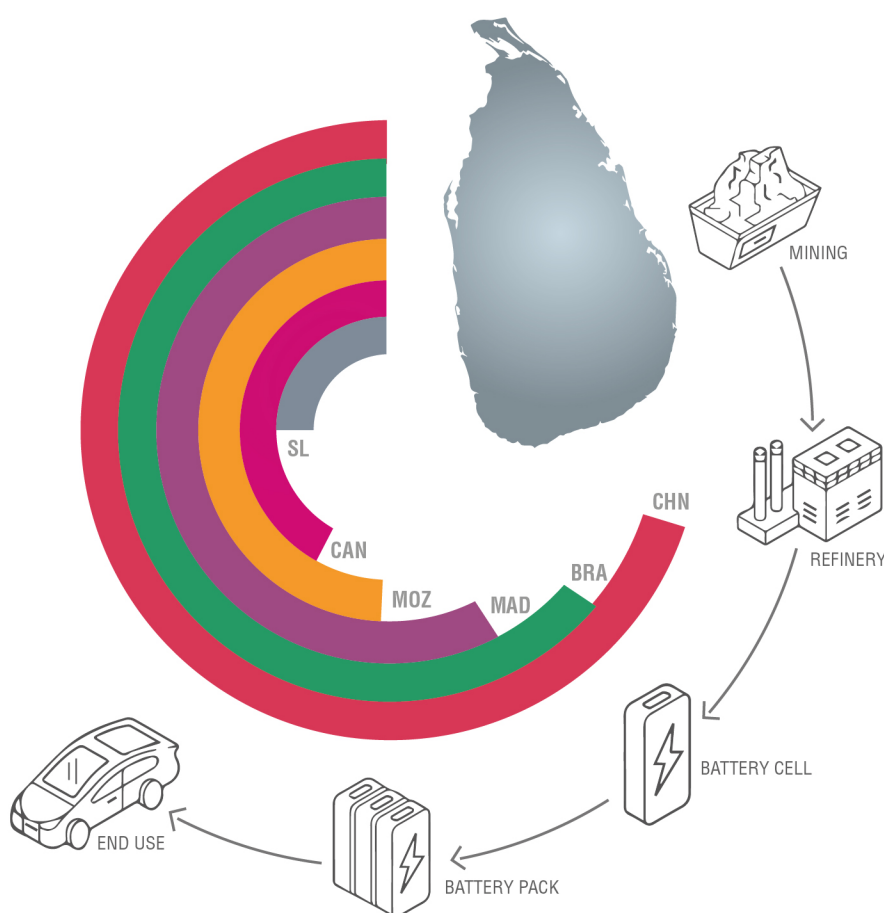


Trade Wars in Electric Vehicle Supply Chains: A Win for Sri Lanka's Graphite Industry?



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Acronyms

APTA	Asia-Pacific Trade Agreement
ASEAN	Association of East Asian Nations
BEV	Battery Electric Vehicle
CMA	Critical Mineral Agreement
CO₂	Carbon Dioxide
CRM	Critical Raw Material
EU	European Union
EV	Electric Vehicle
FTA	Free Trade Agreement
GSP	Generalised Scheme of Preferences
HS	Harmonised System
ICE	Internal Combustion Engine
IRA	Inflation Reduction Act
KII	Key Informant Interview
LFP	Lithium Iron Phosphate
LIB	Lithium-ion Battery
MFN	Most-Favoured Nation
NCA	Nickel-Cobalt-Aluminium
NMC	Nickel-Manganese-Cobalt
PHEV	Plug-in Hybrid Electric Vehicle
R&D	Research and Development
RCA	Revealed Comparative Advantage
RCEP	Regional Comprehensive Economic Partnership
SWOT	Strengths, Weaknesses, Opportunities and Threats
US	United States
USFTA	Countries having Free Trade Agreements with the US

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Trade Wars in Electric Vehicle Supply Chains: A Win for Sri Lanka's Graphite Industry?

Executive Summary

The United States (US) is motivated by several key factors to adopt a proactive green industrial policy. These driving forces include the urgent need to achieve net-zero emissions, considerations related to national security, and domestic political concerns linked to the manufacturing sector. The US employs two main strategies to achieve these goals: discriminatory consumer subsidies to incentivise electric vehicle (EV) adoption and an industrial policy promoting EV and EV component manufacturing within its borders. This strategic approach aims to diversify the supply chain by reducing vulnerabilities by excluding China. The recently enforced Inflation Reduction Act (IRA) encompasses the features of discriminatory consumer subsidies, exclusion of China, and promotion of domestic assembly and manufacturing of EV components decisively affecting the global EV battery supply value chain.

In light of these efforts, the increasing demand for graphite- a critical component of the Lithium Ion Batteries (LIBs)- fuelled by IRA subsidies and the decision to exclude China presents fresh opportunities for graphite producers outside China. This study uses a mixed research approach to investigate the effect of IRA subsidies on the “non-China” graphite exporters. The quantitative part of the research explores the effect of IRA provisions on the global graphite market and which exporters will gain the most from the realignment of the supply chain. The qualitative part of the research focuses on the Sri Lankan setting. It investigates the research question of the possible nodes of the EV battery manufacturing value chain that Sri Lanka can join in light of booming global demand for the critical raw material- graphite, which Sri Lanka exports.

The partial equilibrium modelling results imply that increasing demand will be directed towards “non-China” graphite exporters, mainly Madagascar, Mozambique, Sri Lanka, and the bloc with free trade agreements (FTAs) with the US. However, most nations in the FTA bloc with the US are net importers, reducing the actual competitors to Madagascar, Mozambique, and Sri Lanka.

