BALIHT

# LIFE CYCLE ASSESSMENT

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WP6 REGULATORY, TOXICOLOGY, ENVIRONMENTAL AND SOCIAL LIFE CYCLE ANALYSIS.

DELIVERABLE D6.2

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# DELIVERABLE REPORT

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# LIST OF ABBREVIATIONS

| Abbreviation | Definition |
|---|---|
| S-LCA | Social Life Cycle Assessment |
| LCA | (Environmental) Life Cycle Assessment |
| ORFB | Organic Redox-Flow Battery |
| PSILCA | Product Social Impact Life Cycle Assessment database |
| BMS | Battery Management System |
| CSR | Corporate Social Responsibility |

# 1. Introduction

This deliverable report, along with deliverable report 6.1, fulfils one of the objectives of WP6 Task 6.1, namely to *study the environmental suitability & impact of the target battery components by a Life Cycle Sustainability Assessment (LCA) and Social Life Cycle Assessment (S-LCA).* As set out in the project proposal, this S-LCA considered the entire life cycle of the proposed BALIHT Organic Redox-flow Battery (ORFB) to identify the potential social risk hotspots associated with the supply chain of the battery (i.e., including raw material extraction through material processing, manufacture, distribution, and operation of the battery).

S-LCA results are very different in nature to (environmental) LCA results presented in Deliverable 6.1 in that they are not indicative of actual impacts that can be directly attributed to the battery's supply chain. Rather, the S-LCA method we applied[1,2] allows us to explore how the battery's supply chain may draw on economic products and services from different sectors in countries spanning the globe. These countries and sectors can be linked to socioeconomic indicators representing *average* conditions in which the productive activities take place. Some indicators may be partially related to the economic activities, such as fair salary, workplace safety and gender equality. Other indicators are more related to broader country-specific conditions in which the activities take place, such as illiteracy and access to health services. Thus, S-LCA applied in the context of a proposed technology such as BALIHT is not an assessment of the battery's impacts but a prioritization approach to identify opportunities to mitigate risk and enhance socioeconomic development across the battery's value chain. These priorities are identified as sectors/countries where the battery's value chain actors can make a more meaningful positive contribution if they were to implement targeted social policies and strategies within their activities and organisations. **The S-LCA risk indicator scores presented below only highlight potential hotspots in countries and economic sectors, and thus the social conditions analysed are not be linked causally or directly attributed to the specific supply chain of the proposed BALIHT battery**[i].

This report builds on the publication by Koese et al. in the Journal of Industrial Ecology *"A social life cycle assessment of vanadium redox flow and lithium-ion batteries for energy storage"*[3] which was a key output of WP6. Additional details on methods and assumptions, as well as detailed results for the benchmark Vanadium RFB and Lithium Ion batteries can be found in the publication and its Supplementary Information. In this report we present only key summary results for the BALIHT Organic Redox Flow battery which were not reported in the publication.

[i] Other S-LCA approaches that can be more directly linked to organisational social performance have been proposed in UNEP S-LCA guidelines[4] as well. Such example is the "Reference Scale" approach where suppliers are evaluated one at a time on their organisational social performance, starting from direct suppliers and then extending as far upstream in the supply chain as possible. However, there is no practical way to implement this approach across the entire life cycle of a product or service, and usually only the first 2 or 3 tiers of upstream suppliers are evaluated. This does not provide for an actual life cycle-based analysis, since the key impacts and risks are often found much further upstream, e.g. in the extraction of raw materials or in the generation of electricity. To keep with the life-cycle perspective of work package 6, we opted to implement the PSILCA approach[1,2] instead, allowing us to cover the entire supply chain while restricting the interpretability of the outcomes as explained above.

