The Roles of Variable Information Exchange and Ethical Prescription in the Social Determination of Lithium Ion Battery System Technologies in Global Production Cycles

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September 9 2023

Abstract

The distinguished methods of tapping into, and harnessing renewable energy potential have proven to be an epicenter of sociological debate, ever since the tangible beginnings of the climate revolution in the early 21st century. The environmental repercussions of the excessive combustion of fossil fuels on a large scale are not new to the global society. They have persisted in being an existential threat to multiple demographics, the consequences of which have varied based on multiple social factors. The supply risks associated with these factors include wealth distribution, location, literacy, race, development status, and class. lithium ion battery system technologies are one such medium through which the transition to renewable energy sources will outlast the long-supported extraction mechanisms for crude oil. Lithium ion is a revolution for battery manufacturing as a whole. This paper analyzes the ways that the ethical attitudes and the general investment interest in lithium ion battery technologies are influenced by several socio-scientific factors, which is further developed through how exclusive geographies can access variable information exchange. When part of a social risk assessment, these factors induce an investment or a divestment in lithium ion technologies on a governmental scale, from more than just the angle of adverse environmental hazards. This paper also uses the configurations of product life cycle metrics and the technical synthesis of novel lithium ion batteries, on the basis of supply chain shifts due to social hotspots, such as financial corruption, child labor, modern slavery, industrialization, and internal displacement of the poorer substrata of a population. These assessments lead to ideas about how the availability of variable information motivates public strategies to accelerate the production of lithium ion battery systems, a recycling-based supply chain, and the back-end considerations/recommendations for doing so. Furthermore, this paper examines how these social determinants are responsible for varying public expenditures on lithium mining and cell research in different geographic locations, therefore reaching more deeply into the geographical multiplicity of scientific discourses surrounding the engineering of sustainable materials. To elucidate said discourses, this paper makes use of an interview with a sustainable energy expert who has worked in power transmission and public sector grid planning in the Caribbean, Eastern Africa, and the Netherlands, which are the three primary scholastic cases for evaluating the relationship between lithium ion battery manufacturing and the aforementioned social hotspots in this paper.

I. Introduction

The orientation of the socio-scientific debate surrounding lithium ion supply chains stems from the collective scholarly understanding of the need for a holistic cross-examination of the development stages of lithium ion products. This has warranted the publication of an assortment of literature that evaluates supply chain efficacy in terms of prices and market forces within the renewables sector. Typically, its corresponding data has been supported practically with a risk assessment of the social attitudes surrounding mining, bulk manufacturing, transport accountability, and waste management. These social attitudes are the primary drivers of prevalent market expansion patterns in different epicenters of the global supply chain for lithium ion battery systems. These attitudes also revolve significantly around the pockets of sustainable energy requirements that surface when concerning the national targets of unique supply chain stakeholders.

The first constituent affected by said attitudes, is variable information exchange. In this paper, variable information exchange is the categorical monitoring and transfer of data surrounding raw material projection and its distribution across a battery production process. Rather than analyzing the systems through which the transfer of this information is mandated, this paper takes an exploratory approach into the entities themselves, namely the concerned parties in the global industrial sectors for lithium ion and associated chemicals. The latter is prescribing material techniques that aim at resolving fallacies in battery system projection frameworks, which ultimately result from a variety of ethical and financial considerations. The prescription usually revolves around the validity of the growth of the metal mining industry, or the premise for the commoditization of electric or micro electric products (Ching 2021). Exploration is performed on these frameworks and their connections to social construction of the system's engineering design, through risk determination in cases unique to different regions. Further exploration in manufacturing is also conducted, pertaining to engineering discussions surrounding the optimization of a currently cost-intensive, energy-wasteful process of smelting lithium ion batteries to obtain recyclable metals that motivate circular economic strategies. From the viewpoint of geographic multiplicity, these are once again, region-oriented cases, based on the degree of involvement of the national production methods that are studied here.

The enhancement of resource flow can help one ascertain how the incentive for cell research prescribes belief systems that have induced changes in consumer expenditure on community levels to varying degrees. This is simply because disruptive methods to battery innovation will continuously be created proportionally to the expansion of the industry itself, which directly pertains to very primitive stages of production, all the way to its terminal. Existing literature often concludes that this has been contingent on the strategies motivated by public sectors in conjunction with the SDGs, to strengthen the market for lithium ion battery powered products, given its preconceived scientific status as an emerging technology. Keeping the veracity of this conjecture momentarily aside, the traction of the global sustainable energy movement subsequently affects such decision-making in the industrial sectors of manufacturing and transportation. On the contrary, the vast dissemination of information regarding its environmental aspect in a multitude of scholarly bodies of work places it outside the scope of this paper, in order to reinforce the scholarly principles surrounding the equal distribution of variable information. [1]

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[1] In this investigation, information exchange *surrounding* the validity of manufacturing and production flow of lithium ion technologies is weighted according to the expansion of the industrial sector of the case in question. This in itself will be subject to direct variation by the biases that exist inherently in the distribution and consumption of information regarding governance over the technology, certainty, externality of transfer, utility, and shares. This information is possessed by different actors of authority, depending on the contribution of the case to the focused movement on lithium ion supply chains. This is nothing but the technicality of variable information that must be equitably distributed amongst different populations to ensure even, or *reliable* industrialization—hence bringing the importance of knowledge repositories and databases into question (explained thoroughly in the below analytical features).

In recent studies, variable information exchange as a material determinant has yet to be crystallized. The aforementioned locations have been chosen with the purpose of introducing a fieldwork analysis on supply chains that pertain to consumer demographics that are *less* represented scholastically in global markets for metals, cathode arrays, battery storage systems, and EVs, all of which are connected in some form, to the fundamental device of a lithium cell. For instance, data for assessments of lithium ion manufacturing and productivity in the global superpowers such as the United States, China, and India, or social strategies influencing metal mining in Latin America, has been much more widely distributed compared to that of the African Continent. Qualitative exceptions include the Congo, being the primary producer and exporter of cobalt, majorly used for electric grid applications and similar material substrates. Existing debates are only beginning to open up ethical techniques to address loopholes in the consolidation and temporal dynamics of the lithium ion market across all stages of (more so, the physical transitions between) production levels (Ching 2021).

Ultimately, the aim of this research is to unravel the intricacies of those debates. This paper aims to better understand the social forces acting on the ever-growing industry for battery system raw materials—a modified form of intensive scrutiny on the loopholes present in the transitional processes of lithium ion manufacturing. By analyzing this from the angle of chemical composition, to occupational danger, to the lens of collective social risks, the science behind lithium ion manufacturing gets yet another set of facets added to it for a successful achievement of the earlier mentioned holistic cross-examination. The future of an arguably less wasteful lithium ion cyclical supply methodology, rests on, and *injects* into the perspectives offered by the future reference angles, in a way that simulates socio-scientific workings both behind and ahead of the manufacturing and production cycle of battery system technologies. Not only does diving into the structure behind these facets aid in assessing their reliability (See “Novelties, Visions and Socioeconomic Concerns” and “Supply Chain Qualification and Governance”), but also their status in the social determination hierarchy, and its measurable significance to the entities of information transfer. Objectively, it is possible that such examinations into what visibly determines variable product information to be variable, could introduce relatively newer framework reinforcements in the global configuration of supply chains for emerging technologies on a broader spectrum. Within such a widely concerned, diverse forum of scholarly communities and disciplines, this is all in the hopes of developing the continuously overlapping realm of engineering and interdisciplinary studies.

For the sake of standardized nomenclature in this research paper, variable information exchange is abbreviated as VIE, and ethical prescription is abbreviated as EP.