Considering the market trends, size of graphite deposits, relative productivity advantages, and cost efficiencies, Madagascar and Mozambique stand in a favourable position to benefit from the growing demand for “non-China graphite.” However, on the one hand, concerns regarding the sustainability of extraction practices, issues related to child labour, and governance challenges may hinder the prospects of these nations, particularly as the major importers seek to diversify their supply chains away from China to mitigate potential vulnerabilities. On the other hand, Sri Lanka may face challenges in terms of cost competitiveness within the global graphite export market. Nevertheless, it holds high potential to tap into the increasing demand in the future. Sri Lanka distinguishes itself by producing high-quality graphite with battery-grade purity, minimal environmental impact, and adherence to acceptable labour standards. Additionally, Sri Lanka possesses a comparative advantage in graphite production and benefits from an established mining sector with an existing consumer base.

An in-depth SWOT analysis (this analysis identifies strengths, weaknesses, opportunities and threats) for potential involvement in EV battery value chains underscores that the most promising opportunities for Sri Lanka lie upstream, particularly in the mining and processing of graphite into battery-grade material. To mitigate risks arising from the US industrial policy, Sri Lanka can explore mineral trade agreements with the US, thereby stimulating additional investments in the country's mining sector. Furthermore, the analysis suggests that value addition, such as anode production, could become rational if Sri Lanka successfully attracts investments. However, global investments have been largely redirected towards North America during the post-IRA period.

Leveraging Sri Lanka's growing trade relationships with the Association of East Asian Nations (ASEAN) to attract investments in anode production is another avenue worth exploring. Additionally, investing in research and development (R&D) initiatives, such as establishing battery testing laboratories for local university researchers, will bolster the country's technical expertise in EV battery component manufacturing. These strategic measures will likely generate positive interest among potential investors and create high-quality employment opportunities within the manufacturing sector. However, producing complete batteries within the country may pose logistical challenges, given the global concentration of EV battery manufacturing in selected economies.

The strategy of the US for achieving net-zero targets relies on consumer subsidies rather than carbon taxes. This approach effectively transfers the environmental responsibility associated with clean energy production to the countries that supply critical minerals, potentially leading to significant environmental and social costs in these mining nations. The US policy at the current stage does not have provisions to incentivise sustainable extraction, although the European Union (EU) has put some measures in place. Thus, "non-China" graphite exporters face the risk of considerable environmental pollution and social ramifications if mining lacks sustainability.



1. Introduction

With rising concerns about climate change and the energy crisis sweeping the world, the need for electromobility and electric vehicle (EV) production is also increasing. In 2023, 14 million (Mn) units of EVs were expected to be sold worldwide (International Energy Agency, 2023a). The average share of electric cars in total sales across China, the European Union (EU) and the United States (US) is set to rise sizeably to around 60% by 2030. An EV's energy storage system, typically a battery, is an integral part of the EV, significantly influencing the cost of a vehicle. Lithium-ion batteries (LIBs) are the widely used energy storage system in all EVs, also called battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The popularity of LIBs rests on its high energy density, better performance in high temperatures, low self-discharge rate, and ability to withstand many charging cycles (Chen, Wu, Ai, Cao, & Chen, 2022; Wang et al., 2021). According to battery chemistry, LIBs usually contain lithium, cobalt, manganese, nickel, and graphite. Graphite, found in the anode of EV batteries, plays a pivotal role in this context, as an EV battery contains 50 to 100 kilograms (kg) of graphite per vehicle type (Trost & Dunn, 2023). Consequently, the US considers graphite a critical raw material (CRM) or critical mineral as classified by the US Department of Energy (Kitamura, 2023; US Department of Energy, 2023).

Currently, the downstream supply chains for raw material processing and EV batteries are almost entirely dominated by countries within the Association of East Asian Nations (ASEAN)+3 region- the ten members of the ASEAN, China, Japan, and the Republic of Korea. While South Korea and Japan have some stakes in manufacturing cathode and anode materials of the battery, China trumps all EV battery supply chain stages. Moreover, China also dominates the upstream mining of the CRM supply chain. Consequently, China has considerable control over the supply of critical minerals such as graphite, lithium, cobalt, and nickel, all vital elements in the production of EVs (Castillo & Purdy, 2022). China currently produces 100% of the anode-grade spherical graphite used in EV batteries (Erickson, 2022).

The US graphite imports under the harmonised system (HS) heading 2504 increased by 188% between 2018 and 2023, reaching United States Dollars (USD) 195 Mn in 2023 from USD 67.7 Mn in 2018. Remarkably, imports from China skyrocketed by 441%. China supplied the largest share, 93% of the increased US demand for graphite in this period. Imported graphite has alternative uses, and the lack of granularity of trade data does not allow analysis of the graphite statistics used in the anode of EVs. In 2022, the US imported 89,409 tonnes (mt) of graphite for multiple uses. Estimates show that graphite demand will grow by 2500% by 2040 (The White House, 2021). Due to the absence of domestic graphite extraction, the US is compelled to depend on graphite suppliers to meet this increasing demand for graphite. Reliance to this extent on graphite from external geographically concentrated sources exposes the country to critical mineral supply chain vulnerabilities. The supply chain vulnerability is shaping contemporary US industrial and trade policies. In contrast to the US, China's share of graphite imports in the EU is relatively low, at 35% in 2022.¹ However, increasing demand forces the EU into the race for dependable graphite sources for the EV industry.

