Deliverable Report

Deliverable Title:

LCC result’s report of the different alloys and production technologies

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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Summary

This report delves into the Life Cycle Costing (LCC) analysis of key aluminium automotive components, including the Shock Tower, Frontal Frame, B-Pillar, and Battery Housing, aiming to evaluate their economic implications across their life cycle stages. The study encompassed data collection, stakeholder collaboration, and the analysis of costs associated with material production, manufacturing, labour, transport of materials, use stage and end-of-life management. The LCC methodology, adapted from ISO standards, allows for comprehensive cost analysis, aiding decision-making processes for stakeholders involved in the product lifecycle. Notably, the analysis sheds light on the cost distribution and sustainability considerations, providing valuable insights for industry practitioners, specially towards a more sustainable and circular economy.

Disclaimer

Abbreviations

Abbreviation / Acronyms	Description
EC	European Commission
EU	European Union
WP	Work Package
WPL	Work Package Leader
LCC	Life Cycle Cost

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1. Introduction and Background

As an answer to the imperatives of the European Green Deal[1], the transport sector confronts the dual challenge of lightweighting while reducing dependence on imported advanced materials. In light of these imperatives, SALEMA project endeavours to transform the aluminium industry by developing high-performance aluminium alloys that not only fulfil the technical requisites of lightweight automotive structures but also diminish reliance on Critical Raw Materials (CRM).

Within SALEMA's project there is a commitment to integrate Life Cycle Costing (LCC) assessment, alongside considerations of environmental impact. Through meticulous scrutiny of each phase of the aluminium components life cycle, these LCC assessments encompass Raw material extraction and alloy production, Manufacturing, Use-phase, and End-of-Life stages. The goal is to ensure that SALEMA's solutions are not only technically viable but also economically and environmentally sustainable.

Furthermore, the project demonstrates its dedication to environmental sustainability by conducting a comparative analysis. This analysis evaluates the performance of various aluminium alloys across three key forming technologies in automotive component production: High Pressure Die Casting (HPDC), stamping, and extrusion, resulting in a total of 10 LCC assessments.

1.1. Objectives of task and deliverable

- To assess the economic implications of the SALEMA's high-performance aluminium alloys across key life cycle stages, including Manufacturing, Use-phase, and End-of-Life, to determine their cost-effectiveness and viability.
- To compare the life cycle costs of SALEMA's aluminium alloys, evaluating their performance across three primary forming technologies used in automotive component production (HPDC, stamping, and extrusion).

2. Activities

Cost Data Collection: Gathering comprehensive data on costs associated with each phase of the aluminium life cycle, including raw material procurement, alloy production, manufacturing processes, transportation, use, and end-of-life management.

Stakeholder Collaboration: Engagement with SALEMA's partners to gather insights, cost data, and ensure alignment with industry practices and standards.

Life Cycle Cost Analysis: Quantifying cost associated with SALEMA's aluminium solutions.

Comparative Analysis. Comparing SALEMA's aluminium alloys for the different demonstrators according to their production process (HPDC, stamping or extrusion).

Reporting and documentation: Compiling and documenting LCC results, methodologies, assumptions, and findings in a comprehensive report.

3. LCC Methodology

Life Cycle Costing (LCC) serves as an evaluation of total expenses associated with a product throughout its life cycle and can be integrated with environmental and social factors to evaluate the product's sustainability. All stakeholders in the product life cycle, such as suppliers, manufacturers, consumers, and end-of-life handlers, can utilize the LCC methodology. As a result, this approach is valuable to identify suitable measures and understanding challenges from various perspectives, whether it involves product/service developers or consumers. The application of LCC methodology is done following the ISO 15686-5:2017 Part 5: Life-cycle costing[2].

LCC facilitates the comparison of different alternatives by considering their investment cost, cash flows (during the use stage) and future costs, such as the end-of-life management. The objective of LCC is to offer quantitative analysis of costs throughout the lifetime of each demonstrator, which can then be used as a basis for decision-making or evaluation processes.

Goal and scope are aligned with D8.7 on Life Cycle Assessment for a more holistic approach in the life cycle studies.

