# Assessing Opportunities for Onshoring New Truck Engine Technologies

## A Center for Efficiency, Resiliency, and Community Engagement in Transportation Summary Research Report

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**16. Abstract**

Onshoring vehicle manufacturing in the US has potential for economic development and increased security of manufacturing supply chains. Onshoring may also have social benefits if production processes are moved from countries with low wages and few protections for worker safety to the US., where wages are higher and labor protection is extensive. This project examines the potential social benefits of moving one part of the vehicle supply chain, batteries for heavy duty trucks, from China to the US. We use a life cycle approach and consider the resource extraction and manufacturing phases of battery production. We assume that only the manufacturing phase changes. We use specialized software to compare estimates of social risks in five categories (labor rights, health and safety, society, governance, and community), Our results suggest that relocating battery manufacturing from China to the US would substantially reduce associated social risks particularly with respect to labor rights, health and safety, and governance. Given the potentially significant environmental and social benefits to shifting heavy-duty truck manufacturing from China to the US, a next step would be to evaluate the economic feasibility of onshoring and identify policies that could incentivize such a shift.


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# Assessing Opportunities for Onshoring New Truck Engine Technologies

## Summary

Onshoring vehicle manufacturing in the US has the potential for economic development and increased security of manufacturing supply chains. Onshoring may also have social benefits if production processes are moved from countries with low wages and few protections for worker safety to the US, where wages are higher and labor protection is extensive. Today's truck propulsion systems are produced through complex global supply chains that draw on resources from around the world. As with any product, there is a life cycle: resource extraction, manufacturing, distribution, operation, and finally disposal. To compare different supply chain configurations, costs and benefits should be considered across the entire life cycle.

Our research examines the potential of shifting one part of heavy-duty truck (HDT) production from China to the US, holding earlier stages of the supply chain constant. We use specialized models to conduct a social life cycle assessment (S-LCA) of electric HDT batteries. S-LCA assesses risks related to labor conditions, health and safety, community health, and governance conditions associated with each part of the product production process. We use the cradle-to-gate portion of the life cycle.

### Introduction to S-LCA

Social life cycle assessment (S-LCA) is a methodology for evaluating the social and socio-economic impacts of a product or service throughout its life cycle. S-LCA identifies site-specific supply chain impacts (where the activities occur), both positive and negative, for each phase (material acquisition, transformation, distribution, etc.). Impact categories include health, safety, and working conditions for various stakeholder groups.

S-LCA was developed as part of the United Nations Environmental Program (UNEP) and follows a prescribed process: (1) definition of goal and scope, (2) social life cycle inventory, (3) assessment of social life cycle impacts, and (4) interpreting the results (dos Reis et al., 2024; Thies et al., 2019; UNEP/SETAC, 2009). This process is presented in more detail in Table 1.

**Table 1. S-LCA study phases per United Nations Guidelines (UNEP, 2020).**

| Study phase | Critical activities in phase/Questions to answer |
|---|---|
| **Goal and Scope Definition** | - What is the objective of the study?<br>- What is the function of the product? (define functional unit based on product utility, time, and space)<br>- What is the breadth, depth, and detail to be done? (define scope/system boundary)<br>- Develop boundary diagram |
| **Social Life Cycle Inventory** | - Develop bills of material (product trees)<br>- Map upstream components/materials by supplier location (SourceMap)<br>- Determine process(es) at supplier/site<br>- Are co-products made anywhere in the process?<br>- Identify stakeholders for each phase/process/location<br>- Determine impact categories and subcategories<br>- Collect data via literature review/interviews/publications |
| **Social Life Cycle Impact** | - What methods are to be used for impact assessment?<br>- How should positive and negative impacts be allocated?<br>- What is the allocation procedure?<br>- Calculate impacts and allocations, both quantitative and qualitative |
| **Interpretation** | - Identify "hot spots" for improvement<br>- Provide recommendations that map to UN Sustainable Development Goals (Goals 1, 2, 3, 4, 5, 8, 10, 12, 16, and 17[1])<br>- Communication |

The life cycle inventory study phase is the most time-consuming part of the project. Each component is broken into subcomponents until all raw materials are known. The bill of materials is used to generate a product tree that shows the relationships and quantities required for each component piece. Since S-LCA is site-specific, one must pinpoint where every activity occurs in the life cycle/supply chain. This entails tracing all suppliers involved at every step in the supply chain. If a material or component is sourced from multiple suppliers, the supply chain for each should be included.