Pursuing dependable, cost-efficient, and sustainable graphite sources has incited competition among leading economies, each aiming to secure critical mineral supplies, including graphite. The interplay of the emerging industrial policies in developed nations, resurgent concerns about supply chain vulnerabilities, geopolitical rivalries, and the prevailing China-dominant graphite supply chain collectively present opportunities for sustainable graphite producers outside China.

¹ Sri Lanka exports to US and EU markets, but the market share is quite low. In 2018, Sri Lanka owned 1.6% of the US graphite market share, but it plummeted to 0.4% in 2022, owing to increased Chinese graphite exports and contracted graphite exports by Sri Lanka. Sri Lanka's graphite exports to the US by value contracted by 22% between 2018 and 2022. Sri Lanka's market share in Europe dropped from 1% to 0.8%, with a contraction of value by 15%.

Against this backdrop, pursuing dependable, cost-efficient, and sustainable graphite sources has incited competition among leading economies, each aiming to secure critical mineral supplies, including graphite. The interplay of the emerging industrial policies in developed nations, resurgent concerns about supply chain vulnerabilities, geopolitical rivalries, and the prevailing China-dominant graphite supply chain collectively present opportunities for sustainable graphite producers outside China. The risk of over-dependency on Chinese supplies is one of the primary forces driving European and US economies to look for alternative sources of graphite and find ways to counter China's growing stake in green technology. Globally, government intervention in supply and demand side incentives to promote EV manufacturing is not a new phenomenon (Bown, 2023b). However, the concerns over the "supply chain resilience" stemming from geopolitical anxieties play a central role in the US industrial policy for EV batteries, motivating incentives to diversify the supply chain away from China.

The US passed the Inflation Reduction Act (IRA) in 2022, unveiling an ambitious subsidy programme,² especially for EVs that meet specific criteria. The US intends to lower costs for EV consumers, build a resilient EV industrial base, spur manufacturing in the US, and strengthen supply chains of critical minerals with like-minded partners, mainly with the countries the US has FTAs (The White House, 2023). The eligibility criteria for subsidy include excluding EVs with critical minerals, including graphite and battery components sourced, processed, or made in any designated "foreign entity of concern," which includes China. The IRA mandates that an applicable percentage of the mineral value in a battery must either be extracted or processed in the US or a country that shares an FTA with the US or recycled within North America.³ The applicable percentage will incrementally increase annually, from an initial 40% in 2023, to reaching 80% by 2027.

To fulfil the battery component requirement, the applicable percentage of the battery component's value must be either manufactured or assembled within North America. The applicable percentage will gradually rise, reaching from 50% in 2023 to 100% by 2029. As per the Internal Revenue Service (IRS) guidelines, battery components include a cathode electrode, anode electrode, solid metal electrode, separator, liquid electrolyte, solid-state electrolyte, battery cell, and battery module. In addition, battery components would include any piece of the assembled battery cell contributing to the electrochemical energy storage (Internal Revenue Service, 2023).

The objectives behind the IRA subsidies, the decision to exclude China from these subsidies, and the implementation of domestic content requirements aim to accomplish various policy aims. In February 2021, merely a month following the inauguration, the Biden-Harris administration issued an Executive Order to assess the supply chains of critical minerals and materials, identifying the need for "resilient, diverse, and secure supply chains to ensure economic prosperity and national security" of the US (Exec. Order No. 14017, 2021; The White House, 2022). The 100-day reviews under Executive Order 14017 identified the high reliance of the US supply chain on China for critical minerals, including graphite (The White House, 2021). The reviews recommended diversifying the international suppliers of the US and reducing geographic concentration risk.

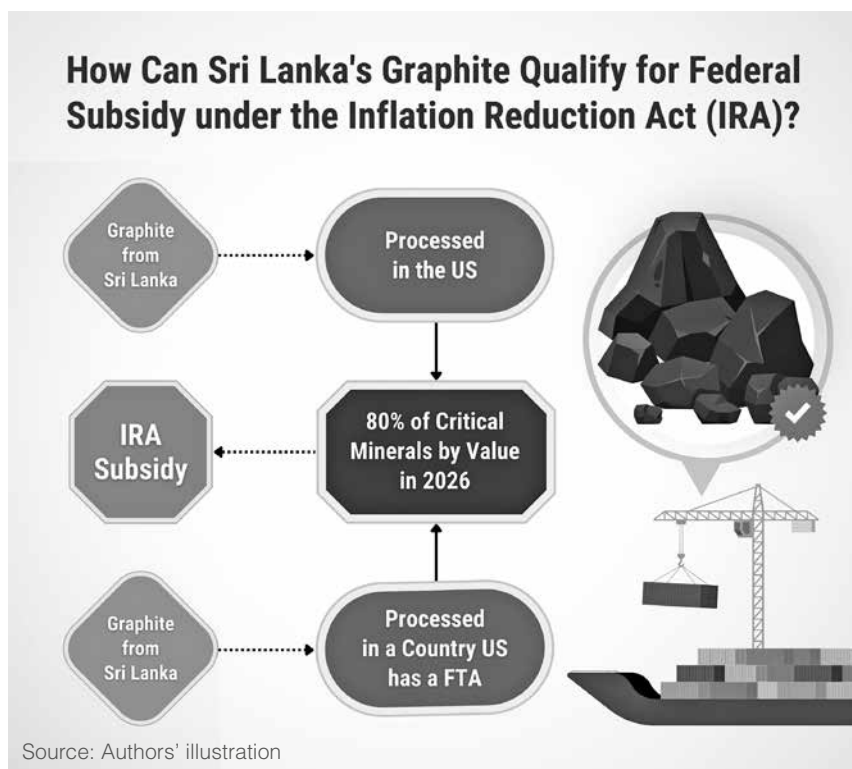
Alongside national security concerns, the interaction of dual goals of reducing carbon emissions and protecting manufacturing employment incentivised a proactive industrial strategy detailed in the IRA. Achieving lower carbon dioxide (CO₂) emissions necessitates a considerable decrease in utilising internal combustion engine (ICE) vehicles. The transport sector was responsible for 27.6% of CO₂ emissions in 2021 in the US (EPA, 2023). Yet, adopting EVs risks harming the strong US car manufacturing sector,