Assumptions

SALEMA's different alloys contain different amounts of recycled material. Moreover, recycled aluminium prices have a great variation due to market fluctuations. Due to the lack of sufficient information and the unreliability of the information available online, cost estimations could lead to speculative or arbitrary values, which may not provide a meaningful or accurate representation of the situation. Therefore, we believe it's important to refrain from making any estimations that could lead to misleading conclusions. Accordingly, cost of aluminium is considered as the cost of market primary aluminium in all cases. Moreover, cost of the different inputs is collected from different sources, as stated in Table 1.

Table 1 Inputs cost

Item	Value	Unit	Source
Electricity EU	0,199	€/kW	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics#Electricity_prices_for_non-household_consumers
Aluminium	2,540	$/kg	LME Aluminium | London Metal Exchange
Aluminium	2,692	€/kg	1,06 eur/Usdlls
Lithium	22,814	$/kg	https://www.dailymetalprice.com/
Steel Rebar	0,503	$/kg	https://www.dailymetalprice.com/
Steel	3.670,000	CNY/T	https://tradingeconomics.com/commodities
Aluminium	2.311,500	USD/T	https://tradingeconomics.com/commodities
Monthly average gross salary	1.822,000	€	https://www.surinenglish.com/spain/average-salary-spain-500-euros-lower-than-20230822150814-nt.html https://www.ine.es/en/prensa/ees_2021_en.pdf
Annual average gross salary	28.184,000	€	https://ec.europa.eu/eurostat/databrowser/view/NAMA_10_FTE__custom_4232263/bookmark/table?lang=en&bookmarkId=fafb4e3b-f3aa-4907-9102-16be8df6f775 https://en.wikipedia.org/wiki/List_of_countries_by_average_annual_labor_hours
Average annual working hours	1.644,000	h	https://stats.oecd.org/Index.aspx?DataSetCode=ANHRS
Average cost per hour	17,144	€/h	
HDV EU25	0,140	euros/tkm	Maibach M, Peter M, Sutter D. Analysis of the contribution of transport policies to the competitiveness of the EU economy and com-parison with the United States n.d.2023.

Train EU25	0,110	euros/tkm	Maibach M, Peter M, Sutter D. Analysis of the contribution of transport policies to the competitiveness of the EU economy and com-parison with the United States n.d.2023.
Ship	0,007	euros/tkm	Christen E, Meinhart B, Sinabell F, Streicher G. External Costs of Freight Transport-Relevance and Implications of Internalisation at the European Level 1 n.d.
Natural gas	0,083	euros/kWh	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_price_statistics#Natural_gas_prices_for_non-household_consumers
Natural gas	0,007	euros/m3	11,70 kWh/m3, 1MJ=0,277778 kWh;
Sand	139,000	$/m3	https://rawmaterialprices.com/sand-price/
Sand	0,088	€/kg	1682 kg = 1 m3 of sand
Deionized Water	0,001	€/kg	Deionized Water Type 1 - On Sale and Buy today (chemworld.com) 275 gallons - 1500 US dlls 1 gallon= 3785 l = 3785 kg 1,06 USD = 1 euros
Compressed air	0,180	USD/m3	https://www.energy.gov/eere/amo/articles/determine-cost-compressed-air-your-plant
Compressed air	0,191	€/m3	
Desalinated water	0,795	€/m3	https://www.energymonitor.ai/tech/can-desalination-save-a-drying-world/?cf-view
Wastewater treatment	1,442	€/m3	Cost Comparison Analysis of Wastewater Treatment Plants (ijste.org)

Functional Unit for all the assessments has been defined as 1 kg of component in a Battery Electric Vehicle (BEV), in consonance with LCA in D8.7 for a harmonized approach.

Use stage considers a lifetime driving distance of 180.000km according to the EEA Report [3] in conjunction with energy consumption depicted on Table 2, also based the same Report. Average energy consumption is then considered as 20,09 kWh/kg during the lifetime of the vehicle.