Impact categories are defined for each stakeholder in the supply chain. There are six stakeholder categories: Local Community, Value Chain Actors, Consumer, Society, and Children. Each stakeholder category includes categories of impacts. For example, "Worker" includes fair salary, forced labor, health and safety, employment relationship, etc. "Society" covers contributions to economic development, corruption, and the ethical treatment of animals, among other topics (UNEP, 2020).

The life cycle impact phase identifies benefits and harms for each site-specific activity for all stakeholders with recommendations for improvement. This phase is vital to developing a method to assign quantitative or qualitative measurements to a process/stakeholder/impact category. Finally, the interpretation phase

[1] Development goals are defined as follows: 1 No Poverty; 2 Zero Hunger; 3 Good Health and Well-being; 4 Quality Education; 5 Gender Parity; 8 Decent Work and Economic Growth; 10 Reduced Inequalities; 12 Responsible Consumption and Production; 16 Peace, Justice, and Strong Institutions; 17 Partnerships for the Goals. Source: https://sdgs.un.org/goals, accessed on June 25, 2026.

identifies “hot spots” where significant harm exists. Where feasible, policy recommendations can be derived from this outcome.

S-LCA has been applied in various industry sectors, including manufacturing, mining, energy, agricultural products, and packaging (Ferrão et al., 2014; Heidari et al., 2019; Koese et al., 2023; Kruse et al., 2009; Schau et al., 2012; Sharma & Manthiram, 2020; Springer et al., 2020). These studies generally focus on different stakeholders and various impact subcategories, depending on the research goals. For example, a study focusing on fertilizers considered Workers, Local Community, Society, and Consumers as stakeholders (Martínez-Blanco et al., 2014).

## Alternative Supply Chain for Vehicle Batteries

The focus of this research is on the potential for onshoring HDT battery production to the US. China is the largest battery manufacturer, accounting for over 80% of global production in 2025 (IEA, 2026). The US’s battery manufacturing relies heavily on imports, especially from China and other Asian countries. Considering alternative supply chains helps ensure global supply security and resilience (Shi et al., 2023; Thies et al., 2019; Xu et al., 2022).

Some S-LCA studies have considered relocating battery manufacturing. Thies et al. (2019) examine supply chain scenarios in China and Germany and conclude that shifting cell and pack manufacturing for lithium manganese nickel (NMC) batteries from China to Germany can significantly reduce the risk of negative social impacts. A thesis from the Politecnico di Torino examines the S-LCA of lithium-ion batteries across the European and non-European supply chains and highlights that varying social risks exist under different supply chain scenarios (Heydari, 2025).

Battery production is currently concentrated in China and some Asian countries. Some countries and regions, such as North America, are planning to increase their local battery production capacity. Therefore, it is important to evaluate the potential impacts of relocating battery production from China to other regions, such as the US.

## Methodology

We conduct a S-LCA of the lithium nickel manganese cobalt (NMC811) battery for Class 8 day-cab electric HDTs. China dominates the global battery production supply chain, accounting for more than 80% of the global battery production in 2025 (IEA, 2026). Based on the current vehicle battery supply chain, we evaluate the potential changes in social impacts of shifting the manufacturing stage from China to the US. We use a specialized model developed by Argonne National Laboratory to calculate production chain inputs and outputs. To conduct the S-LCA, we use OpenLCA, a life cycle modeling tool, and the Social Hotspots Database (SHDB), a software package for estimating risks of social impacts.

We consider two supply chains: (1) the China scenario, in which the batteries are 100% produced in China; and (2) the US scenario, in which the batteries are produced in the US. In both scenarios, it is assumed that all raw materials are sourced from the same countries and that the technologies in both countries remain the same. The system boundary in this study is defined as cradle-to-gate, covering raw material extraction and processing, component production, and battery pack production. The life cycle terminates upon completion of battery pack manufacturing, excluding transport of the battery to the HDT vehicle manufacturing.

The SHDB is designed to identify potential social risks associated with products or services across supply chains. To do so, the SHDB identifies a series of measures of social risk (e.g., use of child labor, exposure

to toxics at the work site) and links them to the labor hours of specific processes of the supply chain. The link is made via a multi-region input/output (MRIO) model. The MRIO is derived from the Global Trade Analysis Project (GTAP) database, containing country-sector combinations across 140 regions (mostly countries) and 57 economic sectors. The GTAP is a global network of economists, researchers, and policymakers coordinated by the Center for Global Trade Analysis at Purdue University that conducts international policy analysis. The general process for calculating social risks is: 1) enumerate all the steps and inputs in the production process, 2) identify the country of origin of every input and process, 3) assign a dollar value to each input and process, 4) use the MRIO data to assign labor work hours of each input or process based on the dollar values and country-level labor proportions, and 5) use the work hours to calculate values for each social risk indicator.

