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Total cost of ownership of electric vehicles compared to conventional vehicles: A probabilistic analysis and projection across market segments

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HIGHLIGHTS

- Calculates the total cost of ownership across competing vehicle technologies.
- Uses Monte Carlo simulation to analyse distributions and probabilities of outcomes.
- Contains a comprehensive assessment across the main vehicle classes and use cases.
- Indicates that cost efficiency of technology depends on vehicle class and use case.
- Derives specific policy measures to facilitate electric vehicle diffusion.

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ABSTRACT

While electric vehicles (EV) can perform better than conventional vehicles from an environmental standpoint, consumers perceive them to be more expensive due to their higher capital cost. Recent studies calculated the total cost of ownership (TCO) to evaluate the complete cost for the consumer, focusing on individual vehicle classes, powertrain technologies, or use cases. To provide a comprehensive overview, we built a probabilistic simulation model broad enough to capture most of a national market. Our findings indicate that the comparative cost efficiency of EV increases with the consumer's driving distance and is higher for small than for large vehicles. However, our sensitivity analysis shows that the exact TCO is subject to the development of vehicle and operating costs and thus uncertain. Although the TCO of electric vehicles may become close to or even lower than that of conventional vehicles by 2025, our findings add evidence to past studies showing that the TCO does not reflect how consumers make their purchase decision today. Based on these findings, we discuss policy measures that educate consumers about the TCO of different vehicle types based on their individual preferences. In addition, measures improving the charging infrastructure and further decreasing battery cost are discussed.

1. Introduction

1.1. Total cost of ownership of electric vehicles

The transport sector can strongly contribute to the alleviation of greenhouse gas emissions (Kley et al., 2011; Kotter, 2013; Shafiee and Topal, 2009). In the European Union (EU) for instance, passenger cars and vans currently emit around 15% of total carbon dioxide (CO_2) emissions (European Commission, 2014a). Hence, policy makers have set transport regulations (e.g. California Corporate Average Fuel Economy standards, European Union transport regulations) to reduce CO_2 emission from vehicles. Since these regulations consider the tailpipe, not the well-to-wheel emissions (European Commission, 2014a), purely electric vehicles (EV) count as zero emission cars.[1] The automotive industry has further developed EV through hybrid or pure electric powertrains, an effort partly supported by national and regional policy initiatives. California, for instance, initiated the Clean Vehicle Rebate Project, which offers up to 5000 USD rebate for the private

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[1] Tailpipe emission only takes emissions from the onboard source of power of a vehicle into account, whereas well-to-wheel emission also takes the emissions produced in the process of energy provision into account.

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Table 1
TCO literature review.

Source	Model type	Powertrain technology focus	Vehicle classes covered	Use case consideration	Future extrapolation	Sensitivity/uncertainty analysis	Reference country
Wu et al. (2014)	Mainly economic	PHEV	C/D (single reference models)	Yes	No	No/No	USA
Al-Alawi and Bradley (2013)	Techno-economic	PHEV	Compact, Midsize, Midsized SUV, Large SUV	No	No	Yes/No	USA
Lin et al. (2013)	Techno-economic	ICEV-SI, HEV	SUV (Single reference models)	No	No	Yes/No	China
Plötz et al. (2013)	Mainly economic	ICEV-SI, ICEV-CI, PHEV, REEV, BEV	Small, Medium, Large (Category of reference models)	Yes	Yes	Yes/Yes	DE
Tseng et al. (2013)	Economic	ICEV-SI, HEV, PHEV, BEV	Midsize vehicles (Single reference models)	No	No	Yes/No	USA
Hill et al. (2012)	Techno-economic	ICEV-SI, ICEV-CI, HEV, REEV, BEV	C/D, Van (Representative average)	No	Yes	No/No	UK
Propfe and Redelbach (2012)	Techno-economic	ICEV-SI, HEV, PHEV, REEV, BEV, Fuel Cell Vehicle (FCEV)	Midsize vehicles (Category of reference models)	Yes	No	No/No	DE
Prud'homme and Koning (2012)	Mainly economic	ICEV-CI, BEV	A/B (single reference model)	No	(Yes)	Yes/No	FR
Bickert and Kuckshinrichs (2011)	Techno-economic	ICEV-SI, REEV, BEV	Micro, Subcompact, Compact (single reference vehicle)	No	Yes	Yes/No	DE
Contestabile et al. (2011)	Techno-economic	ICEV-CI, HEV, PHEV, BEV, FCEV	Super-mini, Lower-medium, Multipurpose, Luxury (Single reference models)	No	Yes	Yes/No	UK
Douglas and Stewart (2011)	Techno-economic	ICEV-SI, HEV, REEV, BEV	A/B, C/D, E/H (Category of reference models)	No	Yes	Yes/Yes	UK
McKinsey & Company (2011)	Mainly economic	ICEV-SI, ICEV-CI, PHEV, BEV, FCEV	A/B, C/D, SUV (Category of reference models)	No	Yes	Yes/No	EU-27+CH+NO
Thiel et al. (2010)	Mainly economic	ICEV-SI, ICEV-CI, HEV, PHEV, BEV	Midsize vehicle (Single reference models)	No	Yes	Yes/No	EU-27
van Vliet et al. (2010)	Techno-economic	ICEV-CI, HEV, PHEV, FCEV	Midsize vehicles (Single reference models)	No	(Yes)	Yes/Yes	NL
Kromer (2007)	Techno-economic	ICEV-SI, ICEV-CI, HEV, PHEV, BEV	One reference model per technology	No	Yes	Yes/No	USA
Lipman and Delucchi (2006)	Techno-economic	HEV	B, D, SUV, Van (Single reference models)	No	No	Yes/No	USA
Delucchi and Lipman (2001)	Techno-economic	BEV	D (Single reference vehicle)	No	No	Yes/No	USA