Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 135 (2025) 642–647

www.elsevier.com/locate/procedia

32nd CIRP Conference on Life Cycle Engineering (LCE 2025)

Digital product passport data to improve the material flow and stock monitoring and projections at EU-level: the case of EV-batteries

J.Lennartz[a,*], K. Jansen[a], E. Rietveld[a]

[a]*TNO, Princetonlaan 6, Utrecht 3584 CB, The Netherlands*

* Corresponding author. Tel.: +316-; *E-mail address:* Jelmer.lennartz@tno.nl

Abstract

Macro-monitoring of material flows and stocks enables policy-makers to evaluate progress towards meeting its resource use-related commitments. Additionally, it allows to revise the products' circularity requirements laid down in the regulations based on realistic scenarios on a societal scale. Current monitoring practices often rely on non-specific and not regularly updated data. This study examines whether the current practices satisfy the need to create realistic policies, by the case of electric vehicle batteries. A prospective material system analysis is conducted to evaluate the uncertainties in the existing data for macro-monitoring the availability of recycled lithium by 2030. The information is crucial for revising the recycled content requirements in regulation (EU) no. 2023/1542 concerning batteries and waste batteries. The analysis concludes that considerable uncertainty is associated with projecting recycled lithium availability, due to the variability in battery composition and lifespan. The study emphasizes the need to mitigate the uncertainties associated with the expected material outflows from the urban mine, in order to establish realistic recycled lithium content requirements. The recently introduced regulation also mandates battery producers to disclose sustainability-related information via a digital product passport (DPP). This paper proposes an approach for leveraging DPP-information to enhance the material flow and stock monitoring and projections, thereby facilitating well-informed policy-making, to create executable eco-design guidelines.

Keywords: Digital product passport; Policy-making; Circular economy; Resource criticality; Urban mine

1. Introduction

A series of directives, regulations and acts are initiated and adopted by the European Commission to transition towards a more sustainable economy. The transition primarily aims to achieve climate neutrality, establish a circular economy, and ensure strategic autonomy while ensuring social fairness. To identify the state of play of the economy and the progress of the transition, it is essential to monitor the material flows, stocks, and (embodied) environmental impacts on a macro-level (national and/or European Union (EU) level). This need for macro-monitoring is also set out in the various EU regulations and acts, as it is required:

- To evaluate its progress towards meeting its international and internal commitments and obligations [1].
- To evaluate and monitor the effectiveness of implemented policy instruments [1].
- To identify risks by assessing the current situation and mapping the future [2].
- To revise the products' sustainability requirements laid down in the regulations based on the realistic, technical, economic and scientific situation [3].

Although not specified in each regulation separately, these four main needs are generally applicable from a government perspective for macro-level monitoring in the context of transitioning towards a circular economy.

10.1016/j.procir.2024.12.057

1.1. Problem definition

Exchanges in the economy are often not registered on a material/emissions level but predominantly on a monetary level. Therefore, monitoring practices use the data regarding exchanges of products and activities performed in the economy in combination with supplementary information (i.e. emission factors or material equivalents of products), which comes with challenges related to the currentness and representativeness. As the monitoring results form the basis for policy-making, such as the formulation of eco-design guidelines, a certain degree of accuracy is essential. A range of newly introduced legislations forces economic operators to disclose sustainability-related information concerning their products, processes, facilities, or transport. Digital Product Passports (DPP) are repeatedly used as means to document product-data [3][4]. This new source of information, and other reported information, could be used to enhance the macro-monitoring practices.

The use of DPP-data for macro-monitoring requires a data sharing architecture to allow governments to have access to the business data. To explore whether the investment in DPP-data collection for well-informed policy-making is justifiable, the aim of the study is to evaluate existing monitoring approaches and explore the added-value of DPP-data.

1.2. Electric vehicle-batteries case

In this study, material flow and stock monitoring of Electric Vehicle (EV)-batteries is used as case to explore the relevance of improved data, potentially by DPP-data. Regulation (EU) no. 2023/1542, concerning batteries and waste batteries, introduces recycled content requirements for new batteries put on the European market [3]. The regulation enforces a minimum percentage share of materials recovered from battery manufacturing or post-consumer waste for critical/ strategic raw materials: cobalt, lead, lithium and nickel. Recycled content requirements, defined for the years 2031 and 2036, will be revised based on the existing and projected availability of materials and given the technical and scientific advancements. The regulation underscores the need to monitor the Union's status concerning particular material flows and stocks.