The SHDB has a total of 160 social risk indicators that are allocated to five categories and 30 subcategories. Table 2 gives the mapping between the five categories and 30 subcategories. Each of the subcategory measures is a weighted sum of the individual indicators assigned to the subcategory. This weighting is fixed by the software. A sixth category, social economic contributions, is intended to measure the economic value of the product. Indicators are not provided for economic value. Figure 2 shows that Labor Rights and Decent Work, Society, and Community have a large number of indicators. Health and Safety and Governance have only a few indicators. Indicators were developed by the SHDB designers and are based on quality and availability of data, timeliness of data, and validity (quality of measure to represent the underlying concept) (Bennema et al., 2022).

**Table 2. SHDB categories and subcategories (Bennema et al., 2022).**

| Main Category | Subcategories |
|---|---|
| Labor Rights & Decent Work (11) | Wage assessment; Workers in poverty; Child labor; Forced labor; Excessive overtime; Freedom of association/collective bargaining/right to strike; Migrant workers; Social benefits; Labor laws/conventions; Discrimination/equal opportunities; Unemployment |
| Health & Safety (2) | Occupational toxics & hazards; Injuries & deaths |
| Society (7) | Indigenous rights; Gender parity; High conflict; Human health (non-communicable diseases and health issues); Human health (communicable diseases); Poverty; State of environmental sustainability |
| Governance (3) | Legal system; Corruption; Democracy & Freedom of Speech |
| Community (7) | Access to drinking water; Access to improved sanitation; Children out of school; Access to health care; Smallholders; Access to electricity; Property rights |
| Social Economic Contributions (6$^{th}$ category) | Contributions to value added; Other socioeconomic impacts |

The SHDB evaluates potential social risks by connecting the monetary cost of each activity in the supply chain to a specific country and economic sector. Using worker hours for the corresponding economic activity and social risk levels in each country-sector, the SHDB calculates medium-risk-hour equivalents (mrheq) to express social risk. The mrheq is calculated based on worker hours and the country-sector social risk levels, as follows:

$$mrheq_i = \sum_c \sum_s Worker_Hour_{c,s} * Mrh_factor_{c,s} \quad (1)$$

where $mrheq_i$ is the medium risk hour equivalent for the impact category $i$; $c$ is the country in which the production activity occurs; $s$ is the economic sector in which the activity happens; $Worker_Hour_{c,s}$ is the estimated worker hours for the country $c$ and sector $s$, which is calculated by the economic output and labor intensity, as shown in Equation (2); and $Mrh_factor_{c,s}$ is the medium risk hour (Mrh) factor in the country $c$ and sector $s$ designed by SHDB.

$$Worker_Hour_{c,s} = Economic_Output_{c,s} * Labor_Intensity_{c,s} \quad (2)$$

where $Economic_Output_{c,s}$ is the economic output of a product or service in the country $c$ and sector $s$, usually in USD; and $Labor_Intensity_{c,s}$ is the estimated number of worker hours required to produce 1 US dollar (USD) of economic output in the country $c$ and sector $s$, in worker hours/USD.

Table 3 presents the Mrh factors used in the SHDB. The SHDB collects data from multiple international sources to determine the risk level for each impact category, including the International Labor Organization (ILO), the World Bank, the World Health Organization (WHO), and the United Nations Children's Fund (UNICEF) (Bennema et al., 2022).

**Table 3. Risk level and Mrh factors in SHDB (Bennema et al., 2022).**

| Risk level | Mrh factors |
|---|---|
| Low risk | 0.1 |
| Medium risk | 1 |
| High risk | 5 |
| Very high risk | 10 |

For example, suppose that battery production in the sector $s$ of the country $c$ requires 0.5 worker hours to produce 1 USD of output. If the social risk of Child Labor in that country-sector is assessed at a high risk level (i.e., the Mrh factor is 5), the corresponding potential social risk of Child Labor is 2.5 mrheq. The result of 2.5 mrheq for Child Labor does not mean that 2.5 hours of Child Labor occurs in that country-sector. The mrheq measures the potential social risk exposure, rather than the occurrence of actual social impacts. A higher mrheq value indicates a greater potential social risk within that impact category in the supply chain, but does not confirm that there is social harm happening. Moreover, because the SHDB uses assigned Mrh factors to calculate potential social risk, the mrheq values may not be zero even if, for example, child labor is legally prohibited in a country.

