Powerful Advanced N-Level Digital Architecture
for models of electrified vehicles and their components

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Written By	Michael Samsu KOROMA (VUB) Giuseppe CARDELLINI (VUB) Maarten MESSAGIE (VUB)	2020-05-10
Checked by	Joris JAGUEMENT (VUB)	2020-06-08
Approved by	Ronan GERMAN (ULille) Johan LECOUTERE (Bluways) Alain BOUSCAYROL (ULille) - Coordinator	2020-06-07 2020-06-08 2020-06-07
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Publishable Executive Summary

Electric vehicles are projected to take a large share of the future passenger car fleet. This is mainly due to their potential to significantly reduce climate impacts compared to the internal combustion engine vehicle. A central component of the electric vehicle technology is its traction battery for energy storage. Several battery chemistries are currently available in the market. Among the leading battery technologies deployed in EVs is the Lithium Nickel Manganese Cobalt Oxide (NMC) battery. Despite its widespread use in current electric vehicles, there are still opportunities to further improve its performance, especially from an environmental perspective.

As part of the PANDA project, the environmental life cycle assessment (LCA) of an NMC battery is required to effectively compute the potential environmental impact of electric vehicles. Since the goal of the project is to provide a unified organisation of digital models for smooth integration of virtual and real testing of all types of electrified vehicles and their components (subsystems). This study fits into the PANDA objective of integrating environmental impact indicators for models of each vehicle components.

The study aims to estimate the life cycle environmental impacts of an NMC battery subsystem, highlight potential environment hotspots, and estimate its contribution to the overall environment impacts of electric vehicles. For this, a representative battery electric vehicle (BEV) and plug-in hybrid electric vehicle (P-HEV) have been used to assess the battery operation in context of vehicle. The LCA methodology have been used to assess the NMC battery system across its entire life cycle – from raw material extraction to its end-of-life. Thus, the study covered a cradle-to-grave assessment of an NMC battery pack for BEV and P-HEV applications. Two functional units were defined, which also corresponds to their respective reference flows: 1) delivering of 1 kWh of the total energy over the average battery service life, and 2) driving the mass of the battery in an electric car for 1 km. A sensitivity analysis was conducted on selected parameters to check their influence on the results.

The results showed that the energy requirement for cell manufacture is the most impact intensive parameter, followed by impacts along the production chains of the cathode, and the anode. The global warming potential of producing the NMC battery pack was 27.7 kgCO2 eq./kg or 263 kgCO2 eq./kWh (manufacture step). Much of this impact has been driven by the energy requirement for cell manufacture, for which the source of electricity (manufacturing location) dictates the scale of impact. However, the sensitivity analysis showed that this could be reduced significantly, for example by -61 % if hydroelectric-based electricity is used to produce the BEV battery. The global warming potential (GWP)due to operating the battery in a BEV was mainly driven by the carbon intensity of the operational electricity mix – which in this study was 449 gCO_2 eq./kWh for the 2016 EU mix. In the case of P-HEV, the added burden due to gasoline production and combustion to transport the battery further increases the use-phase impact of its NMC battery pack.

The cumulative energy demand (CED) for cell and battery pack production followed similar pattern like GWP, and that CED is directly linked to GWP impacts across all battery components. Most of the energy demand comes from energy need for cell manufacture, followed by energy demand along production chains for cathode and packaging manufacture. In light of reducing GWP, the direct linkage between impacts of CED and GWP across the battery production stage underscores the importance of strategies to reduce production energy demand and the use of low-carbon energy for production. For impact categories related to toxicity, mining activities for metals have been found to dominate. Impacts from mining waste for copper (in battery), cobalt (in battery) and lignite (used in production electricity mix) are higher in almost all toxicity categories. Impacts of fine particulate matter formation (FPMF) and Terrestrial acidification (TAP) shared similar pattern, but different compared to that of GWP and CED. Most of fine particulate matter formation (FPMF) and terrestrial acidification potential (TAP) impacts comes from cathode production and were linked to mining activities for nickel, aluminium, and copper production; these impacts could be reduced by using recycled materials. In addition, sulfur dioxide emissions during the synthesis of reactants for producing the main NMC oxide - cobalt sulphate, manganese sulphate, and nickel sulphate were also dominant.

Recycling contributed to reduce the overall life cycle environmental impacts across all categories – most notably are on mineral resource scarcity and toxicity related categories. These results are expected since the use of recycled materials can reduce demand for mining virgin materials, which directly impacts indicators of mineral resource scarcity and toxicity from mining wastes.

In conclusion, the energy requirement – its source (renewable) and demand - for cell and battery manufacture have been shown to be important parameter to further improve production impacts related to GWP and CED. In addition, mining activities for metals, especially strategies to improve mining waste management could further improve toxicity, acidification, and eutrophication related categories. Likewise, the lifetime of the battery has been found to be the most sensitive parameter, seconded by the source of electricity mix for production and, then for use phase.

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#	Type	Partner	Partner Full Name
1	UNIV	ULille	Université de Lille
2	IND	SISW	Siemens Industry Software SRL
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