Table 2 Use stage energy consumption per kg

Type	Typical battery weight (kg)	Typical vehicle weight (kg)	Energy consumption (kWh/100km)	Lifetime driving distance (km)	Energy consumption per kg of EV (kWh/100km kg)	Energy consumed during lifetime (kWh/vehicle)	Energy consumed during lifetime per kg of vehicle (kWh/kg)
Luxury car	553	2100	21	180000	0,010	37800	18,00
Large car	393	1750	19	180000	0,011	34200	19,54
Medium car	253	1500	17	180000	0,011	30600	20,40
Mini car	177	1100	15	180000	0,014	27000	24,55

For the end-of-life, the cost of recycling and in general end-of-life management of the different metals from vehicles can be influenced by factors such as the initial production cost, the value of scrap, the efficiency of recycling processes, and the quality of recycled scrap produced, all this, especially for aluminium. Despite the fluctuating costs and assumptions, it is estimated that the cost of recycling can be around 0,15 euros per kg[4].

4. Shock Tower

As a structural component, is designed to support the upper ends of the shock absorbers, which are crucial components of a vehicle's suspension system. For this element, there is an input of primary aluminium that is currently transported in average 2433 km until it reaches the manufacturing plant where melting and feeding require natural gas, while die casting, heat treatment and surface treatment use electricity in their processes. A comprehensive cost inventory for all these inputs is provided in Table 3 per unit of shock Tower. These data outlines the various inputs contributing to the shock tower's cost inventory, including material production, processing, labour, surface treatment, and transportation. These details provide insight into the resources and energy consumption involved at each stage of production and distribution.

Table 3 Shock Tower Cost Inventory

Description	Units	Qty
Material		
Alloy production	kg	6,800
Processing		
Die casting machine	kWh	2,628
Die casting peripherals	kWh	2,020
Heat Treatment	kWh	4,700
Shock Tower Labour	h	0,017
Surface treatment	kWh	1,224
Alloy melting and feeding	m3	1,640
Transport		
Road transport	tkm	0,680
Transport Barge	tkm	0,453
Transport Transoceanic	tkm	12,513

LCC analysis per kg of Shock Tower is presented in Table 4 showcasing the investment and production costs associated with each component. Notably, processing and material production constitute significant portions of the total costs. and depicted graphically in Figure 1 for a clearer understanding of the cost distribution.

Table 4 Shock Tower LCC results

Concept	Investment (€)	Production (€)	TOTAL (€)
material	**-**	**2,692**	**2,692**
Baseline Alloy production	-	2,692	2,692
processing	**2,167**	**0,352**	**2,519**
Alloy melting and feeding	0,259	0,002	0,261
Die casting machine	0,556	0,077	0,632

Die casting peripherals	-	0,059	0,059
Heat Treatment	1,352	0,137	1,489
Shock Tower Labour	-	0,042	0,042
Surface treatment	-	0,036	0,036
transport	**-**	**0,027**	**0,027**
Road transport	-	0,014	0,014
Transport Barge	-	0,000	0,000
Transport Transoceanic	-	0,013	0,013
USE			**3,990**
END-OF-LIFE			**0,149**
TOTAL	**2,167**	**3,072**	**9,378**