This case is chosen because the information base concerning material flows and stocks is already comprehensive, enabling a quantitative evaluation of existing monitoring accuracy caused by the uncertainty of or variability in supplementary information. Despite the extensive research conducted and information available, the level of detail and representativeness of the information is relatively coarse. Secondly, the formulation of recycled content requirements requires more precise monitoring practices to establish realistic requirements. In contrast, more general monitoring practices, such as evaluating the overall economy's material demand, primarily focus on mapping trends, where accuracy and precision are less critical. Lastly, this case deals with challenges in representativeness related to the supplementary information used for the monitoring, given the considerable variation in battery compositions possible. It is important to note that the uncertainty and variability studied may not necessarily apply to all cases where supplementary information is used, it is case-dependenten.

2. State-of-the-art macro-level monitoring

Structural monitoring of material flows, stocks, and environmental impacts on a macro-level is not a new practice [1]. Different monitoring practices have already been put into place by the EU and its member states to keep track of the state-of-play, and these practices are currently being extended. In the core of implemented macro-level monitoring practices, two approaches can be distinguished [5][6], see figure 1:

- *Bottom-up approach | Input-Output Analysis (IOA)*: The approach builds on the input-output data, e.g. compiled from life cycle inventories of products, on exchanges in the economy. The IOA does not make use of complementary sources to extend the analysis, to create more detail in the assessment. The approach is particularly relevant to analyze aspects that can be tracked, such as the import of specific goods, energy, or raw materials. The detailedness of the IOA is dependent on the resolution of input-output data documented.
- *Top-down approach | Environmentally extended Input Output Analysis (EEIOA)* [7]: Similar to the bottom-up approach, the top-down approach is based on input output data, but makes use of supplementary information regarding composition and/or input-output flows. The supplementary information can be extracted from a variety of sources, such as scientific publications and databases, or be based on expert judgment. The extension with data on resource use, emissions and/or other information allows a more detailed analysis than possible with the available input output data its resolution.

Most macro-level monitoring practices make use of a combination of IOA and EEIOA, also known as a Hybrid Input-Output Analysis (HIOA)[6]. The approach applies EEIOA in the case the resolution of the input output data does not suffice in the desired information. Monitoring practices using supplementary information are experienced as less representative, which is not necessarily the case. Both sides of the spectrum deal with data related challenges.

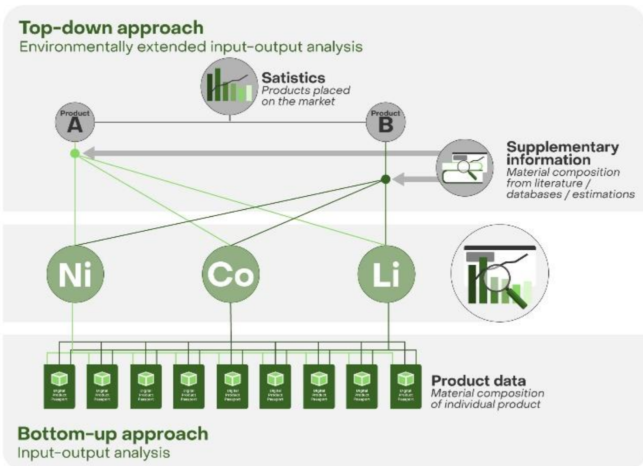

Fig. 1. Example top-down and bottom-up approach material flows.

2.1. Challenges

The consistency, uniformity and comprehensiveness of the collected data is a key challenge for the bottom-up approach. For the monitoring of material flows, stocks and environmental impacts, the data is often created and collected by a variety of parties. Data creation according to similar guiding principles is required to ensure the analysis' quality. For example, a similar environmental impact assessment method should be used to determine the global warming potential, just as the scope and the allocation procedures applied should be similar. The top-down approach make use of less data sources and, therefore, the quality of data can be reviewed more easily.

