Application and Comparison of Online Calculators for Calculating the Economic Efficiency and Sustainability of Vehicles

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Abstract The aim of this work is to use different online comparison calculators in order to compare the results and to work out limitations and potentials for improvement. The research hypothesis is that due to uniform initial data of the case study, the different calculators provide approximately the same results. To investigate this hypothesis, four steps are carried out: first research and categorization of online calculators; second creating a case study and scenarios; third application of online calculators and fourth comparing the results of the calculations, also with the benchmark calculator DIPO-tool, for a critical evaluation. Generally, one can say that only a small number of the reviewed calculators can provide a functionality that is necessary for a professional and proper comparison of economic efficiency and sustainability. For the economic comparison, one can state, that in some cases, the calculation results deviate strongly from each other, contrary to the formulated hypothesis. When considering sustainability, it becomes very clear that tank-to-wheel and well-to-wheel considerations fall far short of the mark and must be supplemented by a holistic approach that includes the manufacturing phase and the after-use phase (recovery and recycling).

Keywords:
alternative drive technologies, calculation tool, case study, life cycle assessment, profitability analysis

JEL:
M10, R40, Q56

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1 Introduction

Against the backdrop of climate change and increasingly concrete political measures such as the EU ban on new combustion engine cars from 2035, there is growing interest in finding out about the sustainability of vehicles. However, this is not just about an ecological assessment, but also about making an economic decision. Numerous online comparison calculators are available for this purpose, and this article takes a closer look at them. The focus is on the question of whether different comparison calculators deliver the same results with the same initial data.

2 Theoretical Background

The basic prerequisite for comparing vehicles is the availability of comparison criteria for assessing economic efficiency and sustainability. Criteria for the economic efficiency of vehicles mainly concern the acquisition costs minus any subsidies and the residual value of a vehicle as well as running costs such as energy consumption (Bertram & Bongard, 2014; Hacker et al., 2015) The decision criterion for assessing economic viability is usually the total cost of ownership (TCO) of the vehicles (Jöhrens et al., 2021). For the consideration of environmental sustainability, generic terms in the literature include environmental accounting, life cycle analysis (LCA) or life cycle assessment (LCA). These terms holistically encompass the phases of production, use, and recycling or disposal of products (Koch & Toedter & Weber, 2020). Other terms commonly used in this context are "Well-to-Tank (WtT)", which covers greenhouse gas emissions on the production side from the source to the vehicle tank, and "Tank-to-Wheel (TtW)", which stands for a purely consumption-based view. The term Well-to-Wheel (WtW) is the sum of energy (WtT) and vehicle processes (TtW) (Schmied & Mottschall, 2014).

A wide range of online comparison calculators for calculating the economy and sustainability of a vehicle are available on the Internet, which include a wide variety of factors and data in their comparative calculations.

Comparison calculators with stored databases have a limited selection of vehicles and models that the user can select for comparison. Some user-related parameters can be determined by the user, such as the annual mileage or energy prices. Vehicle-related data such as list prices and costs for insurance, inspection or taxes are predefined with approximate values. Examples of this type of online comparison calculator include Alternative Fuels Data Center (U.S. Department of Energy, 2022), E-Fahrer (E-Fahrer, 2022), Journey Cost Calculator (Zap-Map, 2022), and Linz AG (Linz AG, 2022). Due to the numerous features of the Linz AG e-mobility calculator, it is considered for this case study.

Comparison calculators with stored formulas do not access databases. The user must research all data, such as acquisition or running costs, on the Internet or via other sources of information. This takes time, but is rewarded by more precise results, as no approximate or average values are used. Another advantage is that users are not restricted by a limited choice of vehicle models. Examples of this type of online comparison calculator include EMIL from the Vorarlberg Energy Institute (Energieinstitut Voralberg, 2022), e-Stations (e-Stations, 2022), and Stromdrive (Stromdrive, 2022).

3 Methodology

The EMIL and e-Stations calculators were selected for the case study. The reasons for this are the diverse input options and features for sustainability consideration. A case study comparing an internal combustion engine (ICE) vehicle, Mini Cooper S, with a comparable electric vehicle (BEV), Mini Cooper SE, is used to evaluate the selected online comparison calculators.

Configuration of the comparison vehicles and case study data are shown in Table 1.

The annual mileage is 20,000 km and after a holding period of five years the vehicles are sold with a residual value of 30 %. Prices are constant over the entire holding period.