# 2. Methods

## 2.1. Overview

The S-LCA approach builds on environmental life cycle assessment (E-LCA) and the ISO 14040 framework. In this report, the PSILCA database and method[1,2] was used to conduct the S-LCA. PSILCA, which was developed by GreenDelta[ii] in accordance with the UNEP/SETAC S-LCA[4] guidelines allows the calculation of 65 qualitative and (semi-)quantitative indicators on social and environmental risks and impacts. It is built on the EORA multi-regional economic input/output database[5], and covers around 15,000 country-specific industry sectors and commodities in 189 countries. The PSILCA database incorporates social indicators for different stakeholder groups, that is, workers, local community, society, consumers, and value chain actors, measured at a certain point in time. In the S-LCA life cycle model, the battery is represented by its components: posolyte, negolyte, electrodes, membranes, balance of plant, etc. To manufacture each component, products and services are procured from different economic sectors in different countries. The amounts required by each component from each sector are expressed in terms of costs (in US$). Social risks - generally indicative of a degree to which acceptable conditions are met in each country/sector- are scaled according to the worker-hours and costs incurred by each component in the battery's supply chain. As a result, elements that have higher cost and/or are more labour intensive will be prioritized by the assessment as having greater risk exposure. The resulting indicator values in the PSILCA approach ("medium-risk hours") have no real physical meaning and are rather a semiquantitative way of prioritising aspects of the value chain.

## 2.2. Goal and scope definition

**Goal.** The specific aim of the S-LCA is to assess the potential social risks to which the supply chain of the BALIHT ORFB battery may be exposed.

**Scope.** The scope of the assessment is cradle-to-use, i.e., from raw materials to manufacturing and operation of the battery. The geographical scope of the assessment is for a battery assembled in Germany, installed and operated in the south of Spain. Supply chains span the globe and are modelled as national/regional markets in the PSILCA database. The temporal scope reflects data from World Bank, International Labour Organisation, World Health Organization, United Nations and other organisations from the period between 2013-2019. The technology scope includes all components, activities and materials required by the battery's life cycle.

**Functional unit.** Indicator scores in S-LCA are calculated as in LCA, on the basis of the service provided by a product system, i.e., the *function* of the system. This function is quantified in a *functional unit* which for batteries, following the latest definition put forth in the draft EU Batteries Regulation[6], is *one kWh of the total energy provided over the service life by the battery system*. The total energy provided over the BALIHT battery's lifetime was calculated as:

$$E_{total} = C_{max} * C_{loss-factor} * DoD * yearly\ cycles * lifetime * \sqrt{\eta_{RTE}}$$

Where:

[ii] www.greendelta.com

| | | |
|---|---|---|
| $E_{total}$ | Total electricity delivered back to grid over battery's lifetime | 870 MWh |
| $C_{max}$ | Storage capacity of battery | 200 kWh |
| $C_{loss-factor}$ | Factor that incorporates electricity losses of battery over lifetime | 90% |
| $DoD$ | Depth of discharge | 100 % |
| $yearly\ cycles$ | How many cycles each year: currently 300 values, bit less than 1 cycle every day | 300 cycles/year |
| $lifetime$ | Years of operation | 20 years |
| $\eta_{RTE}$ | Round trip efficiency (the square root is taken to account only for losses during discharging and not during charging) | 65 % |

## 2.3. Inventory analysis

In building the battery's life cycle inventory, the amount of economic inputs (in US$) required from each economic sector by each of the battery's components is collected according to the cost analysis that was conducted for Deliverable 6.3. Table 1 lists the components of the battery and the closest matching sectors that were taken from the PSILCA database to represent the products and services consumed by that component. In the inventory analysis, all consumptions are scaled linearly to satisfy the functional unit, i.e. the delivery of 1 kWh over the battery's lifetime.

