrische PKW mit elektrischer Energie. Bis heute besteht Uneinigkeit über die Frage der "besten" Antriebsoption und obwohl Unsicherheit (d.h. das Fehlen von Wissen) dabei eine wichtige Rolle spielt, haben vorangegangene Forschungsarbeiten hierzu nur unzureichend herausgearbeitet, was *nicht* bekannt ist, um zu entscheiden wie robust die Güte der verschiedenen Antriebsoptionen bzgl. möglicher Entwicklungen der Zukunft ist.

Um diese Forschungslücke zu schließen, habe ich sowohl eine systematische Unsicherheitsanalyse als auch eine darauf aufbauende Robustheitsanalyse der drei Antriebsoptionen durchgeführt. Die Ergebnisse zeigen, dass, einerseits, alle Antriebsoptionen von einer ähnlichen Anzahl und Qualität von Unsicherheiten betroffen sind, und dass sich, andereseits, diese Unsicherheitslandschaft unterschiedlich stark auf die Robustheit der Antriebe bzgl. Ihrer total cost of ownership (TCO) und life cycle GHG emissions (LCE) auswirkt. Meine Ergebnisse liefern Argumente dafür, dass batterieelektrische PKW die robusteste Technologieoption sind, um den PKW-Verkehr in Deutschland zu dekarbonisieren.

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