Environmental Burdens of Large Lithium-Ion Batteries Developed in a Japanese National Project

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Large lithium-ion battery modules have been developed as part of a Japanese national project, as shown in Figure 1. Four types of 2-4 kWh-class lithium-ion battery modules have been developed, which are categorized by application and cathode material. In the project, as part of life cycle assessment (LCA), we carried out an analysis on environmental burdens (energy input and CO_2 emission) of lithium-ion batteries during production, collection, recycling and waste disposal under the assumption of mass production.

Figure 2 shows input energy and CO_2 emission of electric vehicle (EV)-application lithium-ion batteries at production and recycling/disposal stages, as well as the recycling effect, that is, reduction of energy input and CO_2 emission derived from valuable recovered materials. These results were compared with those for a nickel metal-hydride battery and a lead-acid battery. In the figure, metallurgical recovery of Ni and Co as valuable metal compounds was assumed for the Ni/Co-system lithium-ion battery, but no metallurgical recovery was considered for the Mn-system lithium-ion battery.

In the production stage, there were few differences in energy input and CO_2 emission between Ni/Co-system and Mn-system lithium-ion batteries for EV applications. The energy input and CO_2 emission per 1kWh of battery energy capacity were about 360 Mcal/kWh and 75kg-CO_2/kWh, respectively, and were roughly the same as those of nickel metal-hydride batteries but larger than those of lead-acid batteries. The energy input and CO_2 emission for stationary-use lithium-ion batteries, which have lower energy densities, were about 410 Mcal/kWh and 90kg-CO_2/kWh, respectively.

The environmental burdens of used battery collection and waste landfill disposal were much smaller than those of production or recycling processes. The burden required for the recycling process and the reduced burden based on valuable material recovery were almost the same. Therefore, total burdens, including the recycling effect but the excluding operation of lithium-ion batteries, were about 370 Mcal/kWh and 75kg-CO_2/kWh for EV-application lithium-ion batteries and about 410 Mcal/kWh and 90kg-CO_2/kWh for stationary lithium-ion batteries; they are almost the same as those for battery production.

Table 1 shows the landfill waste and CO_2 emission in recycling with and without metallurgical recovery of Mn and Li as valuable metal compounds after physical recovery and calcining for Mn-system lithium-ion batteries. Mn recovery in the form of manganese dioxide according to our assumed recycling process resulted in increased weight of landfill waste and increased CO_2 emission including the reduction effect. These results suggest that metallurgical recovery from Mn-system lithium-ion batteries is not advantageous from the viewpoints of reduction of landfill waste and suppression of CO_2 emission.

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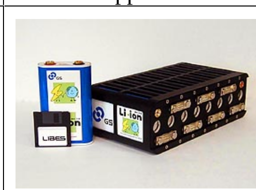
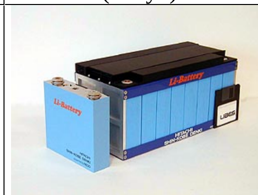
Type	Stationary	EV application
Ni/Co system	 (Sanyo)	 (GS/Mitsubishi)
Mn system	 (Hitachi/Shin-Kobe)	 (Matsushita)

Figure 1 2-4 kWh-class lithium-ion battery modules developed in the Japanese national project

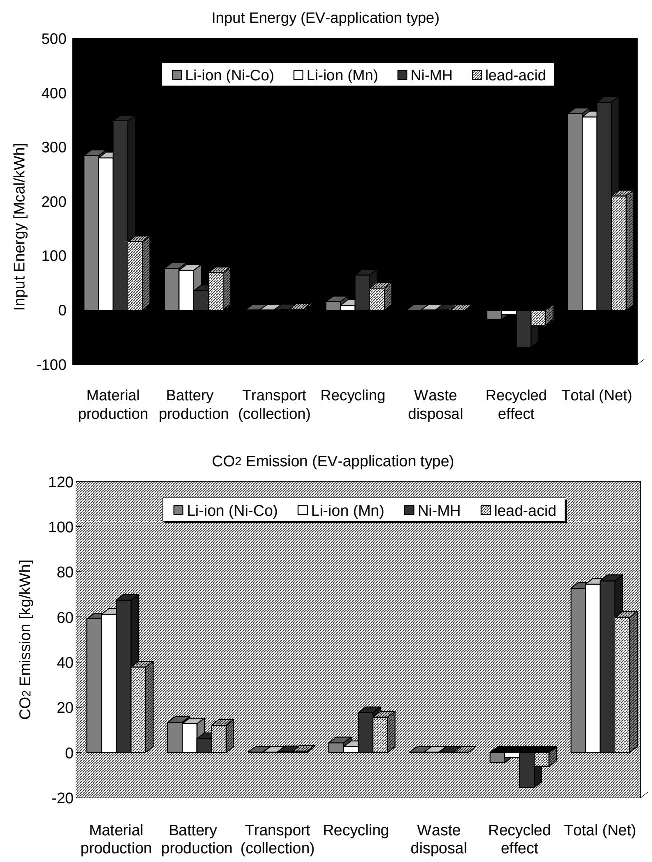


Figure 2 Environmental burdens per 1 kWh of EV-application batteries during production, recycling and disposal (without metallurgical recovery in Mn-system lithium-ion battery)

Table 1 Comparison of landfill waste and CO_2 emission of recycling with and without metallurgical recovery from Mn-system lithium-ion battery

Battery type	Metallurgical recovery*	Battery used kg/kWh	Landfill waste kg/kWh	CO_2 emission in recycling** kg-CO_2/kWh	CO_2 reduction effect*** kg-CO_2/kWh
Stationary	no recovery	7.8	3.5	3.3	-3.6
	Mn-recovery as MnO_2	7.8	9.6	10.7	-7.5
	Li-recovery as Li carbonate	7.8	4.6	12.4	-6.1
EV application	no recovery	6.3	3.2	2.8	-2.1
	Mn-recovery as MnO_2	6.3	8.2	9.7	-5.8
	Li-recovery as Li carbonate	6.3	4.0	11.2	-4.5

* after physical recovery and calcining (roasting)
** including used battery collection and landfill disposal
*** derived from recovered materials