2 US consumer tax credits up to USD 7,500 for EVs date back to 2009 with the enactment of the American Recovery and Reinvestment Act. However, a cap has been imposed on the units sold at 200,000. Major EV producers like Tesla, Toyota, and General Motors exceeded the quota by the summer of 2022. The IRA removed this cap on the number of units eligible for the subsidy and made it applicable for 10 years (Bown, 2023b).

3 This is the territory under Canada, Mexico, and the US, the member states of the United States-Mexico-Canada Agreement (USMCA).

which holds sway in pivotal swing states like Michigan and Ohio in US presidential elections. The existing dominance of Asian economies, including China, in EV production implied that non-discriminatory subsidies for US consumers purchasing EVs might adversely impact the US ICE manufacturing industry. Hence, the pursuit of clean energy had to be coupled with an active industrial policy to promote EV and EV components manufacturing, mainly batteries, within the US. While international tensions between China and the US are often cited as the driving force behind trade and industrial policies delineated in the IRA, the influence of domestic political considerations is also distinct.⁴

The subsidy-based US industrial policy on EV battery minerals affects the global graphite and graphite-based EV battery anode supply chains in several ways. First, the IRA subsidy criteria exclude China from the subsidy programme, disqualifying an EV with a battery containing Chinese-origin graphite or an anode for the federal subsidy. In the US market, an EV with graphite or an anode from China will be relatively more expensive than an EV eligible for the subsidy. The altered relative price incentivises trade diversion away from China to a third country.⁵ In addition, subsidies lower the EV battery price, creating more trade for graphite. Second, the EVs that contain an anode, cells, and battery modules - the components of EV batteries- from a producer outside China will be more expensive than an EV that contains an anode manufactured or assembled in North America. Theoretically, the relative price change should divert the trade of EV battery components away from non-North American producers. Third, non-China graphite producers now face a market advantage in the US, if EVs that contain non-China graphite are processed in a way that is eligible for IRA subsidies by the US, an FTA partner of the US, or recycled by a North American country.⁶ For example, the diagram below depicts how Sri Lanka's graphite can be qualified for federal subsidy under IRA.



4 The labour market and electoral impact of the import penetration, particularly from China, in the US are widely discussed in economic literature (Autor, Dorn, & Hanson, 2011, 2016; Autor, Dorn, Hanson, & Majlesi, 2020; Autor, Dorn, Hanson, & Song, 2014).

5 Trade diversion reduces economic efficiency. In this particular case, China is competitive in exporting graphite as revealed by the existing data. However, due to the relative price difference, non-competitive countries become competitive attracting trade away from a competitive source.

6 The IRS defines "processing" as "non-physical processes involved in refining of non-recycled substances or materials, including treating, baking, and coating processes used to convert such substances and materials into constituent materials"(Internal Revenue Service, 2023).

As a result, the US measures to reduce the supply chain vulnerability by diversifying the supply sources of EV critical raw materials, including graphite, may provide an opportunity for Sri Lanka and other countries outside China to export graphite. Importantly, these graphite exporters, mainly concentrated in the developing world, may get an opportunity for deeper integration with the global EV battery manufacturing value chain. For example, Sri Lanka strives to increase integration and global value chain participation for export-led growth benefits from the fresh opportunity to connect to the global EV battery manufacturing value chain. The renewed trade policy activism in Sri Lanka for global integration

Sri Lanka strives to increase integration and global value chain participation for export-led growth benefits from the fresh opportunity to connect to the global EV battery manufacturing value chain.

and connectivity to the global value chains, the availability of graphite in Sri Lanka, which is an integral resource for EV battery production, together with the international developments in EV battery supply chain, create an economic opportunity for Sri Lanka. Similar opportunities exist for surplus producers of graphite, including Mozambique and Madagascar.

The key drivers behind the adoption of IRA, its impact on the US drive for net-zero emission, investment in the EV industry, and the impact on third-country EV industries are studied in the literature. Reducing the reliance on China, while de-risking the investment in battery supply chains are key drivers behind the adoption of IRA (Mehdi & Moerenhout, 2023). Since the introduction of IRA, a substantial re-directing of green investments to the US, particularly in the gigafactories and other downstream cell project is witnessed. The investment re-direction and price distortions affect third-country EV producers

like South Korea (Bown, 2023a). In addition, the IRA's implication on mineral supply chains and the US mineral supplies for EV batteries are also addressed in the literature (Trost & Dunn, 2023; Vivoda & Matthews, 2023).

Although a broad body of literature exists on emerging industrial policy in the EV sector of developed countries, including the IRA, a systematic study of the implications on the graphite market is lacking. In addition, in the Sri Lankan context, there is no study exploring the opportunities arising for Sri Lanka from global developments like IRA and the possibilities of joining novel manufacturing value chains developed by green initiatives worldwide. This study attempts to fill these gaps.