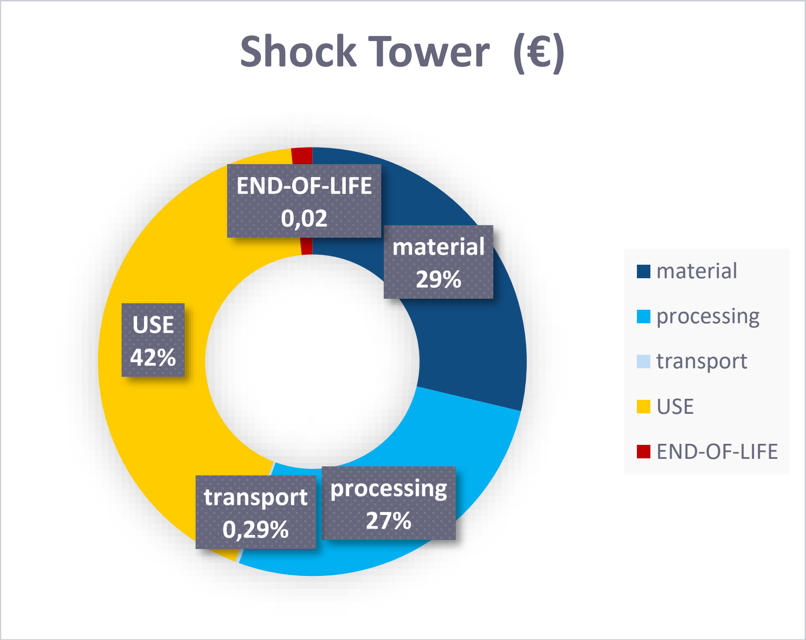

Figure 1 Shock Tower Cost Analysis

From the LCC results and graphical representation, it is evident that both investment and production costs play significant roles in determining the total cost of the Shock Tower, with each contributing nearly equally. However, when assessed by lifecycle stage, processing and use stages constitute approximately 27% and 42% of the total cost, respectively, while the material accounts for around 29%. These findings underscore the criticality of energy efficiency not only during manufacturing processes but also throughout the operational lifespan of BEVs, highlighting opportunities for cost optimization and sustainability enhancement.

5. Frontal Frame

The Frontal Frame is also a foundational component in the vehicle structure. It provides crucial support and rigidity to the front end. Similar to the Shock Tower, the Frontal Frame undergoes a complex manufacturing process. For this element, there is an input of primary aluminium that is currently transported in average 2433 km until it reaches the manufacturing plant where the process begins with the input of the alloy, which is then subjected to various processing stages, including alloy melting, holding, die casting, shot blasting and heat treatment. Alloy melting and holding processes, consume natural gas, while the rest use electricity. A detailed cost inventory for all these inputs is provided in Table 5 Frontal Frame Cost Inventory per unit of Frontal Frame. These data outlines the various inputs contributing to the Frontal Frame's cost inventory, including material production, processing, labour, surface treatment, and transportation. These details provide insight into the resources and energy consumption involved at each stage of production and distribution.

Table 5 Frontal Frame Cost Inventory

Description	Units	Qty
Material		
Baseline Alloy production	kg	19,000
Processing		
Alloy holding	m3	0,595
Alloy melting	m3	1,200
Alloy melting and holding	m3	1,795
Die casting Labour	h	0,025
Die casting machine including peripherals	kWh	9,600
Heat Treatment	kWh	4,700
Shot blasting (die casting part)	-	-
Heat treatment Labour	h	0,100
Holding Labour	h	0,025
Melting Labour	h	0,025
Shot blasting (die casting part)	-	-
Shot blasting Labour	h	0,025
Transport		
Transport Barge	tkm	0,453
Transport Road	tkm	1,900
Transport Transoceanic	tkm	12,513

Table 6 presents the LCC results, highlighting the investment and production costs associated with each of the elements in the inventory. Notably, die casting machinery constitute significant portion of the total cost. Figure 2 visually represents the Frontal Frame cost analysis, aiding in a clearer understanding of the cost distribution.

Table 6 Frontal Frame LCC results

Concept	Investment (€)	Production (€)	TOTAL (€)
material	**-**	**2,692**	**2,692**
Baseline Alloy production	-	2,692	2,692
processing	**3,753**	**0,331**	**4,084**
Alloy holding	0,152	0,000	0,152
Alloy melting	0,154	0,000	0,155
Alloy melting and holding	-	0,001	0,001
Die casting Labour	-	0,023	0,023
Die casting machine including peripherals	2,534	0,100	2,635
Heat Treatment	0,608	0,049	0,657
Heat treatment Labour	-	0,090	0,090
Holding Labour	-	0,023	0,023
Melting Labour	-	0,023	0,023
Shot blasting (die casting part)	0,304	-	0,304
Shot blasting Labour	-	0,023	0,023
transport	**-**	**0,019**	**0,019**
Transport Barge	-	0,000	0,000
Transport Road	-	0,014	0,014
Transport Transoceanic	-	0,005	0,005
USE			**3,990**
END-OF-LIFE			**0,149**
TOTAL	**3,753**	**3,042**	**10,934**