For the top-down approach, the representativeness of the supplementary information used is a key challenge. Inherent to the approach is that more detailed data is not available; thus, the general representativeness of the supplementary information used cannot be verified. The analysis' accuracy is particularly affected when there is a large uncertainty or variability in the supplementary information. For example, the greenhouse gas emission factor of electricity generation by natural gas is rather homogeneous, while the emission factor for steel production could be rather diverse. Therefore, the representativeness of global warming potential for steel is more subject to uncertainty. The bottom-up approach is introduced to overcome the challenge and ensure overall representativeness of tracked flows.

Both bottom-up and top-down approach deal with challenges related to blind spots in the available data. Data gaps as a result of (1) not registered transactions (e.g. illegal supply of goods), (2) mistakes in the registration (e.g. wrong categorization of materials), (3) unidentifiable categorization (e.g. outflow of unidentified waste), or (4) not separately registered flow (e.g. batteries not registered separately, only the products in which they are embedded). As a result of these challenges, substitutive information is applied to overcome the limitations of available information.

3. Material flow and stock monitoring/projections EV-batteries

When revising the recycled content requirements, regarding cobalt, lead, lithium and nickel, defined by the regulation (EU) no. 2023/1542, concerning batteries and waste batteries, the projections of recycled material availability play a crucial role in informed decision-making. The ProSUM project (2015-2017) proposed an approach to project the material availability of, amongst others, the four critical/strategic raw materials (C/SRM) [8]. The stock-lifespan based model developed [9] is a recognized method for projecting the material availability [10]. Furthermore, the general coefficients regarding battery composition created by the project continue to serve as the primary supplementary information to identify the C/SRM flows related to batteries in the Material System Analysis (MSA) studies performed [11].

The approach to projectt the recycled material availability from batteries primarily relies on data about the batteries placed on the EU market for a specific year, average weight of batteries, battery compositions (Bill of Material (BoM)), and lifespan distribution in the stock-lifespan based model. This information is used to model the moment a product reaches the end-of-life, which in turn is used to project the amount of available battery waste for a specific year. The data sources used per data component for the stock-lifespan model [12] are described below:

- *Products placed on the market*: Eurostat provides statistics on the production of manufactured goods, along with related trade data. The data, collected and structured according to the European Business Statistics Regulations, undergoes the Eurostat data validation process [13]. The data is generally reliable due to its strong legal framework. Batteries, when placed on the market, are primarily embedded in other products, identified by the products in which they are embedded. The categories used to identify the batteries are broad. In practice, not for each category the same type and size of battery will be applied.
- *Amount of material per product*: The amount of a specific material applied in a battery placed on the market is not documented. Therefore, the weight per material is determined by the weight of a battery per application (e.g., hybrid electric vehicle or electric vehicle) and the batteries' average composition [12].
  - *Product weight*: Data on the average weight of batteries per application is required since batteries are registered based on units, not weight. Conversion factors from units to weight are determined for various applications, such as hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and electric vehicles (EV).
  - *Composition*: To identify the mass of a specific material, the product composition is required. The ProSUM project provides information on the average composition of various battery types [14]. The battery compositions are determined using a bill of materials from different sources such as academic literature, manufacturer information, and databases. The composition varies significantly across sources, with a 95% confidence interval range of plus/minus 50% [14].
- *Lifespan*: The lifespan of batteries is modeled according to a lifespan distribution based on historical data. Thus, projectionss are based on historical data, with to some extent consideration for improvements in battery technologies and changes in consumer behavior.

3.1. Material system analysis

To assess whether the currently available information can form a basis for realistic recycled content requirements, the implications of key uncertainties for the recycled material availability projections are identified. A simplified stock-lifespan model is used to perform a prospective MSA [11] of lithium in EV-batteries, evaluating the uncertainties related to battery composition and lifespan. This model is simplified as it is based on a fixed lifespan instead of a lifespan distribution. The data sources used, and the approach applied align, as far as possible, with the stock-lifespan model of the ProSUM project [12] and the existing MSA for Lithium[11]. Not all assumptions and modeling approaches are transparently documented, so full comparability cannot be guaranteed.

