Time and Rebound Effects in the LCA of Electric Vehicles - Methodological Approach and Examples

(10) Sozioökonomische und gesellschaftliche Aspekte - Lebenszyklusanalyse

Gerfried JUNGMEIER(1), Lorenza CANELLA(1), Amgad A. ELGOWAINY(2), Simone EHRENBERGER(3), Gabriela Benveniste PÉREZ(4), Pierre-Olivier ROYE(5), Lim OCKTAECK(6), Tugce YUKSEL(7)

(1)JOANNEUM RESEARCH, Science Tower, Waagner-Birostrasse 100, A-8020 Graz (gerfried.jungmeier@joanneum.at); (2)Argonne National Laboratory, USA; (3)DLR, Germany; (4)IREC, Spain; (5)CIRAIG, Canada; (6)University of Ulsan, South Korea; (7)Sabanci University, Turkey

Motivation and Central Questions

There is an international consensus that the environmental effects of electric vehicles (EV) can only be analyzed on the basis of Life Cycle Assessment (LCA) including the production, operation and the end of life treatment of the vehicles in comparison to conventional vehicles. Today we know that EVs using additional renewable electricity can substantially reduce environmental impacts in life cycle if conventional fossil ICE vehicles are substituted. Since 2011 a group of LCA expert works on the further methodological development of applying LCA to EVs in Task 30 "Environmental Effects of EVs" in the Technology Collaboration Program (TCP) of the IEA with 20 participating countries [1]. These new developments address the following questions:

- How does rapidly changing electricity mix affect the LCA results?
- How to apply LCA in scenario analyses adequately?
- And considering known rebound effects: Does each electric driven kilometer really substitute a fossil driven kilometer? Do we need an appropriate new functional unit?
- And how do these aspects effect the application of LCA to whole current or future vehicle fleets?

Methodological Approach

These questions are addressed in the new LCA approach where the changing framework conditions of an EV during its lifetime (e.g. 12 years) are reflected. This is done by calculating the environmental effects of changing electricity production for each year separately and then cumulated over the total lifetime, which should also be graphically shown in the results.

In scenario analyses for the further introduction of EVs it is essential to show the real environmental (e.g. GHG reduction) effects for each analyzed year, so the average environmental effects in the LCA per kilometer is not adequate, as the emissions from production of the EVs occur before the introduction in the scenario and the effects of dismantling/end of life occur after use. So LCA must provide a timely resolution of the environmental effects to be included in scenario analysis which leads to additional so far unrecognized impacts.

The well-known rebound effects of EVs are

- Increasing vehicle stock
- Increasing demand for transportation service
- EV becomes 2nd & 3rd vehicle in household
- Substitution of public transport services

To address these effects in LCA the new developed functional unit is per passenger transportation service or that the substitution rate is less than 100% [2].

Results and Conclusions

These new methodological LCA developments are applied to examples for illustration, which are now discussed and concluded in a broad scientific exchange and discussion led by the IEA HEV task 30 [3].

In Figure 1 the effects of changing electricity mix (2% annual decarburization rate) over lifetime of battery and hydrogen fuel cell electric vehicle is shown. Considering a changing electricity mix the average GHG emissions are with 103 g CO_2eq/km lower than 115 g CO_2eq/km without changing mix; due to the lower energy efficiency this effect is bigger for fuel cell vehicles.

In Figure 2 the effects of different substitution rates (100%, 90%, 70% and 60%) of ICE (200 g CO_2-eq) on the possible GHG reduction of electric vehicles (taken from Figure 1) due to rebound effects are shown. Rebound effects significantly influences the possible GHG reduction and must be reflected in the functional unit of LCA.

In Figure 3 the combined effects of the new LCA approach including time and rebound effects in LCA of EVs compared to ICEs for scenario analyses are shown. These effects are significant as with a substitution rate of 80% a GHG reduction by EVs is reached only after 5 years.

These new developments must be considered in future LCA applications of EVs to receive more adequate timely resolved results, e.g. in scenarios reaching Paris Agreement in 2050.