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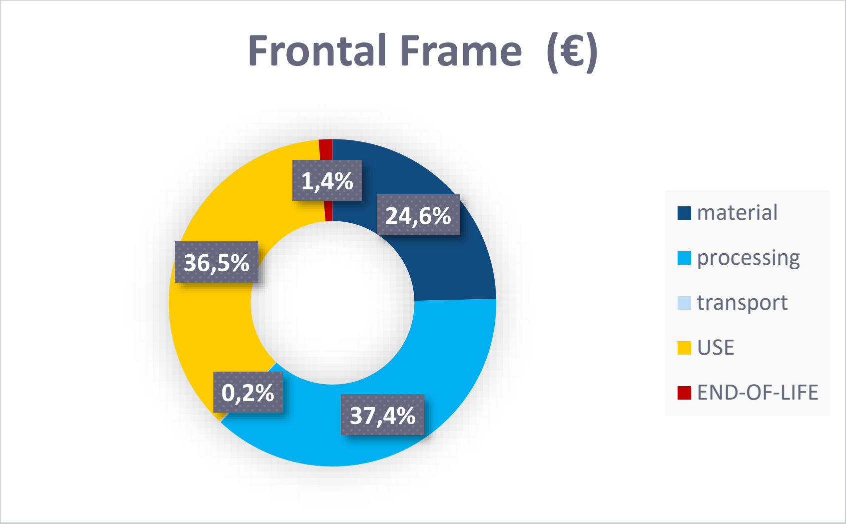

Figure 2 Frontal Frame Cost Analysis

From the LCC results and graphical representation it is noticeable that investment and production costs contribute almost 50/50 to the total cost of the Frontal Frame. On the other hand, if we evaluate it by lifecycle stage, processing and use stage contribute with around 37% of the cost, while the material accounts for 25% of the total cost. All this, proving the importance of energy efficiency, not only during production or manufacturing stages, but also during the use stage of BEVs.

6. B-Pillar

Another important structural element is the B-Pillar, which is positioned between the front and rear doors of a vehicle, plays a pivotal role in enhancing its overall strength, stability, and crashworthiness. It serves as a critical support component, contributing to the structural integrity of the vehicle's body. Production processing starts with the introduction of aluminium alloy, that in this case has been transported an average of 1894 km to the manufacturing facility. At the plant, the alloy undergoes several processing stages, including blank shape cutting, hot forming, laser cutting and aging hardening. B-Pillar manufacturing plant rely solely on 100% green electricity. A comprehensive breakdown of the inventory for the B-pillar, encompassing material production, processing, labour, and transportation, is detailed in Table 7 per unit of B-Pillar. It is worth to note that cost of investment, labour and transport are included in each of the processes.

Table 7 B-Pillar Cost Inventory

Concept	Investment (€)	Production (€)	TOTAL (€)
material	**-**	**3,237**	**3,237**
Baseline Alloy production	-	3,237	3,237
processing	**-**	**3,456**	**3,456**
Aging Hardening	-	0,534	0,534
Blank shape cutting	-	0,394	0,394
Hot forming line	-	1,387	1,387
Laser cutting	-	1,142	1,142