There are some limitations to the SHDB and the S-LCA process. First, the MRIO provides only country-level economic flows. For large countries, country-level measures may not be good measures for some social risk indicators (e.g., access to clean water, exposure to toxics, or labor practices). Second, the same data for a given indicator are not available for all countries. Different data sources are used in the same composite indicator in some cases. There are also problems with missing data and with data collected at different temporal cycles. Third, mrh factors imply nonlinear intervals between risk levels (e.g., low to medium risk is a change by a factor of 10, high to very high risk is a change by a factor of 2); these factors were assigned based on expert judgment rather than empirical risk analysis, and therefore are difficult to interpret. Finally, the social risk indicators are measures of potential exposure, not impacts. There is no causal link between the given production process and risks, for example, the prevalence of child labor or communicable diseases. Furthermore, the social risk indicators and resulting mrheq numbers cannot be interpreted as probabilities of an event occurring. The Mrh factors are from expert judgment, and hence a

higher Mrh and a higher mrheq imply a greater risk of a social impact, but it is not possible to link mrheq levels to particular probabilities of a risk. These limitations suggest that although mrheq are given as numerical values, their interpretation should be one of relative magnitude. The mrheq values should be interpreted as ordinal, not cardinal, values.

We use the SHDB to evaluate the social impacts of NMC battery production. The SHDB requires three inputs for each material or component used in the product: monetary value, country or region, and economic sector. The sector information for each material or component is defined using the sector classification provided by the Global Trade Analysis Project (GTAP)[2]. The SHDB allows for multiple countries of origin. Therefore, we select the three countries with the highest production of each raw material as the source countries, based on the information from the 2024 World Population Review[3]. However, when production is highly concentrated in a single dominant country, only that country is selected. Then, we calculate the corresponding weights based on the proportion from each country.

Monetary inputs are assigned to region-specific industry sectors. We built a monetary inventory based on the mass and cost for each raw material, component, and battery pack. The raw material masses are obtained from the specialized model from Argonne National Laboratory. We use raw material prices, such as for aluminum, copper, and nickel, from the global market[4].

The SHDB converts the monetary inventory with the corresponding country and industry sector into estimated worker hours. These worker hours are used to estimate social impacts by combining them with country-sector social risk levels, expressed in medium-risk-hour equivalents (mrheq). All the monetary values were converted to 2017 US dollars, the year of the data in SHDB.

## Results

We used SHDB to assess social impacts across the HDT battery supply chains in both China and the US. The potential social risk results are shown in medium-risk-hour equivalents (mrheq). A higher mrheq value indicates a greater potential social risk within that impact category, rather than the occurrence of actual social impacts. We consider all five SHDB main categories and their corresponding 30 subcategory measures. The SHDB allows us to calculate the overall social risks for each main category, compare social risks at a high level, and obtain social risk scores for subcategories

[2] Global Trade Analysis Project (GTAP) sector list. https://www.gtap.agecon.purdue.edu/databases/contribute/detailedsector.asp, accessed on July 12, 2026.

[3] Manufacturing/Mining Production by Country. World Population Review. https://worldpopulationreview.com/categories/manufacturing-mining?place=country%2Cstate&subcat=, accessed on July 12, 2026.

[4] Sources for these prices, obtained in Spring of 2026, are, for Nickel Sulfate (NiSO4): https://www.metal.com/nickel/201908270001; for Cobalt Sulfate (CoSO4): https://www.metal.com/cobalt/201102250381; for Manganese Sulfate (MnSO4): https://www.metal.com/manganese/201805300001; for Sodium Hydroxide (NaOH): https://businessanalytiq.com/procurementanalytics/index/sodium-hydroxide-price-index/; for Ammonium Hydroxide (NH4OH): https://www.intratec.us/solutions/primary-commodity-prices/commodity/ammonium-hydroxide-prices; for Lithium Hydroxide (LiOH): https://www.metal.com/lithium/202106020003.

Figure 1 presents the overall social risks across the SHDB's main categories. Results show that "Health and safety" is the largest contributor to overall social risks in both scenarios. Health and safety risks include exposure to toxins and hazards, as well as work-related injuries and deaths. Community contributes the least to overall social risks compared with the other main categories in both scenarios. In addition, the results show that moving battery manufacturing from China to the US would significantly reduce social risks, when measured by mrheq, across all five main categories by around 30% to 45%.