*Table 1 - Economic sectors and countries included in the life cycle inventory of the BALIHT battery (DE: Germany; ES: Spain; HR: Croatia; CN: China; CL: Chile*

| Battery component | Economic inputs from sectors | Notes |
|---|---|---|
| Balance of plant | Electricity generating equipment - DE<br>Manufacture of fabricated metal products - DE<br>Manufacture of rubber products - ES<br>Other machinery - ES<br>Post and telecommunications - HR | Includes: inverter + electronics, container, mechanical equipment, electrical protection, other equipment, firefighting system, cooling system, BMS<br><br>In lieu of data, "Post and telecommunications" is a proxy from a closely sector to represent electrical and electronic equipment in Croatia. |
| Tanks | Manufacture of plastic products - ES | |
| Negolyte | Manufacture of chemical products - DE | |
| Posolyte | Chemicals for special usages - CN | |
| Isolation plate | Manufacture of plastic products - DE | |
| End plates | Manufacture of wood and wood products - DE | |
| Current collectors | Copper - CL<br>Nonferrous metal processing - CN | |
| Membranes | Manufacture of plastic products - DE | |
| Bipolar plates | Electricity generating equipment - DE | |
| Cell frames | Manufacture of plastic products - DE | |
| Battery operation | Production and distribution of electricity - ES | Electricity is only considered here, as it is assumed negligible during the manufacturing phase |

In addition to economic inputs, the manufacturing of the battery components and its operation also incur in work-hours which are listed as social flows. Following the PSILCA approach, working hours are calculated on the basis of the number of work-hours spent producing a unit of output (in $).

## 2.4. Impact assessment

A subset of the social indicators available in PSILCA was selected for the analysis (Table 2). Indicators related to environmental performance were excluded, since environmental aspects were addressed in a more comprehensive way in Deliverable 6.1. The focus is also limited to the indicators relevant for the *workers*, *local community*, and *society* stakeholder groups. The *value chain actor* stakeholder group is excluded due to reported data quality issues in the database. The *consumers* group is also excluded, since consumers are not expected to directly perceive negative social effects from the batteries' operation.

*Table 2 - Stakeholder groups and indicators selected for the analysis*

| Stakeholder group | Indicator subcategory | Indicator |
|---|---|---|
| Local community | Respect of indigenous rights | Indigenous rights |
| Local community | Safe and healthy living conditions | Pollution level of the country |
| Local community | Safe and healthy living conditions | Drinking water coverage |
| Local community | Safe and healthy living conditions | Sanitation coverage |
| Local community | Local employment | Unemployment rate |
| Local community | Migration | International migrant workers in the sector |
| Local community | Migration | International migrant stock |
| Local community | Migration | Net migration rate |
| Local community | Migration | Migration flows |
| Workers | Child labour | Children in employment, male |
| Workers | Child labour | Children in employment, female |
| Workers | Child labour | Children in employment, total |
| Workers | Forced labour | Frequency of forced labour |
| Workers | Forced labour | Goods produced by forced labour |
| Workers | Forced labour | Trafficking in persons |
| Workers | Fair salary | Fair salary |
| Workers | Working hours | Weekly hours of work per employee |
| Workers | Discrimination | Women in the sectoral labour force |
| Workers | Discrimination | Men in the sectoral labour force |
| Workers | Discrimination | Gender wage gap |
| Workers | Health and safety | Accident rates at workplace (non-fatal) |
| Workers | Health and safety | Accident rates at workplace (fatal) |
| Workers | Health and safety | DALYs due to indoor and outdoor air and water pollution |
| Workers | Health and safety | Presence of sufficient safety measures |
| Workers | Health and safety | Workers affected by natural disasters |
| Workers | Social benefits, legal issues | Social security expenditures |
| Workers | Social benefits, legal issues | Evidence of violations of employment laws and regulations |
| Workers | Freedom of association and collective bargaining | Trade union density |
| Workers | Freedom of association and collective bargaining | Right of association, collective bargaining and strike |
| Society | Contribution to economic development | Contribution of the sector to economic development |
| Society | Contribution to economic development | Public expenditure on education |
| Society | Contribution to economic development | Illiteracy rate |
| Society | Contribution to economic development | Youth illiteracy rate |
| Society | Health and safety | Health expenditure |
| Society | Health and safety | Life expectancy at birth |