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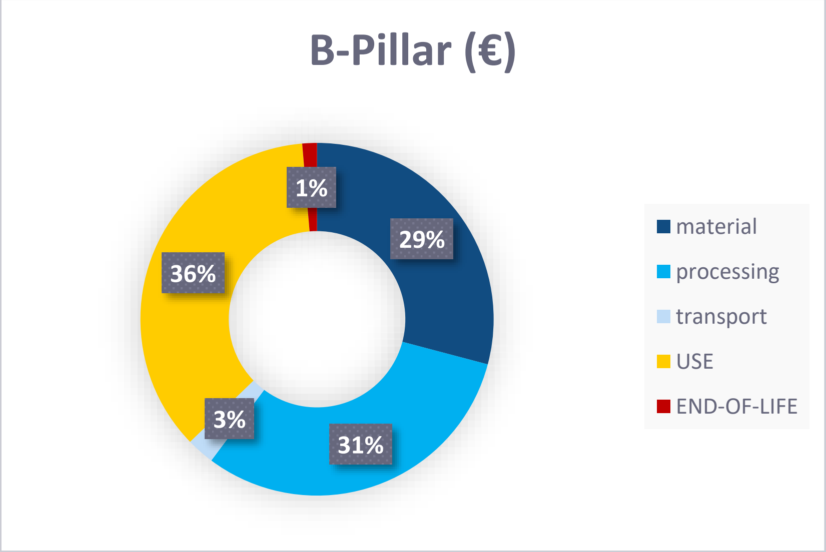
Scrap	-	-	-
transport	**-**	**0,284**	**0,284**
Transport road	-	0,019	0,019
Transport train	-	0,265	0,265
USE			**3,990**
END-OF-LIFE			**0,149**
TOTAL	**-**	**6,977**	**11,116**

Results of the LCC for 1 kg of B-Pillar are displayed in Table 8, shedding light on the cost incurred throughout the lifecycle of a kg of a B-pillar in a BEV.

Table 8 B-Pillar LCC results

Concept	Investment (€)	Production (€)	TOTAL (€)
material	**-**	**3,237**	**3,237**
Alloy production	-	3,237	3,237
processing	**-**	**3,456**	**3,456**
Aging Hardening	-	0,534	0,534
Blank shape cutting	-	0,394	0,394
Hot forming line	-	1,387	1,387
Laser cutting	-	1,142	1,142
Scrap	-	-	-
transport	**-**	**0,284**	**0,284**
Transport road	-	0,019	0,019
Transport train	-	0,265	0,265
TOTAL	**-**	**6,977**	**6,977**

Figure 3 B-Pillar Cost Analysis



Analysing the LCC results and visual representation for the B-Pillar by lifecycle stage, processing and use stages collectively represent 31% and 36% respectively, while material expenses make up almost another third of the costs, 29%. This underscores the importance of energy-efficient practices not only in manufacturing but also during the use phase of BEVs. Emphasizing the need for strategies that optimize costs and enhance sustainability across all stages of the product lifecycle. Analysis on the investment and production cost was not possible.

7. Battery Housing

The Battery Housing plays a pivotal role in the integration and protection of the vehicle's battery system. It’s designed to securely encase the vehicle's battery pack, ensuring optimal performance and safety. The manufacturing process begins with the input of aluminium alloy, which is typically transported over considerable distances, in the case of this Battery Housing it averages 10,500 km. Manufacturing steps involve electricity-intensive casting and extrusion processes. Notably, both casting and extrusion processes require significant energy inputs, including electricity and natural gas. In this case, investment cost is unknown. A detailed breakdown of the cost inventory for the Battery Housing is provided in Table 9 per unit of Battery Housing.

Table 9 Battery Housing Cost Inventory

Description	Units	Qty
Material		
Alloy production	kg	146,395
Processing		
Electricity casting	kWh	1,323
Electricity extrusion	kWh	86,657
Natural gas extrusion	m3	42,257
Natural gas for casting	m3	12,025
Labour casting	h	0,005
Labour extrusion	h	0,013
Transport		
Road transport	tkm	31,165
Transport train	tkm	379,749
Transport Transoceanic	tkm	1.605,529

Results of the LCC for 1 kg of Battery Housing are displayed in Table 10, shedding light on the cost incurred throughout the lifecycle of a Battery Housing in a BEV.

Table 10 Battery Housing LCC results

Concept	Investment (€)	Production (€)	TOTAL (€)
material	**-**	**2,692**	**2,692**
Baseline Alloy production	-	2,692	2,692
processing	**-**	**0,140**	**0,140**
Casting Labour	-	0,005	0,005

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Electricity casting	-	0,002	0,002
Electricity extrusion	-	0,118	0,118
Extrusion Labour	-	0,013	0,013
Natural gas extrusion	-	0,002	0,002
Natural gas for casting	-	0,001	0,001
transport	**-**	**0,392**	**0,392**
Road transport	-	0,030	0,030
Transport train	-	0,285	0,285
Transport Transoceanic	-	0,077	0,077
USE			**3,990**
END-OF-LIFE			**0,149**
TOTAL	**-**	**3,224**	**7,363**