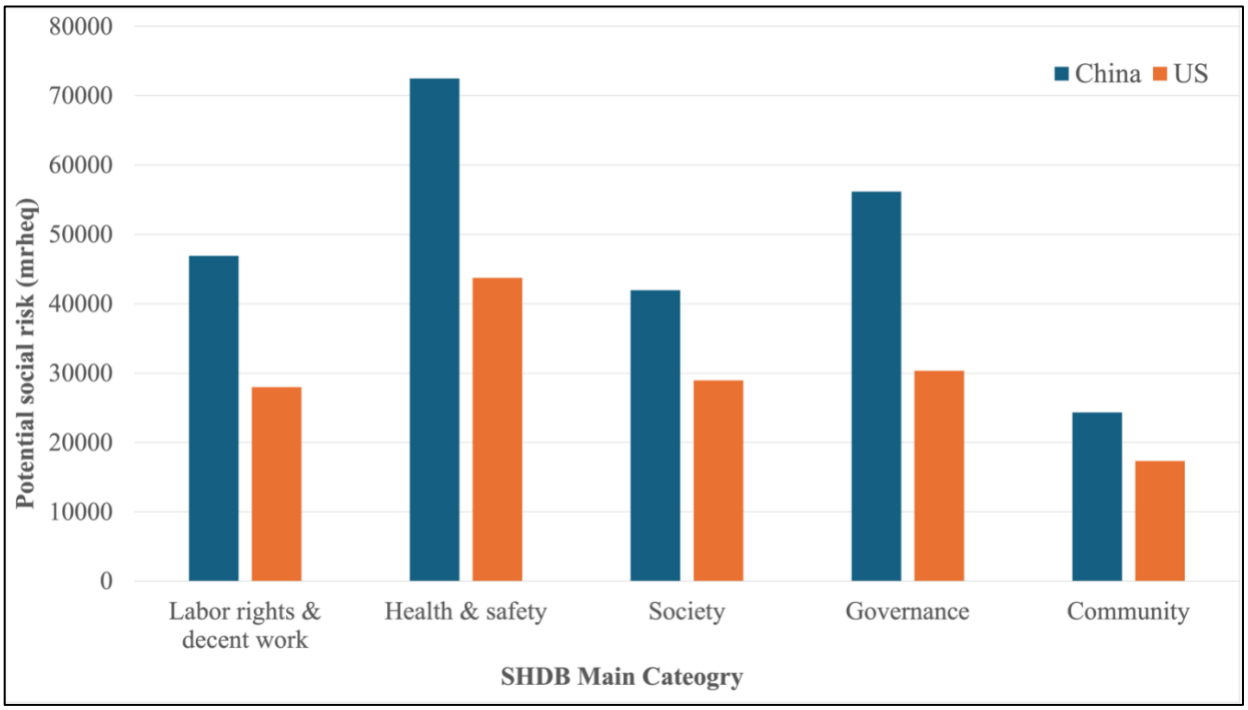



**Figure 1. Social impact under the SHDB main categories for NMC811 battery supply chains in China and the US**

Figure 2 presents the total social risks for each of the 30 subcategory measures, organized by the main categories. All social risk categories are lower in the US. In China, the mrheq of eight social risks exceeds 60,000, while only the mrheq of Child Labor in the United States is above 50,000. The top five social risk categories in China are Occupational Toxicity and Hazards, Democracy and Freedom of Speech, Freedom of Association, Child Labor, and Poverty. In the US, Child Labor, Occupational Toxicity and Hazards, Poverty, Democracy & Freedom of Speech, and High Conflict Zones are the five highest social risks. High-impact categories in Figure 2, in either the US or China manufacturing scenarios, do not necessarily mean that the impacts are occurring in either country. Instead, the differences between the two scenarios can be interpreted as differences in risk factors associated with moving manufacturing from China to the US.

We also calculated the percent differences between the two scenarios for each social risk measure. The greatest difference is a reduction of about 75% in the social risks associated with Forced Labor. In addition, the relocation of battery manufacturing from China to the US results in a 70% reduction in the social risk of Children out of School. The high social risk in Children out of School indicates the potential for insufficient educational access and inadequate educational infrastructure for children in the communities manufacturing the batteries in China. The highest social risk impact categories in both scenarios also show a significant reduction when battery manufacturing locations are moved. Social risks of Occupational Toxicity and Hazards, Child Labor, and Poverty would decrease by 52%, 43%, and 34%, respectively. These results indicate significant potential social benefits from moving HDT battery manufacturing from China to the US.