In PSILCA, the "Impact Assessment" phase rather relates to risk prioritisation. Depending on the social conditions present in the country/sector, the risk is assessed on an ordinal scale, where each risk level is assigned a quantitative factor (analogous to the "characterisation factor" in environmental LCA). These factors multiply the actual number of work-hours incurred by each activity. For each subcategory listed in Table 2, the final indicator score represents the aggregated equivalent medium-risk hours that were incurred by the supply chain to produce the functional unit, in this case 1 kWh of electricity delivered by the battery. So if an activity required 5 working hours under *high risk* conditions for illiteracy in a given country/sector, then the equivalent amount of "medium-risk hours" associated to the activity will be 5 x 10 = 50 medium risk hours.

*Table 3 - Risk level factors*

| Risk level | Factor |
|---|---|
| very low risk | 0.01 |
| low risk | 0.1 |
| no data | 0.1 |
| medium risk | 1 |
| high risk | 10 |
| very high risk | 100 |

# 3. Results and discussion

## 3.1. Social risk indicators

Figure 1 shows the indicator scores for the selected set of socioeconomic indicators. It is important to highlight that the indicators are not comparable, meaning that "fair salary" conditions are not more or less problematic than "Fatal accidents". Rather, the magnitude of the bars reflects a larger amount of life cycle costs and worker hours incurred under potentially higher risk conditions for each specific indicator.