II. Literature Review

Socio-scientific Determination of Manufacturing and Growth

Overviews of Risk Assessment

When considering the sustainability of a product within a certain life cycle, it is a fair practice to accommodate discussions and statistics that look beyond the environmental impacts on its global production cycle, as introduced in *Assessment of social sustainability hotspots in the supply chain of lithium ion batteries* (Thies, Kieckhäfer, Spengler, Sodhi, 2019). By mapping the resource flow of fundamental components of lithium ion cells through a Life Cycle Assessment model (Social Hotspot Database, or SHDB), an extensive *risk analysis* of the social determinants constituting a growth in product valuation across its development was executed, proving certain relationships between the same. This is a predominant example of the results of vast information exchange availability. The interpretations of this variable information therefore allow for quantitative *risk* assessments of lithium ion battery technologies to be produced specifically via pointing towards observations about expenditure and supply made by multistage categorical data.

The assessments are defined under the SHDB for collective enquiries surrounding the production stages of battery cells for electrical applications, using S-CLA - "a *methodology to analyze the potential positive and negative social impacts of products along their life cycle, comprising all activities that are related to the extraction and processing of raw materials, manufacturing, distribution, use, maintenance, recycling, and final disposal"* (Thies, Kieckhäfer, Spengler, Sodhi 2019, page 294). The horizontal workflows illustrated by the battery production configurations corroborate variable information on socioeconomic determination from the SHDB. Within the SHDB's risk assessment framework, these workflows include:

- The assembly of raw materials (qualified categorically by the SHDB as metals, minerals, capital equipment, scientific instruments, and their respective component products);

- Manufacturing the battery cell, for instance, lithium-nickel electrodes / multilayered compound coating setup for lithium cells;

- Battery packs and power grids for mobile applications that shift gross product add value and demand.

The risk indicators used had concluded that the literature is country specific on the basis of seemingly axiomatic assumptions, not unique truths, for lithium ion battery technologies visible in the production centers chosen for this paper. VIE, as aforementioned, is limited and distinguished to a comparative extent (Thies, Kieckhäfer, Spengler, Sodhi, 2019).

The order of the supply chain configurations varied for each center of production, by cumulative risk hours. SHDB's risk mapping tool allowed for information exchange related to the social responsibility of stakeholders and their investments in the supply chain of lithium ion battery cells, to determine that China focused production epicenters expose their facility components to the highest social risk, on the basis of child labor, poverty, corruption, and occupational toxic hazards (Thies, Kieckhäfer, Spengler, Sodhi, 2019). However, even within a dataset pertaining to three production centers, the supply chain configurations changed to such an extent that leads one to believe that information exchange about corporate and government investments in their niche of the supply chain is much more skewed outside of this risk assessment, in the way that they determine lithium ion battery production outcomes. This was best demonstrated by the lack of information regarding the status of the technology's social risk in the DRC, despite being a tremendous acting party in material outsourcing for cell metals. This stagnance of VIE inevitably forced the literature to draw stark comparisons between the consumer demographics of China and Zambia instead—a potential source of information bias in an otherwise quantitative assessment.

For one to therefore understand the application of information about risk determination in other countries, such as the ones of our choice in order to fill a shallow void in the fieldwork, one must simultaneously ascertain the ethics behind sustainable development and how, unlike fossil fuels, an expansion of the industrial sector comprising lithium ion electronics is projected to occur on the basis of EP from corporate entities, public policy, and market demand. Future sections elucidate the dynamics of this expansion as perceived by the lithium battery market stakeholders for the three chosen case studies, in an established coalition with social determination.

The Peripheral Ethics Behind Manufacturing Frameworks

As mentioned before, the focus of this paper is narrowed down to redefining the industrial mechanisms put in place by socio-scientific determination of the market for battery technologies, in a multifaceted distributional manner, and not *exclusively* an eco-activist one. EP as a determinant can be best analyzed in the context of the disconnect between international centers of transport and exchange of materials.[2] If one scrutinizes specifically the origin of production for the application of prescription-based methodology, one can, as introduced earlier, take the example of the DRC, extracting and outsourcing roughly 60% of refined cobalt for cell manufacturing across the production cycle (Murdock, Toghill, Tapia-Ruiz, 2021).

The Modern Slavery Index (MSI) of African nations is a social hotspot within which considerations about life cycle development can be made for primary industrial sectors. The article, *Sustainable Industrialization for Luxury Products: Manufacturers and Retailers Must Commit to Tackling Modern Slavery in Africa* (Taifa 2021), uses MSIs to quantify the industrialization of sustainable manufacturing, not related to lithium ion battery packs as products, but rather luxury materials that require similar metal

[2] The asking question: What would the definitive purpose of peripheral ethics be in a prescription assignment to sustainable technologies, in the lithium ion battery system supply chain's numerous industries? Prescription of ethics induces the incorporation of economic arguments *when* holding truth and relevancy to the communities of stakeholders in the industry. It is to invalidate logical fallacies in production methods—integral to the devices used in the manufacturing aspect of these systems. The "periphery" here widens to concern all of sustainable bioethics, be it behind material chemistries or part assemblies, or any other exclusive stage in the supply of the technology. This is where the dissection of the production processes comes into being on a ubiquitous level for *all* cases in question.

compounds. This is done in order to create a social understanding of East Africa's apparent modern slavery, and how it has catalyzed developing countries' investments into lithium and cobalt ores. It evaluates the supply of products related to MSIs in East Africa, as a parameter to investigate the payoff of investments into sustainable material technologies in the continent, such that it focuses on the social implications of bodies of labor and neo-slavery themselves.

Previous analyses related to other products that are explicitly disparate from lithium ion battery systems but comprise similar raw materials, such as luxury items like jewelry are presented. MSIs being challenging to distinguish from the homogenous pool of identifiable crimes in Eastern and Central African countries makes the analysis of spending patterns on receiving ends of the supply chain, (such as in the United States where MSI data reads little to nil), much more ambiguous than expected. Several conglomerates that endorse the distribution of finished products from Congolese manufacturers that were charged with illegal exploitation of workers, are simultaneously responsible for over a third of the shares of lithium ion battery system transport facilities in their host countries, keeping them actively part of the life cycle. Taifa draws from data on contemporary slavery in the DRC from the Global Slavery Index (GSI), acknowledging the net pressure acting on the industrialization of markets due to advocacy of sustainable production practices from a manufacturing standpoint, with direct scrutiny of the African continent.

One might question the relevancy of a methodology such as this, which is associated more towards a risk analysis of luxury products instead of lithium ion battery components. However, when taking into account the preconceived skewed distribution of lithium ion battery system consumption across different geopolitical areas of influence, our primary observation is that the motivation of strategies for the outsourcing of metal oxide components, bulk production of cathodes, and then mass transportation, are all in tandem, qualitatively contingent on the disparities of gross national income (Killer, Farrokhseresht, Paterakis 2020). The adverse effects of income-based determination of the supply chain are experienced by different contributors to the supply chain in different manners. It is therefore fair to infer that battery systems using lithium ion cathodes are necessarily the opposite of inferior goods, causing an extension of this scrutiny directly into the dynamics of the manufacturing process in countries that have higher stakes in the overall cycle, like the Netherlands. Data need not be assimilated for this inference, but since the economic strategies of lithium ion recycling are to be analyzed on the basis of development, (See "Determination of a Circular Economy" and "Field Discussions"), our socio-scientific analysis takes us to the interpretations of the production configurations in our two other epicenters—warranting us to attempt to draw at least an abstract correlation (See "Supply Chain Qualification and Governance") between socioeconomic motivations within each epicenter and their respective industrial growths (Navalpotro, Castillo-Martinez, Carretero-Gonzales, 2021), using a *crucial* Central-East African case like this, as one of our many assessment references. At this juncture, ethical consideration as a determinant of lithium ion supply projection becomes more complex than it seems—a visible trend with numerous emerging technologies.

