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ScienceDirect

Energy Procedia 99 (2016) 380 – 391

Energy Procedia

Economic and environmental prospects of battery and fuel cell vehicles for the energy transition in German communities.

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Abstract

The CO_2 reduction potential of battery and fuel cell electric vehicles (BEV/FCEV) is linked to the success of the energy transition. Both vehicle types can facilitate the integration of intermittent renewables. H_2 generation and storage infrastructure to support FCEVs is a promising opportunity for synergy between the transportation and building sectors in renewables integration, through grid storage and Power2Gas (i.e. blending H_2 into the natural gas supply). However, as FCEVs also require more than twice as much electric energy per distance traveled than BEVs, an integrated analysis is necessary to evaluate which electric vehicle (EV) offers the lowest cost for reducing CO_2 emissions.
We use an integrated analysis to determine the overall cost and CO_2 emissions when BEVs or FCEVs are deployed in two communities in southern Germany. Based on a comprehensive scenario for future cost and technology developments for 2025 and 2035, the cost-optimal mix of energy generation and storage technologies is determined to meet all energy demands (heating, electricity and transportation) in the communities.
This integrated analysis finds, that the higher energy consumption of FCEVs could not be compensated by system benefits like Power2Gas and grid storage. The result is consistent with a similar analysis of a community in California. The simulation results reveal, that while the two vehicle types enable similar CO_2 emission reductions, these can be realized at lower costs with BEVs than with FCEVs. The most striking observation was, that in the event seasonal H_2 grid storage becomes necessary, FCEVs would in fact be less favorable than BEVs, which require less energy per km traveled and therefore leave more energy available for stationary applications.

Keywords: energy transition, battery vehicles, fuel cell vehicles, Power-to-Gas, hydrogen infrastructure

1. Introduction

Battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) both offer convenient personal mobility with no tailpipe emissions. Their potential to reduce CO_2 emissions in Germany depends on providing them with energy from a low-carbon source - in other words, on the success of the German energy transition. However, they both offer interesting co-benefits for the integration of intermittent renewable energy sources (RES) such as wind and solar power that may facilitate the transition.

When connected to the grid, BEVs can contribute via smart charging (load shifting to times of high RES generation) [1, 2, 3, 4] or as short-term energy storage (vehicle-to-grid, V2G [5]). When considering FCEVs, the hydrogen infrastructure consisting of electrolyzer (H_2 generation) and gaseous or liquid storage tanks, is particularly interesting for the energy system. For one thing, hydrogen could be generated during renewable power generation and converted back to electricity in a stationary fuel cell at a later point in time. Compared to V2G and stationary batteries, considerably more electricity could be stored [6]. Second, would it be possible to convert renewable (over-)generation, that would otherwise be curtailed, to hydrogen and feed it into the natural gas grid (Power2Gas, P2G) - thereby linking electric power and heat sector.

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Preprint submitted to IRES 2016 / Energy Procedia Journal *August 7, 2016*

Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy
doi:10.1016/j.egypro.2016.10.128

Nomenclature

BEV	Battery powered electric vehicle
EV	Electric vehicle, powered by an electric motor
FCEV	Fuel cell powered electric vehicle
ICV	Internal combustion vehicles, usually powered by gasoline or diesel fuel.
NEU	Neumarkt i.d.OPf., Germany
P2G	Power2Gas - hydrogen infeed to the natural gas supply
PUT	Putzbrunn, Germany
RES	Renewable energy sources
SI	Supplementary Information
V2G	Vehicle-to-Grid, short-term electricity storage using BEVs

In this study, the cost and CO_2 emissions impact of BEVs or FCEVs together with their accompanying infrastructure was investigated in the communities Putzbrunn and Neumarkt i.d.OPf. (PUT/NEU) in order to evaluate the potential benefits of either technology. The aim of the analysis is to determine if the potential co-benefits Power2Gas and H_2 grid storage from the use of hydrogen for transportation can compensate for the two- to threefold higher electric energy consumption of FCEVs compared to BEVs per distance traveled [7, 8, 9] (compare fig. 1).

The results were obtained with the simulation model VICUS [7] which uses hourly data[1] on RES availability and the energy demands in the community (Heat, Electricity and Mobility) as well as a comprehensive scenario on the further development of the energy vectors and available technologies.
For the years 2025 and 2035, the cost-optimal way to meet the energy demands was determined in three scenario cases: First, the all-ICV reference case (100% Internal combustion vehicles, no EVs); second, a BEV case with 13% (2025) and 38% (2035) BEVs in the vehicle mix; and finally a similar FCEV case[2].
The first part of the paper provides an overview on the overall costs and corresponding CO_2 emissions in the different cases. Second, the benefits of Power2Gas are investigated, prior to the third and final part, where the implications of hydrogen as a large-scale grid storage system are analyzed for a scenario with limited grid power in 2035.

2. Methodology – Simulation model, Input Data & Sensivity analyses

For this study, the same method as described in [7] was used to "determine the cost-optimal mix of different technology options to meet the energy demands" in the two communities. In [7], "a scenario was developed to account for future electric vehicle penetration rates as well as technical and economical learning curves of the energy conversion and storage technologies (compare supplementary information, SI). For the comparison of battery and fuel cell vehicles, the model determined results for three electric vehicle cases (BEV, MIX, FCEV) and an all-ICV reference case for 2025 and 2035."

1 for one year ≙ 8760 timesteps
2 2025 and 2035 ICV cases: 100% all-ICV, no electro-mobility
2025 BEV / FCEV cases: 87% ICV + 13% BEV / 87% ICV + 13% FCEV
2035 BEV / FCEV cases: 62% ICV + 38% BEV / 62% ICV + 38% FCEV.