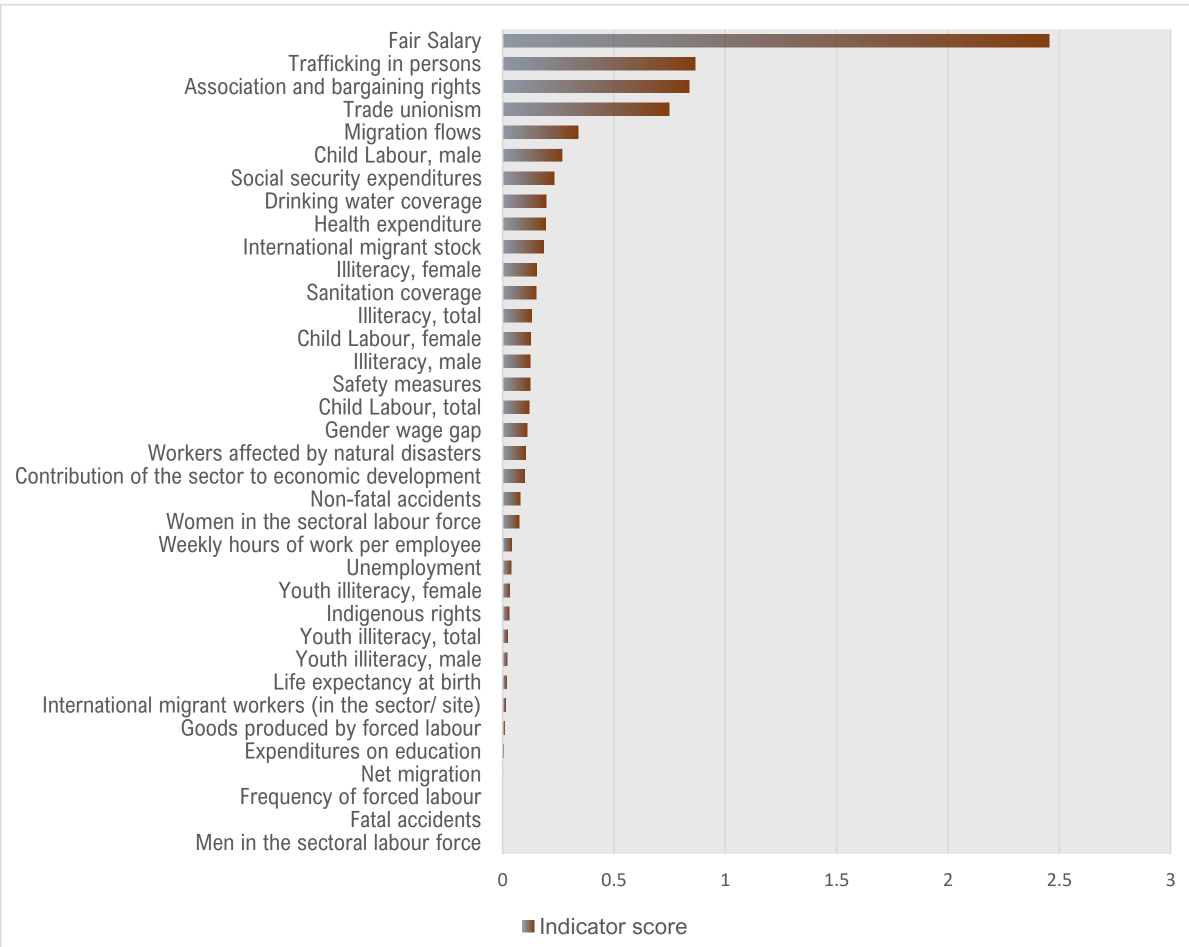


*Figure 1 - PSILCA social risk indicator scores for the BALIHT Organic Redox-flow battery*

## 3.2. Interpretation and discussion

The indicators scores point to where the BALIHT ORFB could make a significant positive contribution in enhancing socioeconomic development within the relevant economic sectors and countries associated to each battery component. As explained in the methods, battery components that are more expensive to assemble or procure, as well as those that require more labour will be more represented than others. In the following subsections we briefly describe what some of the highest ranked indicators represent and the data sources for risk assessment as reported in the PSILCA documentation[iii], to which we refer the reader for a more elaborate description. Within each indicator, we describe the components of the ORFB that may trigger sectors in countries that are at higher risk.

### 3.2.1. Fair salary

As per the PSILCA manual and UNEP/SETAC guidelines[5], "Fair wage means a wage fairly and reasonably commensurate with the value of a particular service or class of service rendered, and, in establishing a minimum fair wage for such service or class of service. Codes of conduct which deal with wages and benefits have focused on three standards when assessing level of wages: the minimum wage required by law; the local 'prevailing industry wage'; and the 'living wage' (also sometimes designated as a 'floor wage' or 'non-poverty wage')." In PSILCA, data for this indicator is collected from the WageIndicator.org database. Within the BALIHT supply chain, there are higher risks for this category within the countries and sectors supplying the balance of plant components, particularly in Croatia and Germany for the BMS. A second component is the production of chemicals for the posolyte, which largely takes place in China.

### 3.2.2. Trafficking in persons

Trafficking in persons is defined following the Palermo Protocol as "the recruitment, transportation, harbouring or receipt of persons, by means of coercion, abduction, deception or abuse of power or of vulnerability, for the purpose of exploitation.[7] It goes on to specify that exploitation shall, at a minimum, include sexual exploitation, forced labour, slavery and slavery-like practices". Data in PSILCA is based on the Tiered Placements of countries provided by the Office to Monitor and Combat Trafficking in Persons in the "Trafficking in Persons Report 2018"[8]. The chemical sector in China supplying the posolyte is most at risk, i.e. "very high risk" corresponding to the highest (3rd) tier of the report. According to the report, 3rd-tier countries are those "whose governments do not fully meet the minimum standards and are not making significant efforts to do so". This is evidently a country-level indicator and may not apply specifically to the sector.

### 3.2.3. Association and bargaining rights

In PSILCA, data for this indicator is derived from the Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (ICTWSS)[9] that compiles datasets regarding workers' rights, Wage Setting; Social Pacts and Agreements, Works Councils and employee representation in the enterprise; Employer organization; Union density and bargaining and others for 51 OECD, EU and emerging countries since 1960. In the BALIHT supply chain, this risk is mostly present in the chemical sector that would supply the chemical precursors for the posolyte.