Against this background, the main objective of this paper is to critically assess the opportunities arising from IRA to the global “non-China” graphite exporters to join the global EV battery manufacturing value chain. In addition, Sri Lanka is taken as a case study in the paper to evaluate the potential for Sri Lanka's graphite to join the EV battery manufacturing value chain, taking capacity, quality, cost competitiveness, and emerging global development into account adequately and identify potential positions of the value chain-upstream positions or downstream positions- in EV battery manufacturing.

This study followed a mixed-method approach, incorporating Key Informant Interviews (KIIs) into the quantitative analysis. Stakeholders in the mining and EV battery sector, including the mining firms, EV battery researchers, and exporters in Sri Lanka were interviewed. This assisted in identifying the opportunities, capacity, constraints, and required policy changes to integrate Sri Lanka's graphite sector into the emerging EV battery manufacturing value chains. Descriptive analysis was used to identify the existing tariff levels, trade patterns, and market shares of graphite trade. A quantitative partial equilibrium modelling was done to estimate the trade diversion of natural graphite from China due to the federal subsidies proposed by the IRA. Finally, combining the qualitative and quantitative data, a SWOT (this analysis identifies strengths, weaknesses, opportunities and threats) was done to assess the potential of Sri Lanka graphite joining the EV battery manufacturing value chain.⁷

⁷ SWOT analysis is a framework for identifying and analysing an organisation's strengths, weaknesses, opportunities and threats.

This study finds that in the absence of China, fierce competition exists among graphite exporting nations to seize a significant portion of the market share of “non-China graphite”. Low-cost producers like Mozambique and Madagascar are poised to gain more from the trade creation by the US consumer tax credits, which may act as a subsidy to buy EV batteries. The high-purity level, thermally processed battery-grade graphite with a minimum environmental impact, substantial deposits, and established firms put Sri Lanka in a position to benefit from the trend/direction of growing demand for graphite to be used in EV batteries. In this scenario, Sri Lanka stands among surplus countries with a considerable comparative advantage in graphite production. However, high unit costs and depleting market penetration may challenge fully achieving the benefits of global developments. This study concludes that Sri Lanka has a better chance of exporting processed battery-grade graphite to join the EV battery manufacturing value chain. Madagascar, Mozambique, and Sri Lanka will benefit from IRA-induced demand for graphite in the US as North American countries and countries having FTAs with the US will not meet the demand even if they completely realign their total exports to the US.

Logistic reasons and lack of investments, technological know-how, and laboratory facilities narrow the feasibility of joining more downstream nodes in the value chain. Notably, US industrial policy drastically realigns the EV battery ecosystem, incentivising firms to move to the US or North America. Against that backdrop, Sri Lanka might not be able to develop a battery pack-producing manufacturing industry. Considering the above, it is recommended that Sri Lanka enter into critical minerals agreements (CMA) regarding graphite/mineral exports with the US and EU like the Japan-US CMA. Sri Lanka can also utilise the emerging trade relations with ASEAN countries like Thailand and Indonesia to join the EV manufacturing hub as a reliable and sustainable supplier of graphite. This study also calls for practising sound environmental policies and enforcing labour laws to position Sri Lanka as a reliable, sustainable, and responsible battery-grade “non-China graphite” supplier.

This paper contributes to a few strands in the literature. First, by exploring the impact of IRA on the global graphite supply chain, the study contributes to the broad literature on growing industrial policy impact on global value chains. Second, this study contributes to the literature on the graphite trade fuelled by the demand for EVs. Third, this study links to the literature on developing countries’ global manufacturing value chain participation, taking Sri Lanka’s graphite sector as a case study.

The paper is structured as follows: In section two, the background discusses the role of graphite in EV battery manufacturing, focusing on its forms in different processes. Additionally, it examines the emerging US industrial policy for EV battery manufacturing and the associated opportunities. Section three outlines the study’s methods and data. In section four, the results and discussion cover the graphite trade analysis, findings from KIIs, and SWOT analysis. Finally, the conclusion section explores policy implications and proposes avenues for further research.

2. Graphite in EV Batteries: Supply Chain and Trade

The EV battery supply chain can be divided into six stages: mining and extracting, raw material processing, cell component production, battery pack development, EV use, and recycling. These stages can be subdivided into three main parts- cell manufacturing, module manufacturing, and pack assembly (Coffin & Horowitz, 2018). Cell manufacturing covers the stages of mining and extracting raw material processing and cell component production. These activities may take place in several locations. The battery cells are then collated to manufacture modules housed within a battery pack, battery management system, and electrical connections.

The geographical fragmentation of the cell production allows countries a bundle of benefits like joining the EV battery manufacturing value chains, capitalising on the critical mineral availability, comparative advantage, available technology, factor productivity, and market access to the battery pack-producing countries. Packing of battery components usually happens in close proximity to where the vehicles are assembled. This is primarily due to the expenses of transporting battery packs, which are bulkier and heavier than individual cells or modules (Coffin & Horowitz, 2018). Thus, the EV battery manufacturing value chain might not be available at the battery pack production stage for the countries outside the hub of EV manufacturing countries.