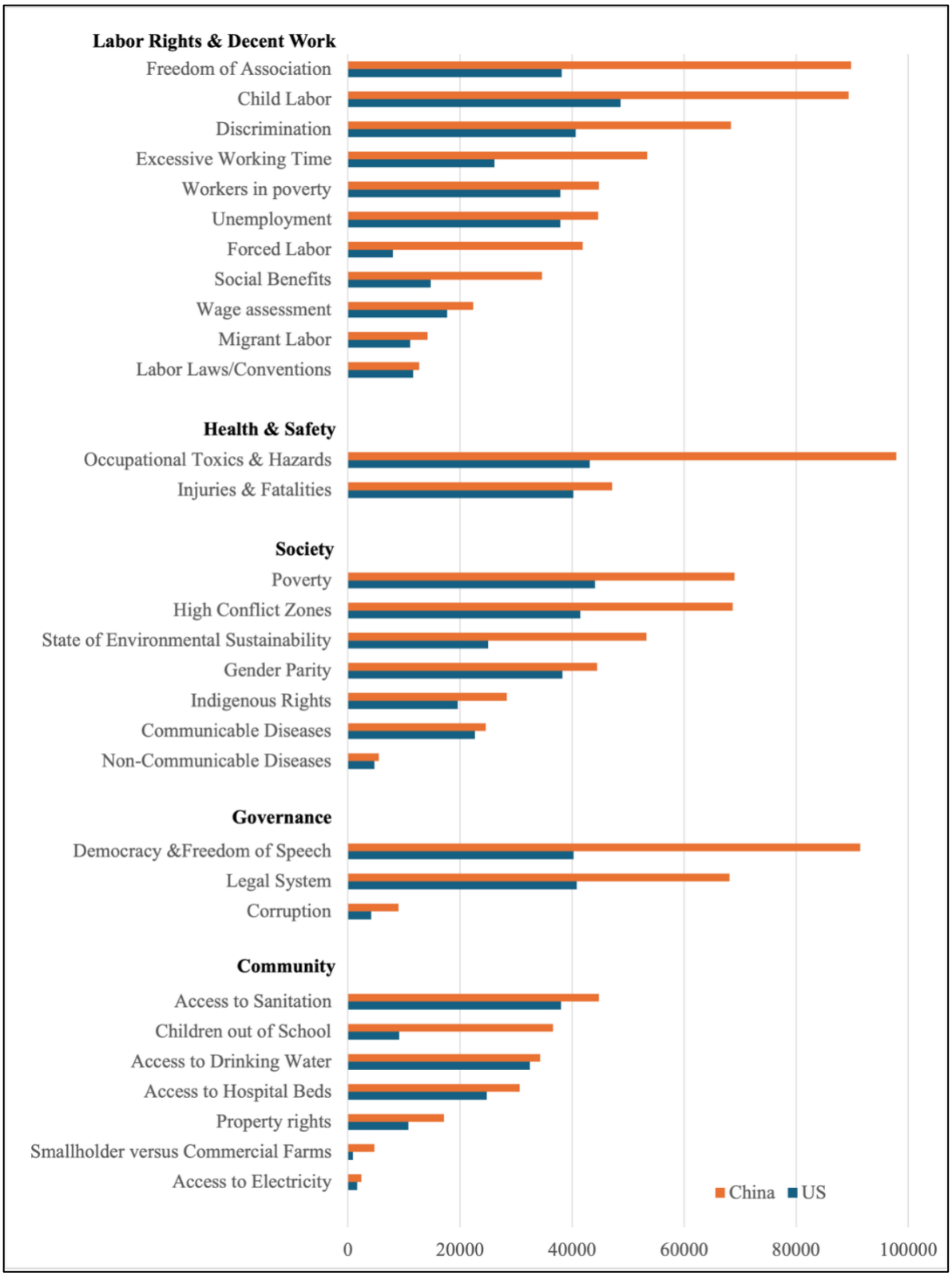



**Figure 2. Total social impact of the NMC811 battery supply chain in China and the US scenarios, 30 subcategory measures**

We also examined differences in social risk at each stage of the supply chain. A few examples are given in Figure 3. We selected three social risk impact categories that rank among the top in both China and the US supply chains (Occupational Toxicity and Hazards, Child Labor, and Poverty), as well as the two impact categories that have the greatest differences between China and the US (Forced Labor and Children out of School), to conduct a further analysis of the social risks across each supply chain stage.