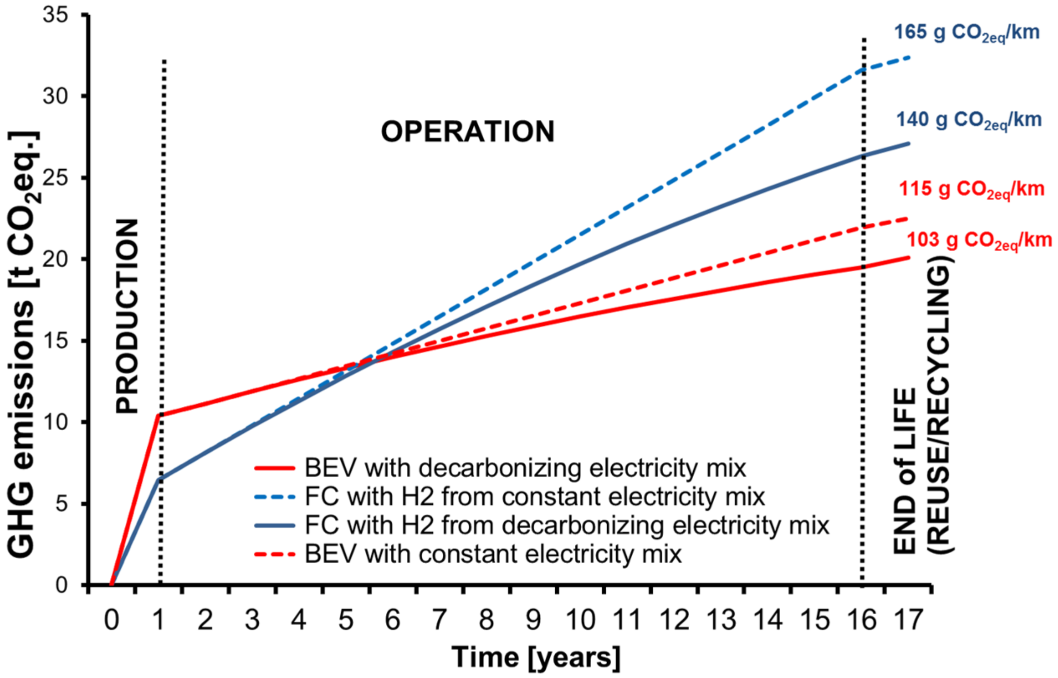

Figure 1: Effects of changing electricity mix (2% annual decarburization rate) over lifetime of battery and hydrogen fuel cell electric vehicle

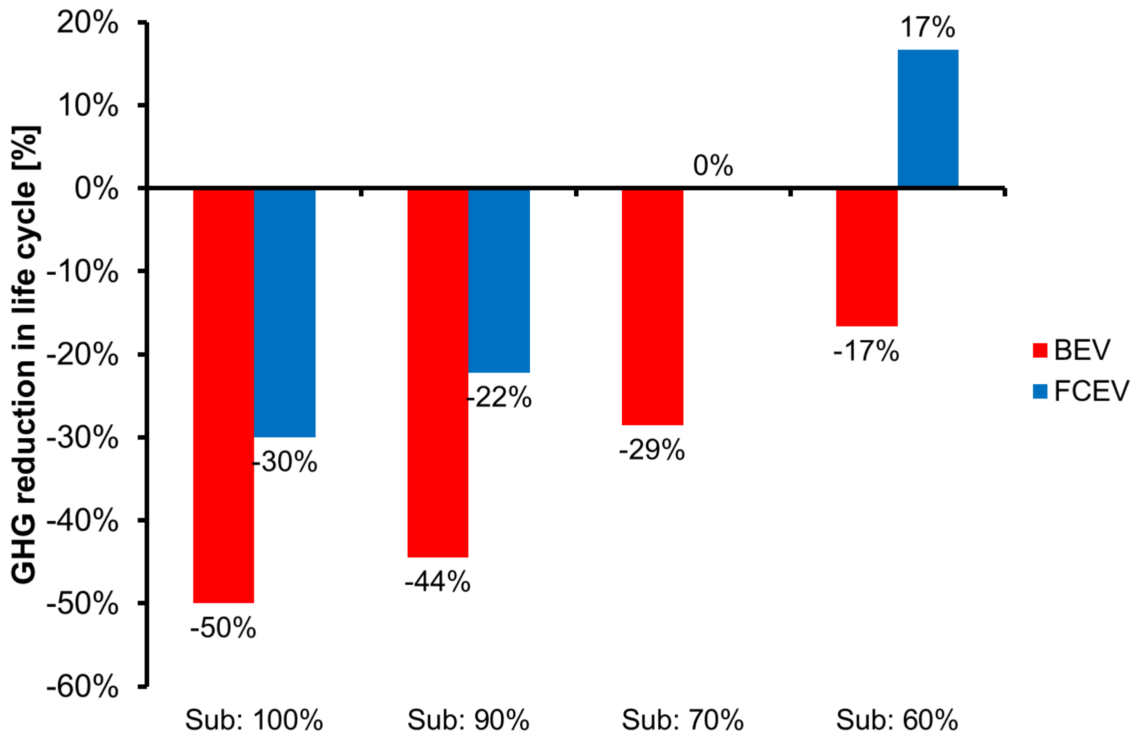

Figure 2: Effects of substitution rate of ICE on the possible GHG reduction of electric vehicles