### 3.2.4. Trade unionism

While association and bargaining rights refers to the actual power unions can have, trade unionism refers to the density of trade unions, which in PSILCA are defined as per the International Labour Organisation: "a workers' organization constituted for the purpose of furthering and defending the interests of workers. This trade union density rate conveys the number of union members who are employees as a percentage of the total number of employees. The indicator "Trade union density rate" from ILOstat database[10] is used. Within this indicator, components that can be prioritised include BOP elements produced in Croatia, the plastics sector in Spain, and the negolyte chemicals in Germany.

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[iii] https://www.openlca.org/wp-content/uploads/2020/06/PSILCA_V3_manual.pdf

### 3.2.5. Child labour, male

For this indicator, PSILCA relies on definitions and data from the World Bank[11], according to which “Children in employment refer to children involved in economic activity for at least one hour in the reference week of the survey". The data represent statistics for children ages 7-14. Again, the chemicals sector in China can be prioritised, even though the statistic is representative of country level and more accurate sector-specific data may change the risk level. In Croatia the risk is classified as "medium", however due to the cost and work-hour intensity of BOP supply chains, the relevant sectors are also reflected in the results as a potential focus area.

### 3.2.6. Social security expenditures

Here PSILCA follows the definitions of the ILO convention No. 102, which identifies nine main social security branches: Medical Care, Sickness Benefit, Maternity Benefit, Old-age Benefit, Invalidity Benefit, Survivors’ Benefit, Family Benefit, Employment Injury Benefit and Unemployment Benefit[12]. Data is taken from the sub-indicator “Public social protection expenditure (excluding health benefit in kind) as a percentage of GDP” in the Social Security Expenditure Database by ILO[13]. China is ranked with high risk and Croatia at medium risk.

### 3.2.7. Other indicators and general takeaways

Most of the remaining indicators follow a trend similar to the one observed thus far, where the importance of sectors (weighted according to cost and labour intensity) is combined with country-risk levels. Under this paradigm, the main parts of the supply chain that can be targeted for due diligence and implementation of CSR programmes towards enhanced social benefits delivery are the chemical sectors in China and Germany, the metals sector in Germany and the electrical and electronics sectors in Croatia and Germany.

# 4. Conclusions and recommendations

The BALIHT ORFB introduces important social improvements in the batteries sector by avoiding metal supply chains in Vanadium RFB's and Lithium-ion batteries that entail considerable social risks, as we discussed extensively in the associated publication to this report[3]. Nevertheless, conducting an S-LCA with the PSILCA approach enables us to highlight what could be priority areas of focus for supply due diligence and for implementation of Corporate Social Responsibility (CSR) and community development programs across the ORFB value chain. The identified priority areas are highly associated to the existing conditions in the countries in which productive activities are expected to occur.

Two key battery components in this analysis are the electrolytes and the balance of plant (see Table 1). With respect to the former, purchases from the chemical sector in China can be carefully monitored and improved by means of supplier due diligence and best-practice transfer. Electrolytes are an important component in terms of cost, so they are highlighted across all social criteria in this analysis (due to risk scaling with cost). The second most prominent component was the balance of plant. Within Europe, the electrical and metals sectors supplying balance of plant elements in Croatia and Germany can also be guided towards above country-average conditions for an improved social performance with respect to criteria such as fair salary, workplace safety, worker's rights, gender wage gap.

It is evident that in aspiring for a full life cycle representation, the PSILCA methodology introduces non-trivial limitations and restrictions as to how the results can be interpreted. The conclusions are very general in nature and are based on the average conditions represented by the current economic sectors in each country. The value-added of the approach is that it provides a roadmap towards implementing more targeted supply due diligence procedures, as will be required by the draft EU Battery Regulation. Furthermore, and more interestingly, it highlights the numerous opportunities as well-guided supply chain management for the ORFB can exploit in delivering social benefits next to the environmental benefits.

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