Because we have assumed that raw materials production does not change, its contribution to each social risk indicator remains the same for China and US production. For each social risk indicator, it can be seen that every part of the manufacturing process generates higher social risks in China. The results show that, among the four battery supply chain stages, the component stage holds the highest potential social risks, especially in the China supply chain. The potential social risks at the module production stage are the lowest in all five main categories. This reflects the relative shares of work hours in each subprocess.

Differences between China and US production are striking. For example, the total social risks of Child Labor during the manufacturing stages would decrease from 42,384 mrheq to 3,978 mrheq when HDT battery manufacturing is moved from China to the US, a difference of about 90%. Forced Labor in the component production stage contributes more than 23,000 mrheq of social risks in the China scenario, but less than 2,000 mrheq in the US scenario. Moving component manufacturing from China to the US would reduce the potential risk of forced labor by more than 90%.

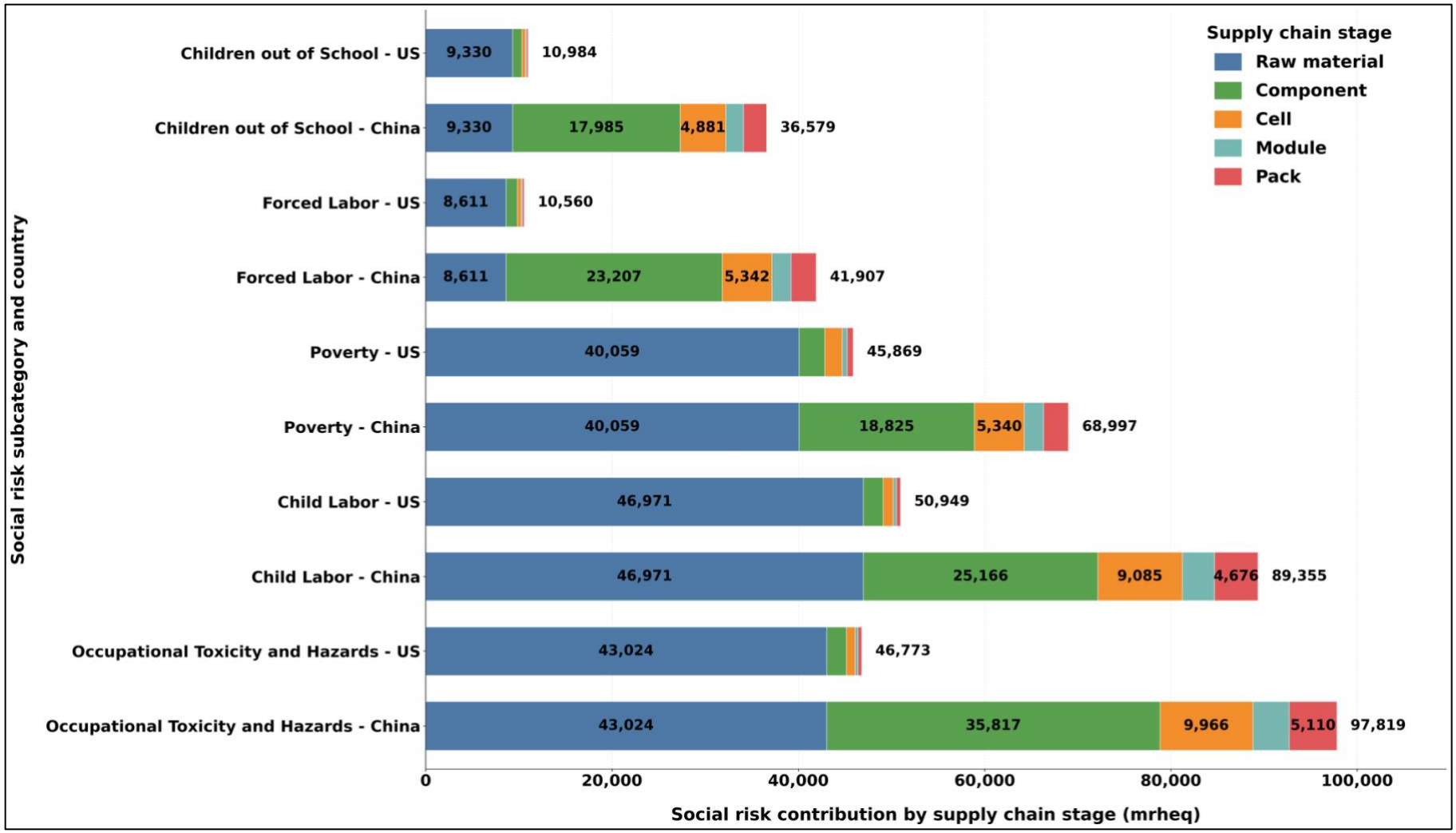



**Figure 3. Potential social risks at each stage of the supply chain for HDT battery production in China and the US.**

## Conclusions

We have used S-LCA to identify the potential social impacts of electric HDT battery supply chains, comparing the impacts of manufacturing (battery assembly) in China and the US. Our analysis suggests that relocating heavy-duty truck battery manufacturing from China to the US would significantly reduce most social risks associated with the manufacturing stage of production. The social risks associated with the main categories, Labor Rights & Decent Work and Governance, would decrease by more than 40%. Decreases are observed for the other categories as well (Society, Health & Safety, and Community). The analysis on subcategories also shows a significant decrease in many measures. For example, the social risks associated with Forced Labor and Children out of School in the battery production supply chain would decrease by about 75% and 70%, respectively. We have also examined the contribution to social risks at each stage of the supply chain. The raw material extraction and refining stage contributes most to the total social risks.

Our research has some limitations. First, in practice, material consumption and production technologies likely differ between China and the US. More detailed data would improve the precision of our results. Second, our assumption that the rest of the supply chain would be unchanged when shifting manufacturing to the US is strong. Components would have to be imported, and it is possible that these would be drawn from suppliers other than China. Finally, we have not considered the economic feasibility of such a shift. For example, the much higher costs of US labor may limit the financial feasibility of onshoring battery manufacturing.