Table 1: Configuration of the comparison vehicles and case study data

Feature	Mini Cooper S (ICE)	Mini Cooper SE (BEV)
Engine power	(131 kW) 178 PS	(135 kW) 184 PS
Energy consumption	6.9 l / 100 km	18 kWh /100 km
CO_2-Emissions	160 g/km	0 g/km
Tank capacity / Battery size	44 l	32.6 kWh
Mini Service Inclusive Plus package (p. a.)	€460.13	€449.82
Comparison price with equivalent equipment	€37,180	€39,980
Subsidy		€9,000
Insurance	€830.36	€652.75
Vehicle tax/Other costs	€124/€48	0/€32
Gasoline/Power	1.90 €/l	0.49 €/kWh plus €5.99 per month
GHG Bonus (Elektroauto-News, 2023)		€350

Source: https://www.mini.de/de_DE/home/the-mini-family.html?&tl=sea-gl-DE_MINI_NEWCARS_CONFIGURATOR_DEU_BND_SEA_MINI2023DE%20LO%20AL%20002-mix-miy-MINI+%C3%BCbergreifend-sech-BRAND_BG_CONFIGURATOR_PERF-.-p-mini%20cooper%20konfigurator-.-.&clc=sea-gl-DE_MINI_NEWCARS_CONFIGURATOR_DEU_BND_SEA_MINI2023DE%20LO%20AL%20002-mix-muks&gclid=EAIaIQobChMIvNm--ub-_QIV6oxoCR1rlAnuEAAYASAAEgKwIPD_BwE&gclsrc=aw.ds

3.1 Application of online calculators

The following is a brief description of how the data from the case study was processed with the selected comparison calculators. Limitations of the comparison result from the fact that in some cases not all data of the case study could be considered. Examples of this are the GHG-bonus, which could only be taken into account with EMIL and the benchmark comparison calculator DIPO-Tool, the missing input option of a residual value with e-Stations and Linz AG and the missing recording options of the charging current subscription fee and the costs for TÜV/AU with EMIL, e-Stations and Linz AG.

3.1.1 Online calculator of Linz AG

A database with approx. 400 gasoline, diesel and electric vehicles is stored in this calculator. The Mini Cooper SE and Mini Cooper S vehicles selected for TCO calculations are not available with their individual configuration and must be created in the database itself. In the comparison calculator, a useful life of 12 years is fixed for the vehicles. The shorter holding period cannot be stored. Annual mileage, financial support for car purchase, prices for fuel and electricity, and maintenance costs can be set variably according to the case study. However, a vehicle tax is fixed and cannot be adjusted to the actual vehicle tax to be paid. For sustainability, only the TtW-CO_2 for fully electric vehicles (0 kgCO_2 /kWh) are shown. No values are stored for combustion vehicles, so that the CO_2 savings shown in the evaluation are not comprehensible.

3.1.2 Online calculator EMIL

The calculator EMIL determines the TCO of the vehicles to be compared with the aid of stored formulas. For individual vehicle categories standard values are stored. The two Mini Coopers can be assigned to the small car category. Performance and consumption values already stored can be replaced by values researched by the user. Gasoline is selected as the energy source for the Mini Cooper S, while the Austrian electricity mix (0.27 kg CO_2e/kWh) is selected as one of the four available choices for the Mini Cooper SE. Holding period and annual mileage can be specified individually.

An environmental bonus and a GHG-bonus can be deposited for the Mini Cooper SE. The annual maintenance costs, tax/insurance and energy costs for fuel (in €/l) or electricity (in €/kWh) as well as the expected residual values at the end of the holding period can be set according to the case study. Sustainability is determined in terms of cumulative greenhouse gas emissions over the entire life cycle. The subdivision is made into the category's vehicle production, production of fuel/electricity, driving operation and battery disposal. The greenhouse gas emissions generated during vehicle production and battery disposal are allocated proportionately to the useful life of the vehicles. Other environmental parameters that are calculated pro rata over the entire life cycle of the vehicles are, for example, particulate matter emissions and NO_x-pollutant emissions.

3.1.3 Online calculator e-Stations

This comparison calculator works with formulas, but it has also a database of hybrid and electric vehicles, which, however, only contains data on acquisition costs, consumption and capacity of the battery. For the TCO comparison, the data from the calculator is replaced by the acquisition costs from the configuration of the BEV. The data for a conventional vehicle with an internal combustion engine must be set by the user. All data of the case study can be transferred except the residual value and income from the sale of the GHG quota are not considered. Only Tank-to-Wheel-CO_2-emissions are considered for sustainability. For gasoline, a value of 2.32 kgCO_2 per liter is stored as the CO_2-TtW coefficient. Since full electric vehicles have no greenhouse gas emissions during driving, 0 kgCO_2 per kWh is shown as the TtW-value.

3.1.4 Benchmark calculator DIPO-Tool

The DIPO tool is a professional solution for the holistic consideration of the economic efficiency and sustainability of vehicles in the field of fleet management and controlling. It consists of various Excel tables and was designed for teaching and research purposes at the Ludwigshafen University of Applied Sciences (Bongard & Friesenhahn & Wolff, 2022; Bongard & Schröder, 2022). In the expansion stage used, the calculation of LCA values in particular was advanced. Bases on an approach developed by Fraunhofer ISI (Wietschel et. al. 2019), depending on a vehicle class a CO_2-value is assigned to the respective vehicle for the manufacturing phase and assumed to be 13 years for a vehicle lifetime. For small cars, these values are 5.0 tCO_2 (0.385 tCO_2 p. a.) for internal combustion vehicles and 8.4 tCO_2 (0.646 tCO_2 p. a.) for electric vehicles. If we now assign values for a small vehicle to both vehicles, the following picture emerges when the useful life is considered on a pro rata basis:

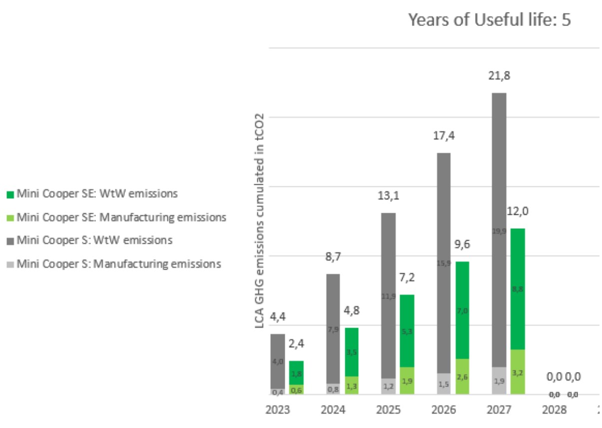

Figure 1: DIPO-Tool LCA Chart
Source: Author's research.

The proportional CO_2-consumption of the manufacturing phase forms a foundation that considers the CO_2-emissions of the manufacturing phase. Further inclusion of the recovery and recycling phase in the calculation methodology of the DIPO tool is already being planned.

4 Results

Table 2 and 3 show the calculation results for the two vehicles of the case study.

Table 2: Results for Mini Cooper S (ICE)

Mini Cooper S	Linz AG	EMIL	e-Stations	DIPO tool (Benchmark)
● Profitability analysis				
TCO in Euro (5 years)	38.120	46.206	57.362	**46.448**
Deviation to benchmark absolute (in Euro)	*-8.328*	*-242*	*10.914*	
Deviation to benchmark in %	*-17,9 %*	*-0,5 %*	*23,5 %*	
Preferable alternative related to TCO	*no*	*no*	*no*	*no*
● Sustainability analysis				
TtW-CO_2-emission in kg	100	14.704	16.008	**16.700**
WtW-CO_2-emission in kg	not available	18.789	not available	**19.900**
LCA-CO_2-emission in kg (comparison basis)	not available	21.697	not available	**21.800**
Deviation to benchmark absolute (in kg)	-	*-103*	-	
Deviation to benchmark in %	-	*-0,5 %*	-	
preferable alternative related to CO_2	-	*no*	-	*no*

Source: Authors' compilation

In case of the combustion vehicle, it can be stated for the economic efficiency that all calculators do not show the combustion vehicle as the more economical alternative. The EMIL calculator shows the smallest deviations in the TCO (-0.5 %), while the other two calculators show considerable deviations of -17.9 % (Linz AG) and 23.5 % (e-Stations). In terms of sustainability, the weaknesses of the Linz AG and e-Stations calculators are clearly evident, as they do not report any LCA values. The deviation between the benchmark and the EMIL calculator is very small at -0.5 %.

Table 3: Results for Mini Cooper SE (BEV)

Mini Cooper SE	Linz AG	EMIL	e-Stations	DIPO tool (Benchmark)
● Profitability analysis				
TCO in Euro (5 years)	27.240	31.591	45.313	32.088
Deviation to benchmark absolute (in Euro)	-4.848	-497	13.225	
Deviation to benchmark in %	-15,1 %	-1,5 %	41,2 %	
Preferable alternative related to TCO	yes	yes	yes	yes
● Sustainability analysis				
TtW-CO_2-emission in kg	0	0	0	0
WtW-CO_2-emission in kg	not available	5.346	not available	8.800
LCA-CO_2-emission in kg (comparison basis)	not available	9.872	not available	12.000
Deviation to benchmark absolute (in kg)	-	-2.128	-	
Deviation to benchmark in %	-	-17,7 %	-	
preferable alternative related to CO_2	-	yes	-	yes

Source: Authors' compilation

For the electric vehicle, it can be stated for the economic efficiency that all calculators show the electric vehicle as the more economical alternative. The EMIL calculator shows the smallest deviations for the TCO (-1.5 %), while the other two calculators show proper deviations of -15.1 % (Linz AG) and very high 41.2 % (e-Stations). In terms of sustainability, there are larger deviations between the benchmark and the EMIL calculator, which shows LCA CO_2 emissions 17.7 % lower.

5 Discussion and Conclusion

The assumption that different comparison calculators provide the same results based on the same input data cannot be upheld, as there are sometimes considerable deviations. Basically, the results are only correct in the sense that the electric vehicle is shown to be the more advantageous alternative for the case study, both in terms of economic efficiency and sustainability. Compared to the DIPO tool as a benchmark, the EMIL calculator performs very well. One limitation, however, is that the EMIL calculator only offers a choice of four electricity CO_2-coefficients.

From the user's point of view, it is therefore important to find out about the corresponding quality of the expected results before using a comparative calculator. It is helpful here to benchmark against a scientifically based calculator that has been tested in numerous practical case studies, such as the DIPO tool used here. Particularly against the backdrop of an urgent need for a more sustainable orientation in the acquisition and use of vehicles, it is imperative to apply a holistic, systemic view based on approaches to vehicle life cycle analysis.

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