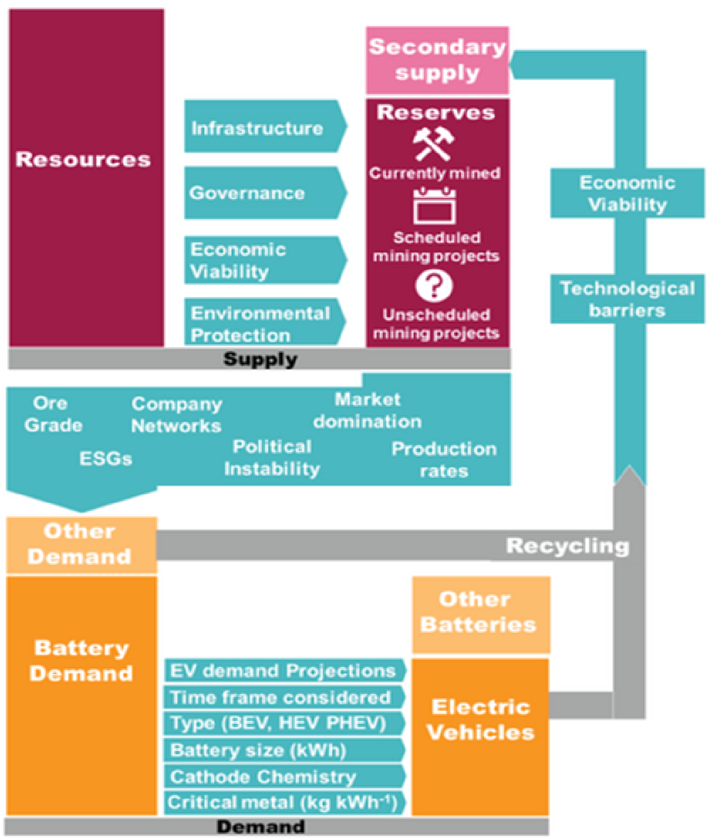
The future engineering priorities for ensuring a sustainable e-mobility transition are outlined to primarily revolve around combating the scarcity of battery system recycling centers in the Global South. The priorities entail recommendations surrounding the enhancement of social determination of *primary* production facilities in Central-East Africa as a risk-prone region for "unethical" lithium ion transitioning and outsourcing (Prates, Karthe, Zhang, Wang, O'Connor, Lee, Dornack 2023), so the "scarcity" is therefore oriented around development indices. Battery system workflows in this region have been labeled as affordable opportunities for "characteristic shifts in the decarbonization of the African continent", which, as part of the ethical weightage, is countered by the gap that was identified in African lithium ion cell production facilities (Prates, Karthe, Zhang, Wang, O'Connor, Lee, Dornack 2023). The paper cites a scholarly article written by Roychowdhury, who states, "*This market still lacks regulation to prevent dumping of end-of-life vehicles and thus lithium ion batteries in the import countries and shifting of responsibility of disposal from the Global North to the South*" (Roychowdhury 2018*).* The unique angle about development disparity cited here, which indeed complements our investigation into VIE, is expressly demonstrated through such analyses. At the same time, it also prompts explanations behind some general production processes that outline the current workflows of lithium ion outsourcing (both raw material and finished array) that optimize its conditions for larger technical investors in the industry (See "Novelties, Visions, and Socioeconomic Concerns").

In a more general sense, we can do so through the interpretation of prescribing simulations to a decently standardized supply chain workflow model. The details of the figure demonstrate the decision specifications needed for the projection of supply in the lithium ion cathode array market, out of which the several dominant factors displayed can be analyzed for all of the aforementioned cases to obtain a holistic approach towards the implications of social determinants on supply specifically, and then use statistical methods to display the variation between results to come to a conclusion.The frameworks it outlines integrate developmental procedures exhibited by common epicenters of lithium ion battery technology production and transfer. Demand in this outline can be directly characterized to suit the effects of the earlier overviewed risk determination, in the *context* of variable information gaps—except in this case, it is externalized by the consumer populace—which incorporates the socioeconomically induced technical risk element (See "Introduction" and "Overview of Risk Assessment"). Literature explicating these elements in the Netherlands and the Caribbean is often seen stating that said elements are omitted in qualitative analyses limited to the environmental objective itself.

In addition to our inferential discussion, the irregularly accelerating investment into engineering circular-flow battery systems, ties once again into previously cited investment and importation opportunities in the industry that have been realized by larger corporate and public entities that endorse the facilitation of standard cathode array projection. This is even clearer with the cases being evaluated here, where, as will be shown in the workflow, the modus operandi is to *efficiently* secure the transitions of material, chemical, and electrical manufacturing components in a circularly economical production method. Linking this to our prior debate on the assessment of social hotspots database for battery technologies, the development framework also suggests that *"Reliable and accurate databases are fundamental to allow adherent policy and decision making for short, medium, and long term as well as predicting and assessing future scenarios*" (Prates, Karthe, Zhang, Wang, O'Connor, Lee, Dornack, 2023).

This means that one precise outcome of a prescription assignment to a standardized battery production workflow such as the one above, is that: Equitable VIE is still a continuous necessity in order to determine the security of battery market forces, which in turn, answer a part of the discussion about whether the manner in which feedback occurs in the production multistage is "correct". The passage of this information between the producing entities and the remainder of the industry is only upheld through oversight of economic viability, (Murdock, Toghill, Tapia-Ruiz, 2021) and hence the regulation of this facet lies as a prerequisite both for the assembly and transport of

Figure 1): A diagrammatic representation of a multistage lithium ion industrial workflow, that outlines the transfer of materials and assembled battery systems to different industrial sectors while accounting for the mitigation of risk through ESGs and recycling. (Murdock, Toghill, and Tapia-Ruiz 2021)



natural resources, *and* in overcoming the technical barriers that exist in circular flow. A sustainable database's role in evaluating the efficacy of a workflow like this through social determination (See "An Overview of Risk Assessment") would therefore diminish the impacts of cost-intensiveness, but also scale the *absolute* value of demand within the global production cycle, accounting for the demographic changes created by access to variable information. One such change is explored below through the lens of ESGs (Environment, Society, and Governance), to see whether currently valuable information allows one to standardize the roadmaps of battery production cycles in varied epicenters, or not.

Supply Chain Qualification and ESGS (1)

Fig. 1 is the explicit multi-stage workflow that models the continuous development of production stages in lithium ion markets, for highly demanded battery technologies in the sector (Murdock, Toghill, Tapia-Ruiz, 2021). The diagram advocates a counterargument to lithium cathode sustainability by analyzing the ESG (Environmental, Social, and Governance) concerns sparked by heavy cobalt-mining in the cathode manufacturing process. To bring clarity to this argument, it is well-suited to take the Congo and how their influence on global supply chains for cobalt ore also steers their national economy towards public investment in lithium ion cathodes. In terms of VIE, the argument presented is: *"Financial viability can be further improved by establishing domestic battery waste schemes by avoiding high transportation costs, in which sufficient policy surrounding battery waste management, increased recycling capacity and increased public awareness will be key. While a secondary supply is crucial, the additional environmental impacts of recycling, such as waste and emissions, adds further complexity. Current literature lacks quantification of such impacts which is necessary for critically assessing and comparing various recycling methods."*(Murdock, Toghill, Tapia-Ruiz, 2021). This literature therefore recognizes supplementary facets that contribute to the groundwork laid in establishing our previous hypothesis about risk determination. According to the amalgamation of the presented concepts, the current framework gap is that the ESGs of transports are barely quantifiable or acknowledged in a scholarly setting. On top of the scholastic under-representation we identified (See "Introduction"), this only heightens ambiguity in a sustainable production cycle—a plausible explanation for why variable information about the cost-effectiveness of primary and secondary supply by researchers' daily-use databases is not entirely accurate.