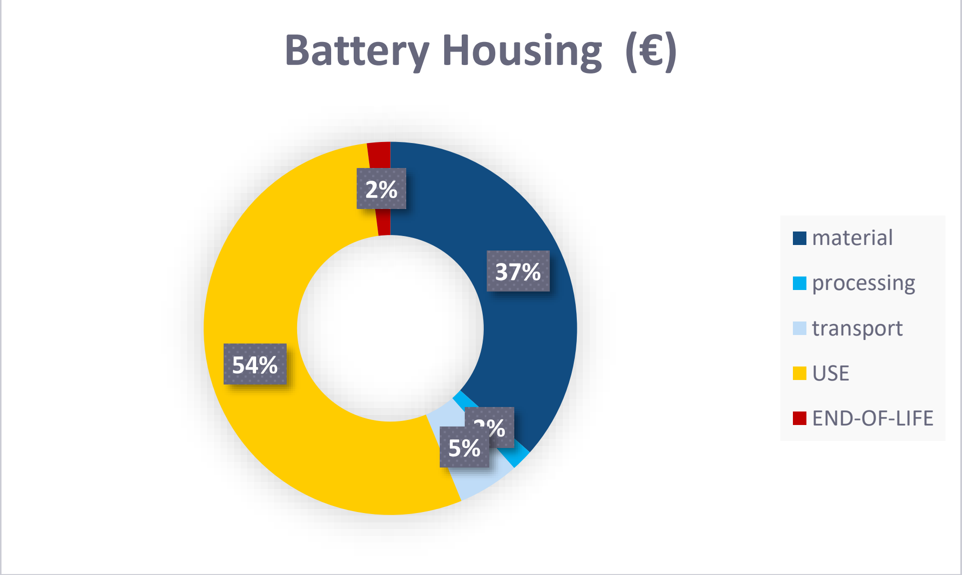

Figure 4 Battery Housing Cost Analysis

Examining the LCC results and visual representation for the Battery Housing by lifecycle stages, processing with no investment cost known has a very low contribution to what could be the average for this kind of processes. Use phase is pushed to 54% of the cost while material cost reaches 37%. Future studies are encouraged to include the investment cost in the study to be able to see the complete picture of the LCC.

8. Closing Remarks

LCC analysis conducted across the Shock Tower, Frontal Frame, B-Pillar, and Battery Housing demonstrators, provides valuable insights into the economic implications of the SALEMA's high-performance aluminium alloys in automotive manufacturing. Through data collection and stakeholder collaboration, the costs associated with material production, processing, labour, transportation, and end-of-life management across key life cycle stages has been studied. Despite inherent challenges and uncertainties, such as fluctuating prices and assumptions, the LCC results serve as a valuable tool for assessing the cost-related aspects in the automotive industry manufacturing.

LCC results highlight the significant contributions of material, manufacturing, use and end-of-life costs to the overall costs of the different demonstrators in a BEV over its lifetime. LCC also offers stakeholders to identify opportunities for cost optimization, process improvements, and resource efficiency throughout the product life cycle.

Through the quantification and identification of cost and key cost drivers, LCC contributes to informed decision making and supports the transition to more sustainable and cost-effective manufacturing in the automotive sector.

Integration of sustainability considerations in future studies will enhance the understanding of the associated impacts and foster a more holistic approach that allows a more efficient transition to a circular economy.

9. References

[1] European Comission. The European Green Deal 2019. https://doi.org/10.34625/issn.2183-2705(35)2024.ic-03.

[2] ISO/TC 59. ISO 15686 – 5:2017; Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing 2017.

[3] European Environment Agency. Electric vehicles from life cycle and circular economy perspectives: TERM 2018: Transport and Environment Reporting Mechanism (TERM) report. 2018.

[4] Cost Profit Analysis - Recycling Services International n.d. https://recyclingfurnaces.com/cost-profit/ (accessed April 26, 2024).