Our research has the following policy implications. Onshoring battery manufacturing in the US has the potential to reduce the social risks of electric HDT supply chains, given higher US wage rates and more stringent environmental regulations. However, it is not clear that large-scale battery manufacturing in the US is economically feasible. An exploration of economic feasibility and identification of supportive public policies may be warranted.

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# Data Summary

## Products of Research

We conduct social life cycle assessment (S-LCA) of NMC811 battery production for Class 8 day-cabs. We use a specialized model developed by Argonne National Laboratory (ANL) to calculate production chain inputs and outputs. Then, the social impacts are calculated by using the Social Hotspots Database (SHDB) in OpenLCA. The raw material masses are obtained from the ANL model with the prices for those raw materials sourced from global markets. The mass and cost for battery components, cells, modules, and packs are collected from the BatPac 6.0 model. The sources of raw material prices are as follows, accessed in Spring 2026:

Nickel Sulfate (NiSO4): https://www.metal.com/nickel/201908270001

Cobalt Sulfate (CoSO4): https://www.metal.com/cobalt/201102250381

Manganese Sulfate (MnSO4): https://www.metal.com/manganese/201805300001

Sodium Hydroxide (NaOH): https://businessanalytiq.com/procurementanalytics/index/sodium-hydroxide-price-index/

Ammonium Hydroxide (NH4OH): https://www.intratec.us/solutions/primary-commodity-prices/commodity/ammonium-hydroxide-prices

Lithium Hydroxide (LiOH): https://www.metal.com/lithium/202106020003

## Data Format and Content

The original data in the ANL and the BatPac 6.0 model are provided in spreadsheet (.xlsm) format. The integrated data are provided in .csv format, including material masses and unit prices in 2017 USD. The supply chains and life cycle inventory are used in the ANL model to calculate the environmental impact of NMC811 battery production and are used in the SHDB to assess the social impacts.

## Data Access and Sharing

Individuals will be able to access the data through the project repository and should contact the principal investigator (Dr. Genevieve Giuliano) prior to accessing the data. The ANL model is publicly available, and the BatPac 6.0 model is available from ANL upon request. The SHDB is a licensed commercial database developed and distributed by NewEarth B. The original BatPac model files and SHDB files are proprietary and cannot be redistributed by the authors. The data should not be hosted in other locations and should be used only within the project repository. Users of the data should appropriately acknowledge this report and the original data sources.

## Reuse and Redistribution

Dr. Genevieve Giuliano and the co-authors hold the intellectual property rights to the processed datasets developed in this research. The data may not be transferred to other data repositories without approval from the Principal Investigator.