The carried out MSA is based on three main-assumptions which affect the result and approach:

- Recycled lithium sourced outside the EU is considered not to be applied for EU-production. Circularity of materials within the geographical boundaries is assumed for this study.
- Recycled lithium in the EU from other applications is not considered. Particularly as lithium from EV-batteries will be responsible for the largest share of lithium stock [15] and the recycled materials from other applications are assumed to be required to fulfill its own recycled content requirements.
- Recycling of battery manufacturing waste is as well considered as recycled content to fulfill the requirements. However, the amount of battery manufacturing waste is considered negligible [16].

The potential share of recycled lithium in EV-batteries is evaluated for the year 2030 and compared to the recycled content requirements set for 2031 by the regulation. The results are based on the analysis of recycled materials available within the EU and the projected lithium demand, which is expressed in a low-demand scenario (LDS) and high-demand scenario (HDS)[17]. The products placed on the EU-market are identified using Eurostat statistics [13]. The amount of batteries for HEV (29102410), PHEV (29102430) and EV (29102450) are retrieved according to its respective *Prodcom*-code, by the sum of the produced and imported product, excluding the exported products. As data from before 2017 of the categories placed on the EU-market is not documented by Eurostat, growth rates described by [18] are used to complement the dataset. Table 1 present the parameters used and the alternative scenario inputs to evaluate the uncertainty and variability of supplementary information.

Table 1. Overview supplementary information

Factor		Amount	Source
Lithium demand 2030	LDS	42.313 tonnes	[17]
	HDS	58.208 tonnes	
Mass battery	HEV	5,4 kg/unit	[12]
	PHEV	56 kg/unit	
	EV	156 kg/unit	
Share Lithium in Li-ion battery	Baseline	2,4%	[14]
	LLS	1,2%	
	HLS	3,6%	
Lifespan EV-battery	Baseline	10 year	[19]
	Alternative	15 year	[20]
Collection rate		95%	[19]
Reuse rate		20%	[21]
Recovery efficiency recycling Lithium		85%	[10]
Lifespan reuse EV-battery		5 year	[22]

3.2. Result interpretation

Figure 2 presents the simplified Sankey diagram of lithium flows in the EU related to EV-batteries for 2030 according to the baseline scenario. A 10 year EV-battery lifespan is modelled, indicating that by 2030 the batteries placed on the market in 2020 will reach the end of their initial life cycle. The results show that most materials for new EV batteries will come from primary sources. The inflow of primary lithium is less than the amount of lithium to in-use stock (see figure 2) , as a share contains the secondary materials extracted from the urban mine. The amount of recycled lithium available by 2030 is limited. The amount of lithium going to batteries reused for grid storage is fractional, as are the collection and recycling losses. With a potential economy wide average recycled lithium content rate of 3.6-5.0%, meeting the 6% requirement for 2031 appears challenging. Improvements in the collection rate (projected to be 95%) and recycling recovery rate (projected to be 85%) could enhance the lithium share to approach the requirement according to the baseline scenario, particularly when considering the assumptions described in 3.1.

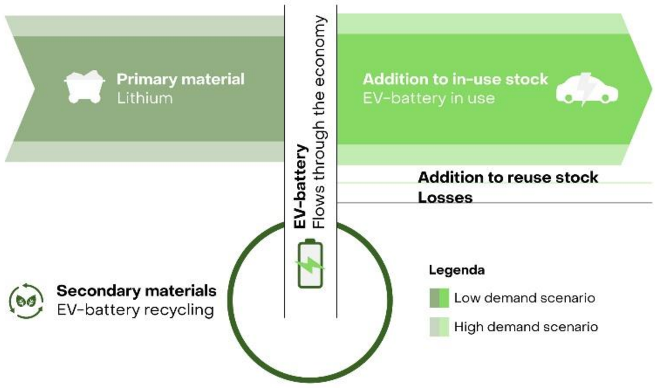

Fig. 2. Results baseline-scenario lithium flows in the EU related to EV-batteries in 2030 presented by a simplified Sankey diagram.

Table 2 presents the potential economy average recycled content share for each of the defined scenarios, evaluating both the uncertainty in share of lithium in the EV-battery composition and the lifespan. The low lithium share (LLS) and high lithium share (HLS) scenario consider the uncertainty of the data used, which is illustrated by the distribution of lithium shares. According to the ProSUM-project, the share of lithium falls within a 95% confidence interval of 1.2 and 3.6%. As presented in table 2, it is a difference between (easily) meeting the requirements and not being able to meet them in any case.