Peripheral ethical consideration behind the manufacturing of the materials would become evident in the supplementary diagrammatic shifts in the outline, ESGs being the most fundamental example of a prescription assignment. Governance in ESG is a primary risk indicator in the moderation of the flow of processed battery equipment. The force by which the expansion of the market correlates to the security of supply networks, depends on how far-reaching public policy is in legislatively molding demand for the recycling of lithium ion batteries within an exclusive demographic (Petravratzi, Sanchez-Lopez, Hughes, Stacey, Ford, Butcher. 2022). Now, bringing recycling into the equation for highly state-involved sectors such as the Dutch industry for mining and imports, we understand that governance also becomes a matter of projecting a self-sustaining reserve supply to battery demand. This conjecture is applicable for when the sector accounts for the government's marginal national income spent on ore refineries, laboratory expense, and waste management facilities (under resources, infrastructure, and to an extent for the secondary supply of finished technologies: cathode chemistry). This hypothesis creates more space in the field for researching political tools that satisfy such recommendations.

Possibly due to variation in the public knowledge repository that constitutes the information about consumer spending, the Netherlands as a case provides an insight to our discussion on VIE through public policy. The Dutch Climate Agreement, till current date affects the aggregate distribution of lithium, cobalt, nickel, and associated electrical components, subsequently affecting its demand within the Netherlands. The approach of device distribution in the Netherlands caters to a resolution to the Dutch transportation industry contributing 12% of global greenhouse gas emissions (Tang, Sprecher, Tukker Mogollón, 2021). To further evaluate this subset of the ESG vertical, *The Impact of Climate Policy Implementation on Lithium, Cobalt and Nickel Demand,* in a projection analysis, makes use of mathematical tools to extrapolate current demand data in the grid manufacturing of lithium ion based products. The discussion's presentation of prescriptions surrounding ESGs help hypothesize that demand will skyrocket in the near future, in time for the effects of lithium ion on the renewable energy sector to complement SDG requirements in the Netherlands, as per the provisions of the Agreement (Tang, Sprecher, Tukker, Mogollón, 2021). Demand and expenditure can be analyzed qualitatively as contingencies of these mechanisms, though sampling bias may still be a small role player due to the database's specificity to the automotive industry—subsequently narrowing down the production branches of lithium ion systems to EVs. This could benefit future research into the matters of EP because of the consistently reiterated need for transport accountability and qualification of the global production cycle, in this paper. The validity of conjectures surrounding the biases that come into play while analyzing public policy's motivation of strategy is subject to immense debate. A similar case is taken up with St. Kitts in "An Analysis of Strategy Motivation and Industrial Valuation".

Where does the periphery shift upon changing our scrutinized demographic? From the investment angle of public corporations rooted in battery exports from the European Union, the Netherlands illustrates a consistent exchange of production and transmission between share entities in most secondary stages of the lithium ion automotive industrial sector. In terms of the policy itself, the socio-scientific groundwork laid for interpretations of the Agreement are yet again determinants playing into symmetric thematic overviews. Similar to the Netherlands' supply chain qualification on ESGs (mostly a qualitative judgment), public strategic motivation such as this can even be seen in the stakeholder's material manufacturing frameworks on infrastructure and market domination, as is subjectively true for cases with higher public investment indices (Murdock, Toghill, Tapia-Ruiz, 2021). Our simulation of the mechanisms of VIE in the Dutch ESG frameworks testifies for this newly arisen claim surrounding governance. However, among other production verticals, *this* information is prone to leveraging *development skew* to alter the focus of our comparisons to the dynamics of the size and efficiency of the Dutch national economy. To curtail that skew, the complications of the battery system industrial sector have been discussed from a primarily technological lens.

The Material Development of Cathodes: Novelties, Visions, and Socioeconomic Concerns

That being said, discussions about the social determination perspective of the lithium ion global production cycle, are not only supported, but enhanced, by the industrial research undertaken to improve the efficiency and sustainability of battery production. Keeping nations as a points of cross-reference aside, we can take the example of lithium polypeptide organic radical construction (Thompson 2021; Grey, Hall, 2020), which involves an organic substrate that substitutes conventional production metal extraction that, according to our analysis of previous social risks, is prone to a large assortment of social concerns (Nguyen, Easley, Kang, Khan, Lim, Rezenom, Wang, Tran, Fan, Letteri, He, Su, Yu, Lutkenhaus, Wooley, 2022). In a comprehensive summary of the organic radical construction research, corresponding authors Lutkenhaus and Easley state that *"Organic radical batteries have emerged as promising alternatives because the active material is a redox active polymer that has potentially increased environmental friendliness, independence from limited inorganic resources, and fast charging rates."*, as a solution to the long-standing problem of *"design of functional polymers with an end-of-life consideration"*, taking us back to Roychowdhury's claim (See "The Peripheral Ethics Behind Manufacturing Frameworks"). To reduce the dependency on metal coatings, organic redox-active polypeptides use polymer backbones, which is an increasing consideration for electrode design. Though organic redox-active materials have their own adaptability benefits and greater abundance, from a VIE standpoint, it is worth focusing on a point about electrochemical structure: current research attempts to reach a production stage where the biodegradability of active-redox batteries is independently easier, where the electrode possesses the ability to dissolve in an acid, allowing for iterations of the assembly cycle, as shown in the below diagrammatic representation (Nguyen, Easley, Kang, Khan, Lim, Rezenom, Wang, Tran, Fan, Letteri, He, Su, Yu, Lutkenhaus, Wooley, 2022).

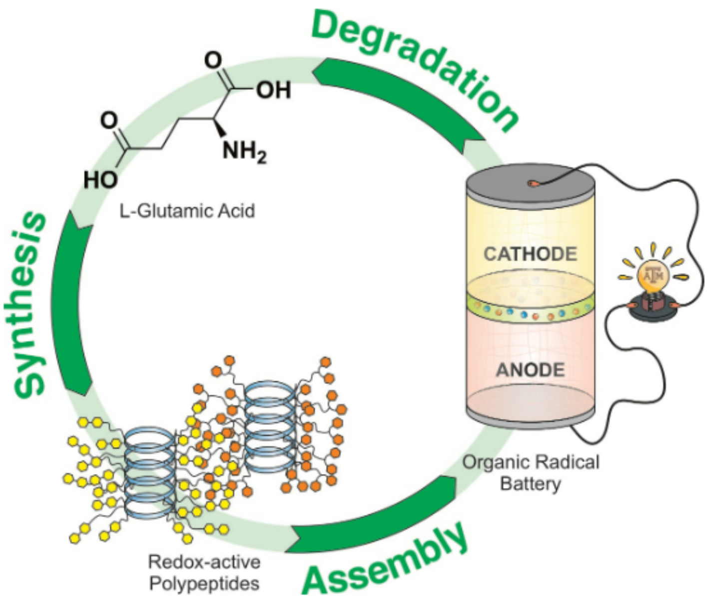


Figure 2 (right): A simple representation of the biodegradable properties of novel redox-active flow polypeptide electrodes in the radical construction of organic batteries—useful in allowing for the social anxieties of raw material mining and extraction, such as child labor, to be omitted (Lutkenhaus, Easley, 2022).

Building on our assessments of the supply risk of cobalt ores, the projection of demand for EVs that occurred post 2015 yielded a growth in findings surrounding $LiFePO_4$ (lithium iron phosphate), which was typically researched to have a decent cycle life for a full assembly through e-waste process, but low energy density—leading to poor demographic utility for long distance vehicular travel. However, it did serve as an alternative to earlier onset exothermic cathodes, essentially those processed with nickel, manganese, and cobalt (NMCs) (Easley, Lutkenhaus, 2022). To prevent cathode degradation, battery system manufacturing costs have tended towards overcompensating for lower material costs that arise from manufacturing systems without cobalt or nickel. The higher manufacturing cost was derived from the need to meet a desired energy output for long term applications with additional processing of dielectric coatings, or even additional electrode layers, to limit the reactivity of nickel as an active cation in the battery electrolyte. From the perspective of mining materials, in order to make a cell applicable for a variety of battery systems, its energy density must be optimized. This comes at a decline in material cost at the expense of incorporating a costlier metal such as nickel (because per unit of energy expended, less material is needed for the electrodes in the manufacturing framework), having its own associated social risks (Murdock, Toghill, Tapia-Ruiz, 2021). However, the demand projection seen in earlier sections does depend on the share of different types of battery technologies in the industry, which prompts further research to be done into the cost-effectiveness of manufacturing organic radical polypeptides and similar active-redox electrochemical converters.

