

Lifecycle Greenhouse Gas Emission Assessment of EVs Using Lithium-ion Capacitors for Dynamic Wireless Power Transfer

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Dynamic wireless power transfer (DWPT) technology, which wirelessly transfers power to a moving electric vehicle (EV), enables a reduction in the capacity of the onboard lithium-ion battery (LiB). Therefore, it is effective in reducing environmental impact. On the other hand, reducing the capacity of the LiB increases fluctuations in the state of charge during charging and discharging. Therefore, accelerated LiB degradation has been reported.

To overcome this issue, hybrid energy storage systems (HESSs) combining a LiB with a lithium-ion capacitor (LiC), which has a higher power density and longer cycle life than the LiB, have been investigated. In HESSs, the LiC reduces the charge and discharge current of the LiB. Therefore, LiB degradation can be suppressed and its lifetime can be extended. On the other hand, greenhouse gas emissions from LiC manufacturing and vehicle operation due to the increased vehicle weight must also be considered.

Therefore, this paper evaluates the life-cycle greenhouse gas emissions per kilometer for a HESS combining a LiB and a LiC in an EV with a reduced LiB capacity enabled by DWPT. Furthermore, the degradation of the LiB and LiC is considered. The LiB type, LiC capacity, and LiC charging power are varied. The objective of this paper is to clarify the effects of these parameters on the HESS lifetime and greenhouse gas emissions per kilometer.

Considering their market shares, nickel manganese cobalt (NMC) and lithium iron phosphate (LFP) are selected as the cathode materials for the LiBs evaluated in this study. The LiB capacity is set to 10 kWh considering the reduced battery capacity enabled by DWPT. The LiC has a gravimetric energy density of 13 Wh/kg and a volumetric energy density of 19 Wh/L. The installation volumes are set to 5 L and 10 L, corresponding to LiC capacities of 76 Wh and 152 Wh, respectively.

In this study, the coil installation ratio, defined as the proportion of the total driving distance where DWPT is available, is assumed to be 20%. The operating condition is set so that the energy required for driving, calculated considering the vehicle weight, is supplied in the DWPT-installed sections. In the DWPT-installed sections, the power required for driving is supplied directly from the DWPT system to the motor without passing through the HESS. In addition, 10 kW or 20 kW of the remaining received power is supplied to the LiC, and the rest is supplied to the LiB. In the non-DWPT-installed sections, the power required by the motor is supplied from the HESS.

Fig. 1 shows the reduction rate in greenhouse gas emissions per kilometer compared with the case using only the LiB. In this study, the lifetimes of the LiB and LiC are defined as the points at which their capacities decrease by 20% from their initial capacities. The HESS lifetime is defined as the point at which either the LiB or LiC reaches its lifetime. As shown in Fig. 1, even if the LiC installation volume or charging power were increased, the environmental impact would not necessarily be reduced. If the LiC charging power is increased, the load on the LiB can be reduced. However, the number of LiC charge and discharge cycles per unit driving distance increases. The LiC reaches its lifetime before the LiB, shortening the total driving distance of the HESS. Therefore, greenhouse gas emissions per kilometer increase. Increasing the LiC installation volume can extend the LiC lifetime by increasing its capacity. On the other hand, the energy consumption during vehicle operation increases due to the increased vehicle weight, and greenhouse gas emissions from LiC manufacturing also increase. Therefore, even if the HESS lifetime is extended, greenhouse gas emissions per kilometer are not necessarily reduced. Therefore, the LiC charging power and installation volume should be set under conditions that provide benefits from introducing the HESS.

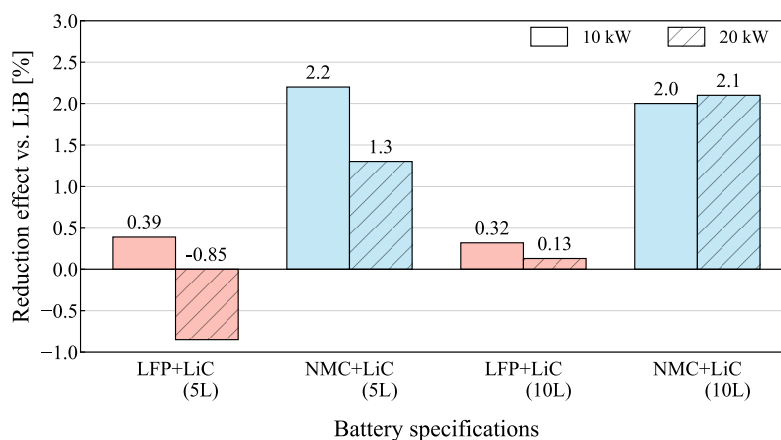


Fig. 1 Greenhouse gas emission reduction.