Table 2. Share of secondary content according to the prospective MSA results

Scenario		Share secondary content (HDS-LDS)
Legislative enforced by 2031		*6%*
Baseline lifespan	Baseline (Mean)	3.6-5.0%
	LLS (2.5th percentile)	1.8-2.5%
	HLS (97.5th percentile)	5.4-7.5%
Alternative lifespan	Baseline (Mean)	0.4-0.6%
	LLS (2.5th percentile)	0.2-0.3%
	HLS (97.5th percentile)	0.6-0.8%

When potential improvements of batteries regarding its lifespan are considered, the formulated requirements are unrealistic in all scenarios. Currently, an average lifespan of 10 years for EV batteries is expected, which could go up to 15 years for batteries currently placed on the market. Due to the rapidly increasing market, the lifespan of batteries has large implications on the amount of recycled material becoming available. Therefore, in the case of a 15 year lifespan, the requirements cannot be met by a significant margin. In the best scenario, achieving even 1% secondary lithium content seems unrealistic.

The analysis shows that using the general coefficients to project the recycled lithium available is associated with considerable accuracy challenges due to the identified uncertainty and variability implications for the potential secondary content shares. Both the average battery composition and battery lifespan seriously affect the projections of lithium availability by 2030. The application of the EEIOA appears too inaccurate for this application, due to the broad statistical categories (i.e. EV) in combination with potential large uncertainty and variation in the coefficients. Furthermore, generalizing data regarding the lifespan to batteries introduces considerable uncertainty to the projection. Therefore, the application of this information for formulating realistic recycled content requirements can be argued, even when disregarding the timeliness of the supplementary information. It could lead to unrealistic or non-challenging secondary content requirements, both which should be avoided.

4. DPP-data for monitoring/projections

New legislation mandates economic operators to disclose sustainability-related data concerning their products, processes, facilities, or transport, including via DPP. The type and detail of enforced sustainability-related data varies across jurisdictions. If the data will be collected and made accessible for monitoring and projection purposes, it could enhance the macro-level monitoring practices, particularly regarding material and emission exchanges within the economy. This new information sources uncovers previously inaccessible input-output data, reducing the need for supplementary information-sources. Applying the DPP data to macro-level monitoring can help overcome challenges related to data representativeness and timeliness, as discussed in section 2.1.

4.1. Digital battery passport data

The introduction of the Batteries and Waste Batteries Regulation ((EU) no. 2023/1542) mandates a Digital Battery Passport (DBP), a product specific DPP containing a variety of (sustainability-related) information [3] [23]. The mandatory data, becoming available due to this regulation [24], allows for improvement of the information used for revising the recycled content requirements. The challenges that can be overcome due to the information retrieved from the DBP are described below, categorized by data component:

- *Products placed on the market*: In the existing approach, batteries placed on the market are primarily identified by the product in which they are embedded. The introduction of the DBP requires registration of each individual battery placed on the market, allowing a more complete overview of batteries on the market. This overcomes the misalignment that arises for batteries placed on the market that are embedded in existing products.
- *Amount of material per product*: The DBP allows the retrieval of the detailed material composition of every individual product, avoiding the use of general coefficients to estimate the C/SRM stock. Changes in the amount of material per product due to repair operations are also tracked, allowing an up-to-date material inventory. Uncertainties are primarily related to the validity of declared information, underlining the relevance of independent control and auditing.
- *Lifespan*: The existing stock-lifespan model relies on lifespan predictions based on ex-post analyses per battery-application. Tracking individual batteries allows for more product-specific predictions, e.g. on series or product application level. Furthermore, the DBP enforces state-of-health registration, making information about battery status available over a lifetime. Variations in actual battery performance and implications of user behavior can be considered to more accurately predict the expected outflow of materials, see figure 3.