As observed with active-redox batteries, the motivator of cell research on a demographic-oriented scale is achieving satisfactory consumer utility. By evaluating the coulomb efficiency, crossover, and other power metrics, these experiments are aiming to find the optimal cell construction methodology for long-distance battery applications, such as in transport. The motivation of this type of methodology is consumer demand. Whether a battery could dissolve on demand for achieving a recyclable electrode structure, or not, would provide future indicators about how for each additional kWh of output, cost variability design would shift at the very fundamentals, should the share of these battery structures increase in the industry (which it is, as we observe countries like China focusing China-based production towards $LiFePO_4$ constructions). The optimization of the power density and utility frame of these components using chemical cathode experiments definitely lies outside the scope of the risk assessment, which is strictly focused on the social determination of the forces surrounding the manufacturing cycle itself. Therefore, socio-scientific determination here leads us to infer that there could be behavioral aspects of technical faculties that influence the acceleration of research into cheaper, more sustainable layered lithium ion cathodes.

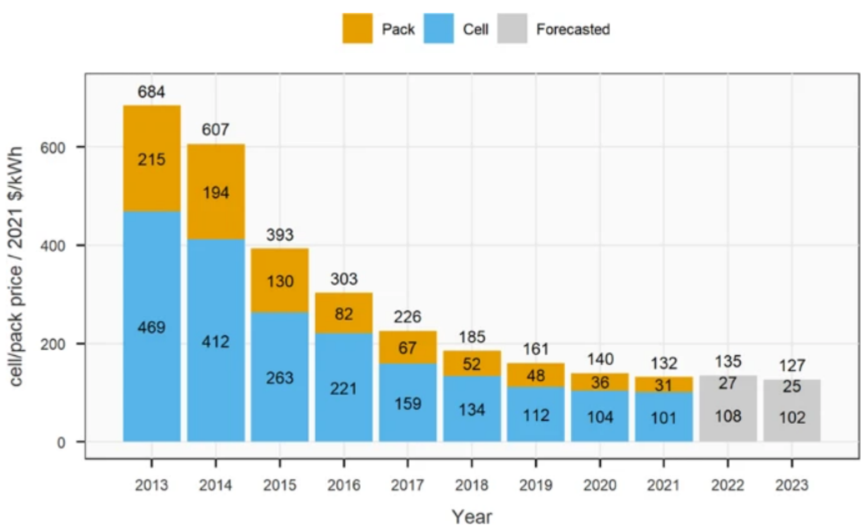


Figure 3: Graphical trend representing the downward-sloping consumer cost (including externalities) progression of lithium ion battery systems, along with a 2 year cost extrapolation using a demand projection as of 2021 (Frith, Lacey, Ulissi, 2023).

A non-academic perspective on the future of lithium-based batteries (Frith, Lacey, Ulissi, 2023) offers substantive insights into these faculties from the perspective of cost-intensivity and social commoditization. It recognizes the distinction drawn between academic research and industrial needs, once again recapitulating on our hypothesis of the cruciality of consumer utility in projecting market costs. As lithium ion technology becomes a common-use system in geographical locations that heighten development bias (i.e, countries higher on the development index) such as nations of the European Union, it is observed in this work that the substitution of active electrodes with the cheapest metal combinations (for instance, NMC 811 which contains less than 8% cobalt), contributes immensely to decreasing prices, but as electrolytes become scarcely produced, commodity costs become detriments to manufacturers (Frith, Lacey, Ulissi, 2023) According to a 2021 Bloomberg-NEF study, this decline is forecasted in the above figure, as of the second half of the year (Henze 2021).

According to a 2022 statistical report by the IEA, the estimated average battery price stood at approximately \$150/kWh, only a margin of error of 11% for all estimated global production cost samples ($p=0.005$) with the aggregate manufacturing cost amounting to about 20% of total battery cost.. The gradual decrease in consumer costs for finished battery packs in major production epicenters, (such as but not limited to multistage operations between Germany, China, and Canada) plummeted by a mean of 5% in 2022 compared to the previous year. By 2030, the global market for lithium ion batteries in the recycling sector is forecasted to reach over 18 billion U.S. dollars, around 36 times that of 2019. The inversion of cost is still on average, unexplored in current research by the methods of social determination for our scholastically underrepresented cases, the logical connections to our data analysis being outlined in "Methodology: A Field Discussion on Strategy Motivation and Industrial Valuation". The assimilation of the data presented in this study is dependent on the sophistication of data collection techniques usually associated with higher development indexes for standard technology-use scenarios. That being a form of VIE for lithium ion batteries, it becomes clearer and clearer as we pursue this trajectory that the development bias that affects the distribution of consumer awareness about such cost patterns and the social risks behind them, affects the entire global production cycle significantly.

For cost declines to accurately depict the ubiquity of lithium ion technology and socioeconomic concerns, it does not make sense to pinpoint the focus of production processes across the multistage, to only major contributors like Australia and China. They are simply not large enough strata representatives of all socio-scientific risks, because as per the accuracy of global development indexes such as the HDI and GSI which have been studied here, the background consequences are incurred by minor epicenters such as those in the Caribbean. These pressurized repercussions on the global production cycle make us reconsider the contextualization of the raw material processing risks in question: If battery components, such as those that are nickel-heavy, are more rewarding in terms of energy density and long-term usage, then where does the social forecasting visions for the next 10-20 years hold effect on the shapes of the global production cycle that we've observed for newer technology? This is the crux of the VIE analyzed thus far. If we were to assign a prescription to this industrial case, taking the previous determination of ESGs into account, we would begin to ensure that the projected costs of materials are maintained in a way that publicly motivates research into active energy substitutes to lithium based NMCs to combat the risks (See "An Overview of Risk Assessment"), outside of forced measures taken through public policy. This takes us towards the concept of social consequences of recycling processes: A socio-scientific determination of a circular economy.

Ethical Considerations for Distribution Security: Circular Methods

The ability to enhance technical faculties in the quaternary sector is in itself, a critically focused form of variable information. Using that principle, the true surge in variable information is almost entirely due to the sudden supply shift from portable device applications to larger grid applications of lithium ion batteries in less than half a decade (Killer, Farrokhseresht, Paterakis, 2020). Within the East Africa and Middle East region (EMEA), the aim of such qualitative analyses has long been to determine the status quo of the expansionary policies naturally widening room for sustainable visions of lithium ion technologies (using redox flow, or any other novelties) in order to meet the SDGs.

However, existing literature advances the argument that such policies have generally proven to be detrimental to the long-desired regenerative processes of lithium ion supply chain operations, in the way that the application of EP gets hampered when scrutinizing the "take-make-waste" process of producing battery systems. Considering all financial and technical risks associated with mining and assembly that we observed earlier on, researchers now have space to directly address the negative socioeconomic impacts this has on the global cycle. It becomes noticeable that the major representatives of the global supply chain, such as China, Australia, and Chile, accounting for around 90% of shares in global production, all lack the social determination of a circular economic strategy. As observed in Fig. 4, China focused epicenters follow a sequential methodology of producing LCE, silicon, nickel oxides (for electrodes) and dielectric substrates, followed by separators and assembly components, leading towards a finished battery pack—each step of the process, each kiloton of raw materials assembled, accumulating an added social risk (Thies, Kieckhäfer, Spengler, Sodhi, 2019). The same approach has been adopted by the rest of the listed nations.