There are several types of EV batteries based on the battery chemistry involved in energy generation. The most commonly used EV battery is LIBs. The LIBs power all the EVs sold in the US (Coffin & Horowitz, 2018). Other alternative battery types are Nickel-Metal Hydride batteries used in hybrid EVs and Lead-Acid Batteries. The LIBs have various types based on differences in battery chemistry. Nickel-manganese-cobalt (NMC) batteries are currently the dominant LIB in the market. Other LIB types are Nickel-Cobalt-Aluminium (NCA) and Lithium-Iron-Phosphate Batteries (LFP) (Trost & Dunn, 2023). Table 1 shows the mass contribution of the critical minerals by battery type. The cell's chemistry involves four critical minerals: lithium, nickel, cobalt, and graphite. While the former three are used in cathode production, graphite is the primary component of an anode. On average, an NMC battery requires 79.2 kg of graphite.⁸

Table 1: Mass Contribution of Critical Minerals by Battery Types

Critical mineral	Mass contribution by battery type (kg)		
	LFP	NCA	NMC
Aluminum	84.7	62.0	64.4
Cobalt	00.0	10.9	17.6
Graphite	92.5	78.6	79.2
Lithium	08.8	08.4	09.5
Manganese	00.0	00.0	18.4
Nickel	00.0	57.0	43.3

Source: Assessing the Feasibility of the Inflation Reduction Act's EV Critical Mineral Targets. *Nature Sustainability*, Trost & Dunn (2023)

⁸ Trost & Dunn (2023) consider the average mineral requirement for different types of NMCs (NMC types are NMC111, NMC532, NMC6111, and NMC811) to get the average mineral requirement for an NMC battery.

Table 2: Average Market Value of Critical Minerals in NMC Battery

Critical mineral	Mass requirement (kg)	Average market price (USD/MT)	Average market value per battery (USD)
Aluminium	64.4	2,123	136.8
Cobalt	17.6	46,992	828.8
Graphite	79.2	1,014	80.3
Lithium	09.5	2,619	24.8
Manganese	18.4	5,710	104.8
Nickel	43.3	12,361	534.8
Total value			1,710.2

Note: MT denotes metric tonnes.

Source: Assessing the Feasibility of the Inflation Reduction Act's EV Critical Mineral Targets. *Nature Sustainability*, Trost & Dunn (2023)

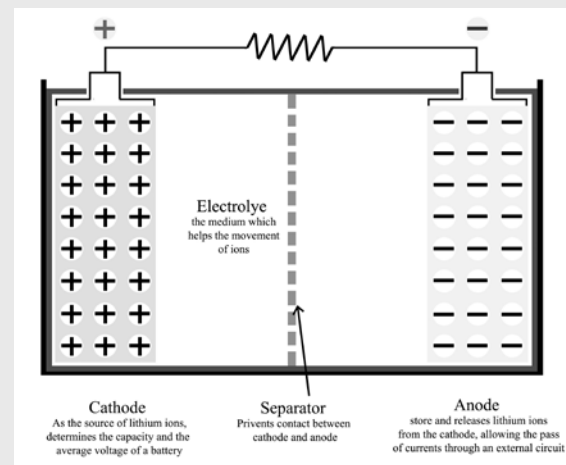
Box 1: Graphite in EV Batteries

Graphite is found naturally, in the form of flake, amorphous, or vein (Ceylon) graphite, or produced synthetically, which is considered more expensive and ineffective. Compared to its counterparts, vein graphite is known to have a high level of crystallinity and electrical conductivity, which translates to better battery performance in EVs. While amorphous graphite and flake graphite have purity levels that can go up to 90 and 97%, respectively, vein graphite has purity levels reaching 99%. The high purity and high crystallinity of vein graphite qualify it as a suitable anode material (Balasooriya, Touzain, & Bandaranayake, 2007; Sasanka Hewathilake, Karunarathne, Wijayasinghe, Balasooriya, & Arof, 2017). The higher purity levels mean that primary processing is often not required and can be directly purified for battery-grade graphite, making it more environmentally friendly and cost-efficient.

Although synthetic graphite is an alternative anode material, natural graphite is to be the most promising candidate for anode in LIBs in terms of cost-effectiveness. Recent progress in graphite processing technology makes high-performing and cost-effective anodes from natural graphite (Asenbauer et al., 2020). Lower discharge capacity and large capacity losses are also reducing the effectiveness of synthetic graphite as an anode material (Rathnayake, Wijayasinghe, Pitawala, Yoshimura, & Huang, 2017; Sasanka Hewathilake et al., 2017; Wang et al., 2021).

Graphite is used for many commercial applications, including refractory, steel, pencils, lubricants, heat and fire protection, and energy storage. The applicability of graphite in EV battery production