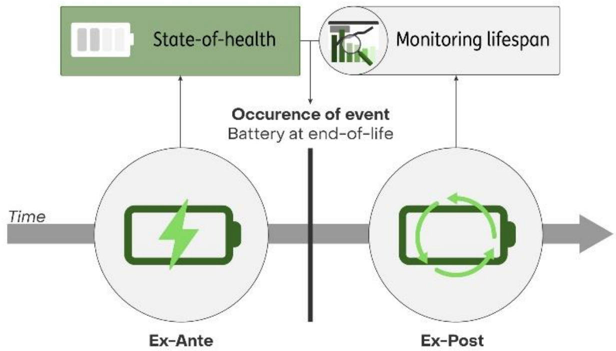

Fig. 3. Schematic representation information used to predict when batteries are at the end-of-life

Uncertainty of results is inherent to monitoring and projections, particularly when human behavior may significantly influence the results. However, monitoring the material stocks using the up-to-date DBP data allows for mitigating some of the key uncertainties in the existing approach. Revising recycled content requirements will require a more certain information base to create realistic requirements. DBP data could provide this basis for future monitoring and projections, which requires a data sharing architecture to allow governments to access business data. The DATAPIPE-project proposes a interoperable data-sharing infrastructure to facilitate the use of DPP-data [25]. The opportunity to improve policy monitoring using the DBP data should not go unnoticed as it is now.

4.2. Consideration

The main difficulty with the use of DPP-data for macro-level monitoring is the ensuring data creation according to similar guiding principles. It is essential for the quality of the analysis as stated in section 2.1. Auditing procedures need to be established for the assurance. DPP-data auditing is not only required to apply data for monitoring purposes but as well for the verification of the claims legitimacy. Therefore, the auditing is not a practice which should newly be introduced for this purpose; however, it's a precondition to use the DPP-data for macro-level monitoring.

Another challenge is that not all information required or desired for sustainability monitoring practices will be mandated by legislation. Therefore, not every assessment can rely solely on DPP-data. Supplementary information will still be needed to provide a comprehensive monitoring overview. However, DPP-data pertaining to product technology, production location, and other characteristics can still enhance macro-level monitoring according a HIOA by improving the specificity of classes. This allows for a more representative match between the class and the supplementary information.

5. Conclusion

The introduction of new needs for macro-level monitoring of material flow and stock, such as to revise the products' sustainability requirements, sets more strict demands regarding the detail of the monitoring practices. For the case of EV-battery it is illustrated that the existing monitoring practices go along with considerable uncertainty, particularly because of the low resolution of input output data used in combination with supplementary material for the HIOA. Detailed business data, such as from a DPP, could enhance the macro-level monitoring on different aspects, such as material inventories, lifespan projections and input output data resolution. It could enable the formulation of realistic and challenging product requirements, which is uncertain for monitoring practices utilizing broad statistical categories in combination with potential large variation in the coefficients. To utilize DPP-data for macro-level practices, continued investment is required in the development of data sharing architecture, just as procedures to audit the incoming information.

Acknowledgements

This research was partially funded by the DATAPIPE project, which has received funding from the European Union's Technical Support Instrument (TSI) programme under grant agreement No 101094495. Ideas and opinions expressed by the authors do not necessarily represent those of all partners.