Circular production would greatly exacerbate the exact opposite impact, ensuring that for each additional market value of moving battery systems in the cycle, revenue growth is accelerated for lower electricity costs, since the origin of materials is now a regenerator. This is the future vision that socioscientific determination depends on. Circular production encourages the motivation of public strategies into recycling in order to achieve a fully efficient waste-managed lithium ion supply chain, which is why the technical expansion of this concept was reiterated innumerably thus far. According to the World Economic Forum, the global production cycle pumped 540 kilotons of raw LCE in 2021. Quantitatively, based on the trajectories of the leading stakeholders in production and outsourcing, demand projections suggest that this value is intended to *triple* in another two years, and increase nearly another *six-fold* in eight years, in order to come close to reaching a net-zero carbon state. *“Although supply has been on an exponential growth trajectory, it can take anywhere from six to more than 15 years for new lithium projects to come online. As a result, the lithium market is projected to be in a deficit for the next few years”*(Bhutada 2021), because of the assertion that due to the cumulation of social risks induced by the take-make-waste system, humankind could be needlessly *“overcharging”* the world. This calls the distribution security of the process of producing lithium ion in a non-circular fashion immensely into question—a question of not only acceleration, but preservation.

To ensure that on the multiple discussed fronts, the reliability of the production cycle is upheld in time for decarbonization costs to be mitigated to their maximum, a World Economic Forum insight report (September 2019), *A Vision For a Sustainable Battery Value Chain in 2023*, outlines the due diligence to be inculcated by each active stakeholder in the supply chain that complements the guidelines established for effective public policy (See “Supply Chain Qualification and Governance”). The report claims that batteries are instrumental in democratizing energy access around all underrepresented production epicenters, for off-grid communities, which could prevent risks such as job insecurity in the market. One counterargument that this ideology does not take into consideration is that the mitigation of such risks are not proportional to the mitigation of the risks that arise with the overuse of the battery value chain. This is because the global sustainability budget for achieving decarbonization by 2030 is exploited on the basis of public investments into the lithium ion sector—it is a “non-renewable” process within a renewable energy transition. However, the insight report did identify that there are certain socio-scientific levers that must be handled by public and corporate entities within their jurisdiction over the lithium ion grid, to change the trajectory of the production process, taking us back yet again to the circular objective.

The report outlines a prospective of a circular battery value chain to *"provide 600m people with access to electricity, reducing the gap of people without electricity by 70%,"* whilst simultaneously expanding *"an industry safeguarding human rights, supporting a just energy transition and fostering economic development, in line with the UN SDGs"*, through the ethical creation of approximately *"10 million jobs, and $150 billion of economic value in a responsible and just global production cycle"* by 2030.

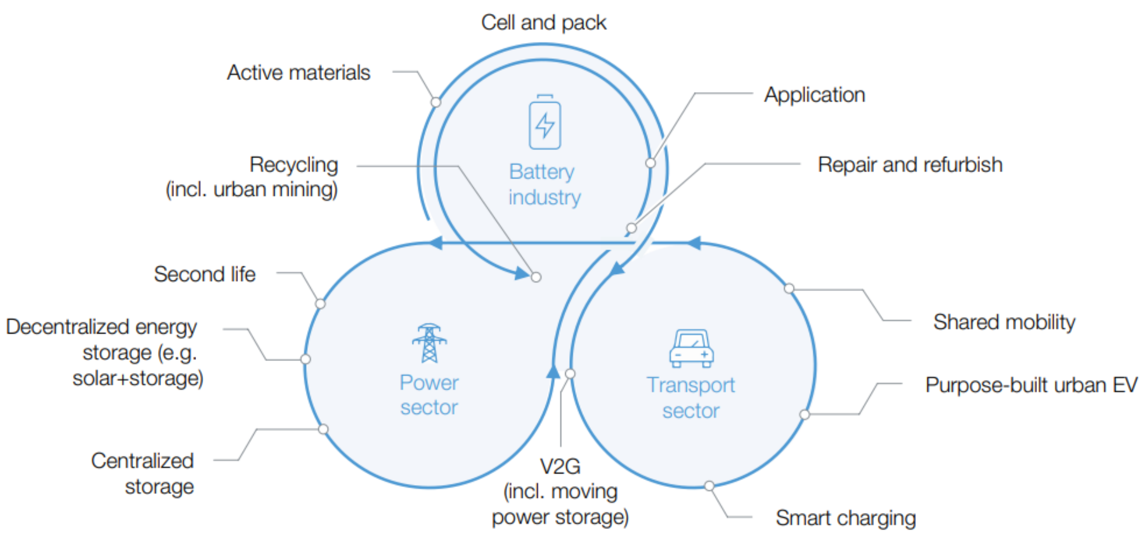


Figure 4: The collective vision for a socially sustainable lithium ion global supply chain, through the determination of circular frameworks, accessing information in e-mobility, storage, power distribution and material reusal. Sourced from weforum.org:"A Vision for a Sustainable Battery Value Chain in 2030 Unlocking the Full Potential to Power Sustainable Development and Climate."

In Fig. 4, which outlines the insight report's vision for a circular global value chain, the areas highlighted by active materials, repair, and recycling, are the three major points of the production cycle that require maximum and frequent prescription of ethics, to make a logistical connection between the battery manufacturing industry and the mobility of the finished product through transport and supply to risk-prone or risk-averse communities (depending on the market cost of the technology respectively). The insight report dictates that the supply chain's trajectory is projected to a nuanced level while considering the grid, as that is where the primary source of interaction between our case study's demographics and the accountability of the public sector for transportation, comes into play, which automatically means that information exchange is underway.

The report also addresses the social need of determining the optimal way of delivering both data and battery system logistics to the off-grid stratum, which currently remains unanswered by production giants, who in turn exploit said stratum for the manufacturing end of the battery industry. No matter the marginality of their localized supply chain's contribution, the Netherlands has been a role model, in using social levers to bring data to the receiving ends of their transportational facilities, making them more recognisable parties in the supply chain. As an epicenter, leveraging the abilities of the Dutch circular economy has allowed their production multistage to inch closer to a target of 275 GWh annual storage capacity on demand of finished lithium ion systems (Jiao 2019). A comparatively novel approach that has optimized the Netherlands' return on EP, is value determination through circular business models or CBMs (Vence, Pereira, 2018; Albertsen, Richter, Peck, Dalhammar, Plepys, 2021). The resultant upkeep from the circular strategy is because of the collective recognition that the key determinant driving the electrification of the European Union is the security and procurement of raw materials. A positive social trajectory for doing this has been created through interlinking internal factors; external factors; and the guidelines of the recycling, repurposing, and refurbishment processes (Albertsen, Richter, Peck, Dalhammar, Plepys, 2021).

The equilibrium of this type of production cycle was reached via the display of governance in the neutralization of multidirectional risks across the three industrial sectors interlinked in Fig. 4, through recycling batteries that had reached their end of life. Lifetime costs that are projected in the cycle are naturally intended to be lower than the upfront capital costs, but fortunately due to circular methodological frameworks, the workflows analyzed in previous sections are able to bring about substantial declines in material expenses. The circular framework has tremendous scope for inspiring magnitudinous lithium ion transitions, only granted that there are no leakages of expense in the supply chain. The leakages in terms of financial negatives, arise when the rest of the world falls behind in enhancing their abilities to use target levers to halve their carbon emissions using material regeneration, and increase their technological output (upscale their contributions to the fluctuations of the market for batteries). Based on the accuracy of current repositories that are being used by state actors to generate forecasting information, the global supply chain excluding scholastically represented demographics is only projected to reach around 28% of demand, out of which nations like the Caribbean have little to no tangible access to receiving ends of the supply chains, amidst high manufacturing costs (taking into consideration the complications of metal ore shipments). This is where VIE, and the study of how it operates becomes so important in envisioning high data accessibility for different members of our production cases, because only with accurate forecasting can the global supply chain continuously upscale the end of life and utility of battery technologies to decades, without any forced stimulations from third parties. More on the cost-sensitivity of each industry is discussed in "Field Discussions".