Figure B.1. Schematic diagram of the inner structure of a LIB



Source: Authors' compilation

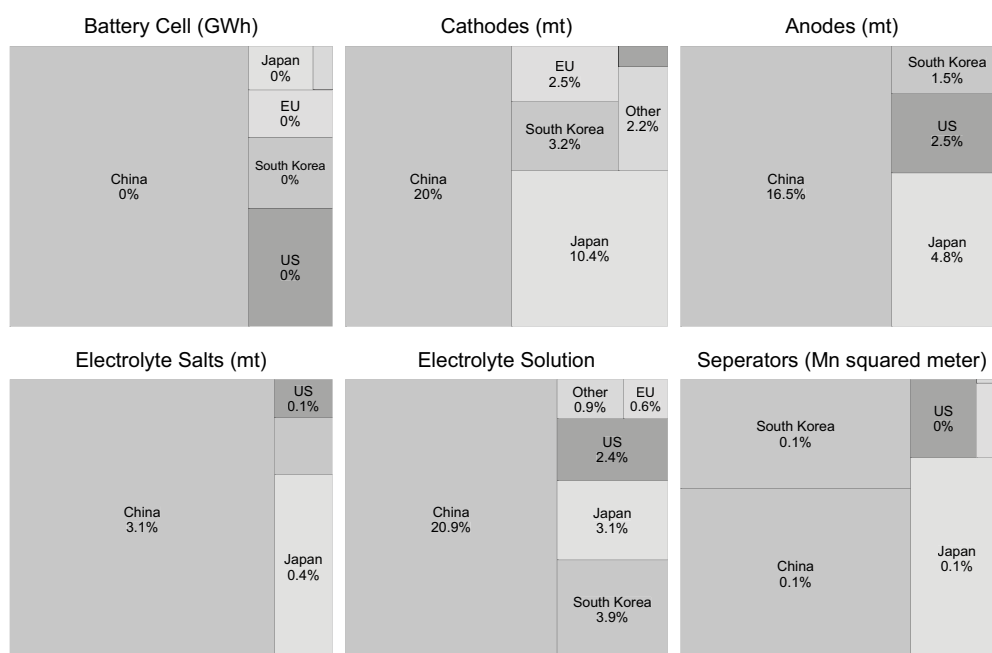
should be discussed, keeping various alternative uses and value-addition graphite options in mind. Natural flake graphite is processed into spherical or “battery grade” graphite for use in EV battery anode. Flake graphite concentrate is processed into ultra-high purity ->99.95%- with particle sizes ranging from 10 to 25 microns. Given the broad applicability of the graphite fast-growing EV manufacturing, it is estimated that graphite may see 6 to 30 times higher demand than today depending on the direction of battery chemistry (International Energy Agency, 2023b). Fastmarkets estimated that in 2021 graphite demand for EV batteries was 437,000 metric tonnes (mt)(Bennett, 2022).

Source: Authors' illustration

Table 1 illustrates that graphite, a key element in LIBs serving as the anode, holds the utmost importance in terms of mass. Notably, China accounts for 65% of the global anode production capacity (Figure 1), while other major anode producers like Japan, South Korea, and the US rely on graphite imports. China is unique as the sole net graphite-anode exporter (Table 3). As a result, regardless of the location of anode production, graphite containing those anodes may be mainly from China. Figure 1 provides an overview of global production capacities for battery cell and component manufacturing, with China exhibiting dominance in each component.

The concentration of supply sources for EV battery components on a global scale significantly impacts US industrial policy due to domestic politics and geopolitical concerns. Safeguarding employment in the domestic ICE vehicle manufacturing sector is of utmost political importance for the US. Moreover, given the strained China-US relationship, mainly due to events spurred in the China-US trade war, an increased reliance on China for critical EV battery components is viewed as a significant security risk (Coffin, 2021). In addition, the energy insecurity of Europe after the Russian invasion of Ukraine further catalysed the moves to lower the supply chain vulnerability of CRMs. At this juncture, assessing the supply origins of EV battery components for the US holds significance.

Figure 1: Distribution of Battery Cell and Battery Cell Components Manufacturing Capacity



Source: Authors' Illustration using data from Coffin (2021)

Table 3: Net Exporters and Net Importers of Graphite in the World: 2018 - 2022

Net exporters			Net importers		
Rank	Country	Net exports (USD Mn; average 2018-2022)	Rank	Country	Net imports (USD Mn; average 2018-2022)
1	China	277.1	1	South Korea	-102.2
2	Brazil	26.8	2	Japan	-89.9
3	Mozambique	26.7	3	US	-65.0
4	Madagascar	25.7	4	India	-30.4
5	Canada	12.9	5	Poland	-29.0
6	Sri Lanka	4.8	6	Germany	-22.5

Source: Compiled based on data from Trade Map, International Trade Center

As Figure 2 illustrates, an exponential growth in US imports of LIBs and storage battery parts can be noticed. China exported 65% of LIBs used for EVs to the US in 2022, while South Korea was the major exporter of storage battery parts, accounting for 39% of imports. China was the third largest EV battery parts exporter, accounting for 22% of exports to the US in 2022 (Figure 3). The exponential growth of graphite imports by the US is visible in Figure 4 and Figure 5.⁹ The US depends entirely on imports to meet the domestic graphite requirement for all graphite applications, including EV battery parts. Notably, the increased graphite imports are mainly supplied by China. When the IRA was introduced in August 2022, about 80% of US natural graphite imports by value were sourced from China. The countries considered to have FTAs with the US, including Japan, which already has a CMA with the US, exported only 8% of the US demand in August 2022.

Box 2: EV Components in Trade Data

The list below details all related materials that may be used to produce an EV battery, their HS six-digit subheading, and an assumed production stage within the EV battery supply chain. Lithium-ion batteries specifically used for EVs are categorised under the broad HS subheading for all LIBs (HS 850760). Polarising the two to identify which batteries are used for EVs is harder to accomplish (although this data is available in the US). Similarly, because there are no globally harmonised EV battery-specific subheadings for other components, identifying the components used in EV batteries within the supply chain is a key challenge when classifying trade trends (International Energy Agency, 2022).