References

[1] Climate monitoring mechanism regulation, "Regulation(EU) No 525/3013," 2013 [Online]. Available: eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0525
[2] G. Ragonnaud, "Critical raw materials act," Brussels, 2024. [Online]. Available: www.europarl.europa.eu/RegData/etudes/BRIE/2023/747898/EPRS_BRI(2023)747898_EN.pdf
[3] Batteries and waste batteries regulation, "Regulation (EU) 2023/1542," 2023
[4] Ecodesign Requirements for Sustainable Products, "Regulation (EU) 2024/1781," 2024 [Online]. Available: eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401781
[5] Eurostat, "Economy-wide material flow accounts," Luxembourg, 2018. doi: 10.2785/158567.
[6] S. Giljum et al., "An empirical assessment comparing input-output-based and hybrid methodologies to measure demand-based material flows," 2015.
[7] Eurostat, "Documentation of the EU RME model," Luxembourg, 2024. [Online]. Available: ec.europa.eu/eurostat/documents/1798247/6874172/Documentation+of+the+EU+RME+model/
[8] J. Huisman et al., "Prospecting Secondary Raw Materials in the Urban Mine and mining wastes (ProSUM) - Final Report," Brussels, 2017. [Online].
[9] ProSUM, "Product Stocks and Flows Deliverable 3.3," 2017. [Online].
[10] Batteries Europe, "Roadmap on raw materials and recycling," 2019. [Online]. Available: energy.ec.europa.eu/system/files/2021-12/vol-2-009.pdf
[11] C. T. Matos et al., "Material System Analysis of five battery-related raw materials: Cobalt, Lithium, Manganese, Natural Graphite, Nickel," Luxembourg, 2020. doi: 10.2760/519827.
[12] ProSUM, "Historic and Current Stocks Deliverable 3.1," 2016. [Online]. Available: www.prosumproject.eu/sites/default/files/24 03 16 Upload ProSUM Deliverable 3.1 v5.1 Final.pdf
[13] Eurostat, "Sold production, exports and imports." Accessed: Jun. 05, 2024. [Online]. Available: ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_11693385/settings_1/table?lang=en&page=time:2020
[14] ProSUM, "Report on consolidation of data into CRM database: Deliverable 2.5," 2017. [Online]. Available: www.prosumproject.eu/sites/default/files/170601 ProSUM Deliverable 2.5 Report FINAL.pdf
[15] S. Lu and J. Frith, "Will the Real Lithium Demand Please Stand Up?" [Online]. Available: about.bnef.com/blog/will-the-real-lithium-demand-please-stand-up-challenging-the-1mt-by-2025-orthodoxy/
[16] G. Wernet, C. Bauer, B. Steubing, J. Reinhard, E. Moreno-Ruiz, and B. Weidema, "The ecoinvent database version 3 (part I): overview and methodology.," Int. J. Life Cycle Assess., vol. 21, no. 9, pp. 1218–1230, 2016, doi: https://doi.org/10.1007/s11367-016-1087-8.
[17] S. Carrara et al., "Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study," Petten, 2023. [Online]. Available: rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2023.pdf
[18] M. Sanders, "The Rechargeable Battery Market and Main Trends 2016-2025," Novi, 2017. [Online]. Available: www.avicenne.com/pdf/The Rechargeable Battery Market and Main Trends 2016-2025_C Pillot_M Sanders_September 2017.pdf
[19] C. Pillot, "The rechargeable battery market and main trends 2020-2030," Lyon, 2021. [Online]. Available: www.avicenne.com/pdf/The Rechargeable Battery Market and Main Trends 2020 – 2030 C Pillot Presentation at BATTERIES 2021 Lyon France September 2021.pdf
[20] M. Abdelbaky, J. R. Peeters, J. R. Duflou, and W. Dewulf, "Forecasting the EU recycling potential for batteries from electric vehicles," Procedia CIRP, vol. 90, pp. 432–436, 2020, [Online]. Available: https:www.sciencedirect.com/science/article/pii/S2212827120302808
[21] Y. Tanf, Y. Tao, Z. Wen, D. Bunn, and Y. Li, "The economic and environmental impacts of shared collection service systems for retired electric vehicle batteries," Waste Manag., vol. 166, pp. 233–244, 2023, doi: doi.org/10.1016/j.wasman.2023.05.008.
[22] M. H. S. M. H. Haram, J. W. Lee, G. Ramasamy, E. E. Ngu, S. P. Thiagarajah, and Y. H. Lee, "Feasibility of utilising second life EV batteries: Applications, lifespan, economics, environmental impact, assessment, and challenges," Alexandria Eng. J., vol. 60, no. 5, pp. 4517–4536, 2021, doi: https://doi.org/10.1016/j.aej.2021.03.021.
[23] D. Aschermayr et al., "Battery Passport Content Guidance," 2023. [Online]. Available: thebatterypass.eu/assets/images/content-guidance/pdf/2023_Battery_Passport_Content_Guidance.pdf
[24] The battery pass consortium, "Data Attribute Longlist," 2023. [Online]. Available:view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fthebatterypass.eu%2Fassets%2Fimages%2Fcontent-guidance%2Fpdf%2F2023_Battery_Passport_Data_Attributes.xlsx&wdOrigin=BROWSELINK
[25] W. Hofman, B. Rukanova, Y. Tan, N. Bharosa, J. Ubracht, and E. Rietveld, "Digital Infrastructures for Compliance Monitoring of Circular Economy: Requirements for Interoperable Data Spaces.," in Future of Information and Communication Conference, Switzerland: Springer Nature, 2024, pp. 332–351.