When we take another look at driving the EP of the circular methodology through public policy influence in off-grid communities, whose logistical placements hinder their acquisition of variable information, we notice the influence of the lithium ion production cycle in St. Kitts, an island in the Caribbean. Leclanché, one of the global frontliners of power storage and distribution, announced a solar storage project for lithium ion power grid applications, as a form of VIE that can lift the St. Kitts economy to unprecedented heights of technical accessibility. A PR Newswire analysis report that declared this dual-entity partnership quotes the St. Kitts Minister of Public Infrastructure, Urban Development, and Transport, in his saying, "*We are set to embark on this vital solar storage project as a key part of our renewable energy thrust that is critical to the future development of our country*".

It is a novelty in the global production cycle to see formerly off-grid demographics beginning to adopt the circular framework, in the specific sense that 30% of St Kitts' current power generation needs, once satisfied by diesel technologies, are provided and subsequently displaced regeneratively, by cost-saving, equally capacious lithium ion systems. Cost-sensitivity of emerging technology is rigid in the Caribbean due to transportational biases. However, the financial strength of this circular production cycle is guaranteed to be projected through localized demand for another 20+ years, according to the CEO of Leclanché. This is aimed to be done with the refurbishment of solar photovoltaic cell systems having consolidated the expected fuel avoidance cost—tremendously reliable for securing the distribution of energy demand and information access over the Caribbean. Similar adoptions of lithium ion technology has seeped through the partnership's implementation of battery energy storage systems used to *"provide a true "base load" power for a utility on a Caribbean island"*, immensely similar to the Eastern African methodological frameworks (Killer, Farrokhseresht, Paterakis, 2020). Because of the savings created by reliable governance, through a successful switch to a positive outcome of EP, the cost of the grid incurred by Caribbean citizens in St. Kitts is zero, over 20 years of installation procedure (contrarily highlighting the need for lithium ion transport accountability in underrepresented communities, once again). However, this is an exceptional case, and the faltering platform on which such epicenters stand in the global production cycle is displayed further, in an extensive methodological discussion of future goals and visions for the determination of the production process.

III. FIELD DISCUSSIONS

An Analysis of Industrial Valuation Through Strategy, Cost, and Social Commoditization

Supply Chain Qualification and ESGs (2)

In order to obtain well-rounded and detailed insights about the cost-based determinants that play into our methodology, while keeping the qualitative nature of this analysis intact, a field interview was conducted with Senior Energy Specialist at the World Bank, for the 'Sustainability For All' project in Sub-Saharan Africa, the Caribbean, the United States, and South/Southeast Asia, Mr. Rahul Srinivasan. Srinivasan's invaluable experience in the operational facilitation of the lithium ion supply chain to meet electricity provision requirements for off-grid communities in production epicenters is ideal for a series of assessments of this order. Below are his remarks on the socio-scientific determination of the global industry for lithium ion battery and energy storage systems using sustainable ethics and VIE.

When asked about his viewpoints about the social commoditization of lithium ion technology with specific emphasis on the *comparisons* between the production risk-handling efficiency of the case studies evaluated in this paper, he stated:

"What they've realized is, even though lithium is more expensive, its lifetime is longer. Let's say you're looking at a lifetime of five to six years, especially in Sub-Saharan Africa, which has effectively become commonplace in the places in which I've worked. Even though the upfront capital cost is marginally higher on demand for lithium ion battery packs, the cost payoff for a lifetime of eight to ten years per finished product is lower because the widespread utility remains." This is what VIE in research novelties

such as redox flow batteries still needs to adjust to, in order to boost the capacities of the global production cycle, without compromising the general investment and expenditure interests that stabilize the movement of raw materials and finished products, therefore avoiding significant capital costs.

"The other key determinant in terms of switching technologies, or the transitional feature that we consider while attributing a technology to its socioeconomic properties, is waste management. We see VIE through mainstreaming of lithium ion systems across the spectrum. On the contrary, in a case-wise sense, this was lacking in Sub-Saharan Africa or Caribbean. As a matter of fact, the Caribbean is tremendously behind on technological adoption, because in their epicenter of the global supply chain, being on the receiving end of cost inflections, their agility towards industrial shifts is comparatively stagnant."

Srinivasan adds further, *"Our analyses presuppose that scholars keep in mind that the Caribbean lifetime costs are always high. We're analyzing the cost sensitivity of lithium ion batteries in islands, so the cost of importation and large scale installation is automatically much higher."* In essence, the time delay for every added output of energy supplied through lithium ion is inversely proportional to the speed of positive VIE in the renewables sector as a whole, in the case of the island nations. If we took a case-wise example of economic determinants in the case of the Caribbean, from Mr. Srinivasan's experience in power supply through electrical grid assemblies and installations, electricity is 40 cents per kWh, approximately 4 times the tract median cost for electricity from grids in the United States. Through complementary product-ripple effects, that automatically increases the cost of every lithium ion based device associated with electricity production, meaning the utility one obtains in the Caribbean on-demand is significantly low, even when scaled against the other two epicenters. This holds *despite* the industry for battery technology following the same exponential decline in both material and manufacturing costs.

The 40% reduction in cost-intensivity of lithium ion battery systems produced in the globalized supply chain, has indeed been largely driven by the contributions made by East and East-Central Africa from a digitisation standpoint. To socio-scientifically determine stable productions similar to that of Netherlands' circular economy use-recycle public strategies, a sub-framework relevant to this assessment would be *remote monitoring* of localized supply chains, which Srinivasan placed importance on. Interest being a direct socioeconomic factor that plays into the development disparity seen between epicenters, due to variation in capital costs, "the diversification of supply chains is one major area of focus for future research", as scholastically underrepresented epicenters like the Caribbean avert the interdependency on larger production facilities that are single-focused and utilize the take-make-waste public policy to supply their enormous demand on transition into lithium ion technology. As Srinivasan puts it, *"...demographics that are still averse to the global transition need not be at the mercy of larger political stakeholders that have fluctuating stances on the exportation and transport of raw materials, because avoiding supply chain diversification creates more room for unethical prescription on the geopolitical relations front."*

As a stakeholder in the lithium ion global supply chain, it becomes imperative to be at the forefront of accessing production mechanisms, and forecasting/growth tools from wherever the stakeholder's production facilities are located, across the entire multistage. This becomes even larger of an imperative, especially considering that the evolution of human ingenuity behind the refinery processes of lithium ion is still sitting within the private sector on average.

Srinivasan advises that active parties that aim to increase their representation in the production cycle using VIE, *"use that data to make smart decisions, to maintain the global production cycle's upkeep."*

In the waste management space, the Netherlands leads by example in dictating the socioeconomic efficiency of the EP they apply to each and every production stage (See "Determination of a Circular Economy"). Their lithium ion supply chain, at least within the EU, is localized. A key determinant in this case is transport accountability, which as we know, fails to be rendered in research about the remaining epicenters. Dutch exportation figures, as lithium ion consumption for battery applications worldwide, rose to 74% in 2021, according to a World Economic Forum (WEF) infographic outlining the relative comparisons between the primary supply chain stakeholders for every forecasted marginal increase in lithium ion cell energy output until 2030.

Being a resource in itself, just like water or oil, the risks associated with interdependency for the lithium ion supply chain only amplify with specialization of production. Diminishing the determination of these elements is a step towards local sourcing of battery components—more regenerative, more *socially* sustainable, and closer towards risk mitigation.

Srinivasan continues his evaluation by stating that when one moves from one technical faculty to another on a population-oriented scale, be it even within the homogenous industry of lithium ion battery production cycles; If we were to situate our socio-scientific focus around redox flow batteries for instance, each and every dynamic ultimately boils down to the fact that it's all a cost game, making the *shape* of the industry very behavioral in nature. He adds that this hypothesis dictates the economics. It dictates the science, so that stakeholders use the *invariable* determinations of costs to make coherent use-cases for their own samples and populations.