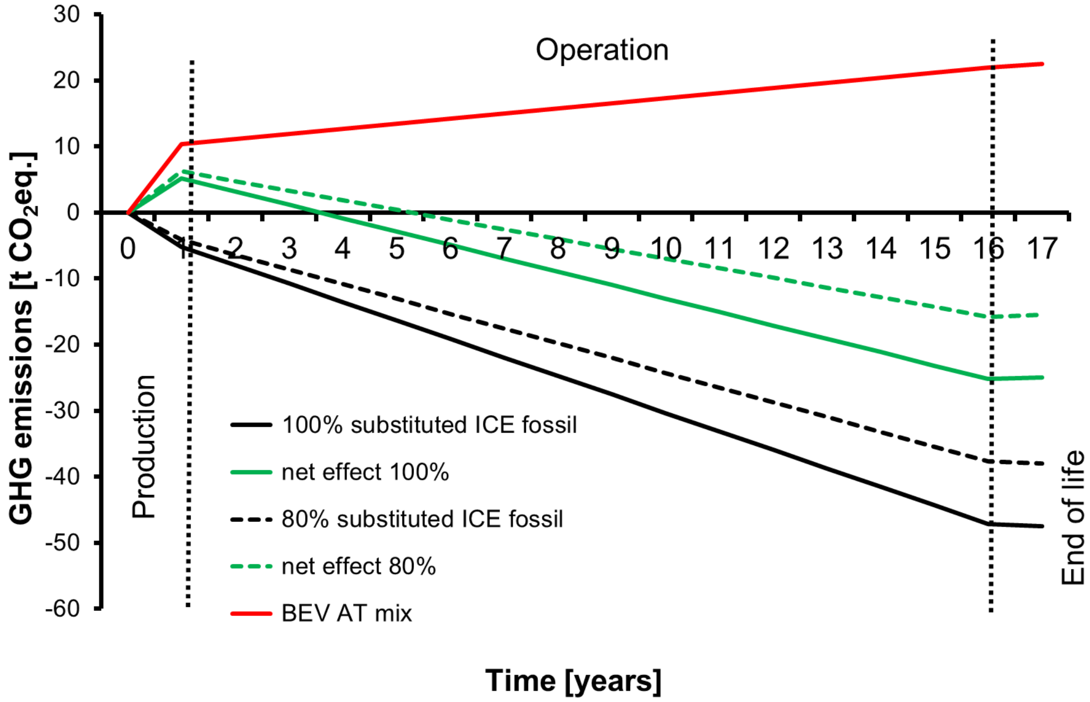

Figure 3: Effects of new LCA approach including time and rebound effects in LCA of EVs compared to ICEs

Literatur

[1] Jungmeier G., Dunn J., Elgowainy A., Gaines L., Ehrenberger S., Özdemirc E. D., Althaus H. J., Widmer R. (2014): Life cycle assessment of electric vehicles – Key issues of Task 19 of the International Energy Agency (IEA) on Hybrid and Electric Vehicles (HEV), Conference Proceedings, TRA 2014 - 5th Conference Transport Solutions – From Research to Deployment, Paris 14 – 17. April 2014

[2] G. Jungmeier et al.: Life-cycle Based Environmental Effects of 1.3 Mio. Electric Vehicles on the Road in 35 Countries – Facts & Figures from the IEA Technology Collaboration Program on Hybrid & Electric Vehicles, Proceedings of EVS 30, Germany, Octobre 9 – 11, 2017

[3] Emissions to Air in the LCA of Electric Vehicles – Current Status and Future Perspectives; Proceedings of Expert Workshop, IEA Task 30 “Environmental effects of Electric vehicles”, September 18&19, 2018, Stuttgart, Germany

The Work of JOANNEUM RESEARCH in IEA HEV task 30 is financed by Austrian klima + energie fonds