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Environmental impacts of electric vehicle batteries weighed up

A recent study has assessed the lifecycle environmental impact during the production and use phase of three battery types for plug-in hybrid (PHEV) and full performance battery electric vehicles (BEV). The study indicates that newer lithium-ion (Li-ion) technologies outperform current nickel-metal hydride (NiMH) batteries and identifies processes contributing to 13 environmental impacts.

There is considerable scientific, political and public interest in the potential of electric vehicles (EV) as replacements for internal combustion engine vehicles. Depending on the electricity mix used, these vehicles could potentially offer considerably reduced greenhouse gas emissions and Europe has established measures to promote efficient vehicles[1] and to focus on electromobility[2]. Currently, most hybrid electric vehicles (HEV) rely on NiMH batteries. However, in the near future, Li-ion batteries are expected to dominate the market, especially with the increase of PHEV and purely electrically driven BEV.

The researchers conducted lifecycle assessments (LCA) of three vehicle battery types -- NiMH, nickel cobalt manganese lithium-ion (NCM) and iron phosphate lithium-ion (LFP) -- to determine which causes the lowest environmental impact. They looked at 13 different types of environmental impacts, from the production and the use phase, for a given amount of energy accumulated by the battery and then delivered to the EV powertrain. These impacts included everything from greenhouse gas (GHG) emissions to freshwater ecotoxicity, freshwater eutrophication, and human toxicity. The results revealed that for a given amount of storied energy, the NiMH battery had the highest environmental impact for all the categories except ozone depletion potential (see Table). This difference is explained by the greater performance of Li-ion batteries in the use phase and the fact that each kilogram of Li-ion battery stores two to three times more energy than a NiMH battery in the course of its lifetime. In addition, the NCM and LFP batteries contained at least one order of magnitude less nickel and virtually no rare earth metals. Of the Li-ion batteries explored, the LFP had greater overall environmental benefits, largely because it has a longer life span and uses materials which are less damaging to the environment when extracted and/or obtained.

50 MJ equivalent charge/discharge	NiMH	NCM	LFP
GWP (kg CO_2 eq)	3.6	1.9	1.5
FDP (kg oil eq)	1.0	0.46	0.37
FETP (kg 1,4-DCB eq)	0.13	$5.1x10^{-2}$	$3.4x10^{-2}$
FEP (kg P eq)	$4.6x10^{-3}$	$2.7x10^{-3}$	$2.0x10^{-3}$
HTP (kg 1,4-DCB eq)	5.6	4.1	2.7
MDP (kg N eq)	1.1	0.85	0.30
ODP (kg CFC-11 eq)	$1.0x10^{-5}$	$1.1x10^{-5}$	$7.5x10^{-6}$

Table 1: Selected life cycle impacts arising from storage and use of 50 MJ of electricity indifferent battery types. global warming potential (GWP), fossil depletion (FDP), freshwater ecotoxicity (FETP), freshwater eutrophication (FEP), human toxicity (HTP), metal depletion (MDP), ozone depletion (ODP), 1,4-DCB refers to 1,4-dichlorobenzene, CFC-11 to trichlorofluoromethane, PM10 to “particulate matter less than 10 µm in diameter”, NMVOC to “nonmethane volatile organic carbon”.

The authors report that differences in battery designs could play an important role in their environmental impacts. For example, the industry has found alternatives to polytetrafluoroethylene, *used as a binder in the electrode material* and for the nickel foam used in NiMH batteries. Both materials were shown to have significant environmental benefits in this study. In addition, battery efficiency is crucial for reducing environmental impacts, with an increase of only 5% leading to 8-23% improvements in life cycle GWP.

1. See: Directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:120:0005:0012:EN:PDF

2. See The European Green Cars Initiative: www.green-cars-initiative.eu/public

Source: Majeau-Bettez, G., Hawkins, T.R. & Strømman, A.H. (2011) Life Cycle Environmental Assessment of Lithium-Ion and Nickel Metal Hydride Batteries for Plug-In Hybrid and Battery Electric Vehicles. *Environmental Science & Technology*. 45(10):4548-4554.
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