Future Projections of the Production Cycle: Neutralizing Development Skew

A key perspective brought in by Srinivasan is that scholars tend to analyze the socio-scientific risk's influence on local supply chains in Africa as though it were one single nation—another result of inherently unjust development bias in quantitative studies. Africa possesses so many different dimensions, multiple geographies, and multiple economic belts. Srinivasan opines that *"In East Africa one will see that technologically, information exchange is more fluid when subject to multidimensional advancements. They have significantly accelerated digital payments, reducing upfront technological costs. Scholars can consolidate coherent future research by observing capital distributions of solar power, like this paper evaluated with the Government of St. Kitts, and observe how their minimum prices fell at statistical means even below that of India's."* Though the socio-scientific determination of solar isn't discussed here, it goes to show the enhancement of resource flow as a subset of VIE, that allows such contributions to be made. From firsthand experience, Srinivasan deliberates on the fact that the Middle East rises to become one of the apex members of the revolution on digitisation in the Global South, which includes the de-compartmentalization of technological outstanding advantages surrounding lithium ion battery production in a way that is accessible and reusable.

Therefore, one key finding in this methodological aspect is that the ability of technological instrumentation to prevent cost decline reduces associated social risks in the global production cycle, since resource flow is then directed and channelized to a particular use-case, be that battery technology in engineering portable systems, or societal advancement through the grid. Hence, for the complexity embedded within lithium ion battery manufacturing frameworks, the East African geography is on a bright trajectory for instrumentation that enables less haphazard production methods, recapitulating on our analysis of the determinants of raw metal extraction and mining.

The Netherlands, as determined earlier, is of course at the forefront of propagating circular economies, looking at active materials and waste management in a more holistic manner. Srinivasan weighs the position of the Netherlands as a supply chain stakeholder by stating that "the degree of development bias or skew found in literature is nothing short of contingent on the fact that the adoption of technology varies in rate for each of these geographic epicenters. So even naturally, outside the realm of EP assignments, it becomes evident that this is the underlying socioeconomic determinant behind the forces seen affecting each of these areas in the market for batteries. Even so, the entirety of the European Union, excluding major raw material assembly epicenters such as Portugal (secondary sector dominated industry), does not even amount to 0.07% of the total kiloton amount of lithium ion battery cells produced by the global supply chain as of 2021, according to the same WEF infographic. Despite having efficacious prescription assignments, the circular strategy's influence in the developing global industry for lithium ion is a minute one. As each of these cases are taken up one by one, we see even through Srinivasan's insights, that VIE is so abnormally disparate for different supply chain stakeholders, that even while considering public strategies put in place to increase investments into the local sphere of the supply chain, not much really matters in equalizing that disparity.

IV. RESULTS AND CONCLUSION

Variable information exchange and ethical prescription are two newly coined terms, never used before in this research field. They do not represent definitions, but research ideas. The fact that they have never been formulated before to describe this series of situations, opens up seemingly infinite scope to address this research area from innumerable lenses.

To circle back to the primary objective of this research, it is crucial to note that this is a qualitative analysis of determinants. The ambiguities surrounding this exploratory phase of lithium ion development is what causes data to be scarce, and that needs to be recognized by pockets in the production cycle that have access to primary data. The expanse of battery system workflows in the contemporary era of multiple spontaneously emerging technologies, the applicability, and more so the distribution of information about electrical output through battery systems is in itself, a peak-load power grid. Research into mechanisms that can autonomously distribute this information for the multiple battery systems supplied across the grid is now the new source of potential social risks—though hypothetically, it makes a viable prospect for the future. This raises the scholarly awareness around questions such as: What would socio-scientific determination look like for a world where the growth of the lithium ion industry could be simultaneously determined by decentralization of supply, as brought up through the analysis of 'valuation through digitisation' in a study of the field? The manufacturing of components that we have analyzed at every step of the production multistage, comprise their own transactions and monitoring strategies—carrying billions of dollars of remote valuation—that also influence the determination of social attitudes towards battery systems, many of which are not accounted for in contemporary research on lithium ion.

The influence of ethics only creates more and more questions in the progress of resolution: Finished products using lithium ion were most definitely assembled in a geography that, due to the scholastic marginality of the cycle, is almost *entirely* invisible to the supply chain, making a multitude of risks continue to go unnoticed. When will the background transactions of lithium ion battery systems rise to their platform of consistent clarity about solving those risks, and what does it take on a community level to push academics into this growing field? VIE, especially in the digital era where the abstraction of data becomes devoid of any physicality, can only be actionable when these dynamics are exposed to and of all involved stakeholders in lithium ion technology.

This study connects innumerable areas of work, from sociology, to cybersecurity, to anthropology, to logistical sciences and behavioral economics, in order to create a collaborative environment in which these unexplored nuances of the production cycle's cross-examination can be explored. This research aims to push future endeavors in this intended direction. If anything at all, the true outcome of this research is that the upstream parts of global production cycles for any emerging technology, are usually the most obscure, and the most difficult to disentangle unless research into their intricacies is *forced*. This is a cause for the majority of social anxieties that come with manufacturing a product as versatile in its applications as lithium ion battery technology. Voicing out this social development bias even in academics shows that sustainability is not all sunshine. When its lapses in policy, framework, and judgment go unnoticed, sustainability for one comes at the expense of society for another.

When we consider the anthropology and ethnography of technology, we notice that when a transition is made, it takes years, if not decades, for society to render that technological transition as generally acceptable. Even the most normal concept now seemed radical at its inception, and the same goes for circular cycles of lithium ion production. In fact, this holds even more truth than when classical battery technology was conceived across multiple geographies with no ethical prescription associated with it at the time.

In terms of the cost alterations observed in both the manufacturing and risk models we evaluated, the global energy transition's upscale has been a reflection on the analysis done in the paper—a reflection of society's future demands, knowledge and prospects in the lithium ion industry. To curtail the dangerous and imminent threat of development bias in these studies, it is imperative that scholars acknowledge the equivalency between the unintended consequences of lithium ion extraction and outsourcing, and the social risks associated with production and development, as a *mutually interdependent* cycle in scholarly analysis. This is a concept that stakeholders in the global supply chain for battery systems have failed to acclimate themselves to. These unintended consequences are quantified through the risks themselves, and are observable with any emerging technology in the 21st century. The aversion of these risks to envisage an accelerated growth towards a sustainable global production cycle in the next 10 years, relies on the aversion of development skew in our production epicenters, let alone global civilisation and regenerative humanity.

Scholastic qualities that imbibe the characteristics of holistic cross-examination, involving the equitable representation of industrial sectors independent of development skew, are ones that reflect equitable VIE. Put together, these characteristics contribute immensely to the ethics of sustainable technology as a whole, that has for so long been a contentious platform for socio-scientific debates since civilisational origins. We see that some geographies, no matter their level of study, are more variable information-laden than others, exhibited by their adoption of continuously reformed policy, thereafter adding to the multiplicity argued throughout this paper.

The crux of this conclusion is that the collective effort of multidisciplinary bodies across the production multistage is allowing this area to be explored to its maximum, so that both public and corporate strategies can *build* on the dynamics of VIE as a positive driving force/mechanism. Acquiring the geographic (more so, developmental) multiplicity of academic thought, to understand such approaches is vital to the way in which we perceive the emergence of lithium ion technology, and a truly sustainable electricity transfer model for generations to come. If we are to improve the life cycle of battery systems by solving the problem of affordable, clean energy distribution without creating yet another problem within the problem, then these qualitative findings yield an optimal avenue to be explored. As Jacob Wallenburg in "Society as a Stakeholder: Up Close" states, *"In a societal ecosystem approach, the focus is on solving societal challenges, and companies view their impact on society through a societal and planetary lens to maximize positive impacts"* (Henriksson, Henrik, 2020).

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