Table B.2.1: Components of EV Batteries in Trade Data by HS Subheading at HS-six Digits

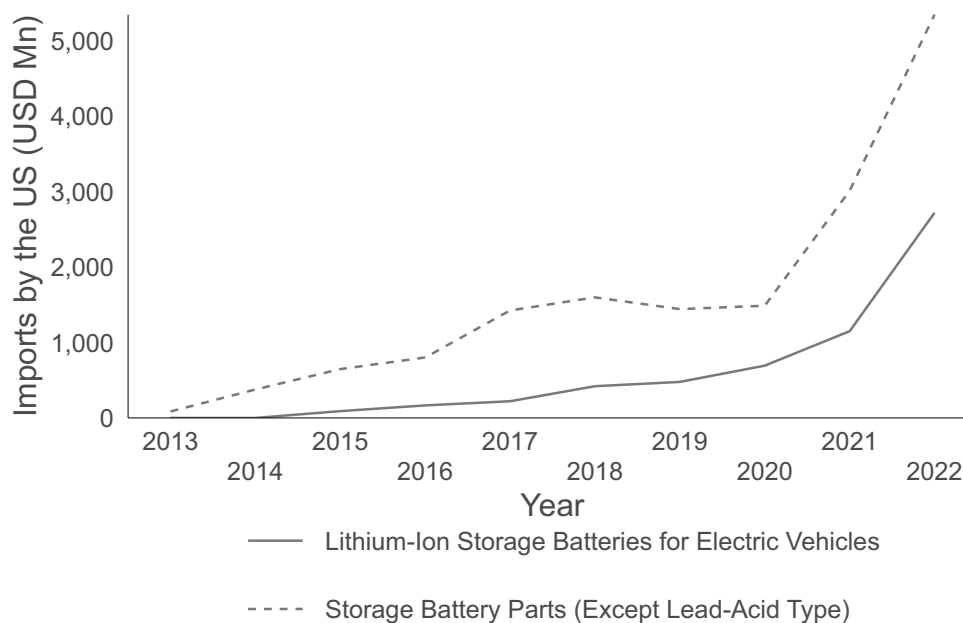
HS Subheading	Label
2504.10	Natural graphite in powder or in flakes
2504.90	Natural graphite (excluding in powder or in flakes)
2602.00	Manganese ores and concentrates
2604.00	Nickel ores and concentrates
2605.00	"Unrefined" raw cobalt ores and concentrates
2820.10	Manganese oxides, Manganese dioxide
2820.90	Manganese oxides (excluding manganese dioxide)
2822.00	"Refined" cobalt oxides and hydroxides
2825.20	Lithium oxide and hydroxide

9 However, it should be noted that graphite imports are for all the alternative uses, not solely for EV batteries.

HS Subheading	Label
2825.40	Nickel oxides and hydroxides
2833.24	Sulfates, alums, peroxosulfates
2835.29	Phosphates
2836.91	Lithium carbonates
2842.90	Salts of inorganic acids or peroxyacids
3801.90	Graphite or other carbon in the form of pastes, blocks, plates or other semi-manufactures
7403.11	Copper in the form of cathodes and sections of cathodes
7501.10	Nickel mattes
7501.20	Nickel oxide sinters and other intermediate products of nickel metallurgy
8105.10	Cobalt mattes
8105.20	"Refined" unwrought cobalt
8506.50	Lithium, cells and batteries
8507.60	Lithium-ion accumulators
8507.90	Plates, separators and other parts of electric accumulators, n.e.s.
8545.19	Electrodes of graphite or other carbon, for electrical purposes

Source: Compiled using Mineral Requirements for Clean Energy Transitions: The Role of Critical Minerals in Clean Energy Transitions, International Energy Agency, 2022

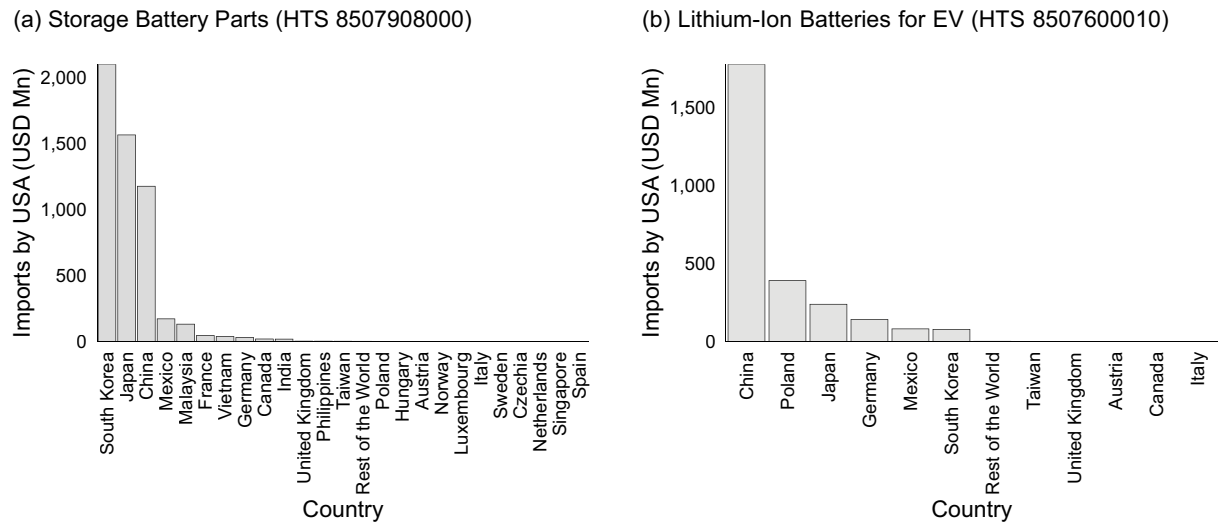
Figure 2: US Imports of LIB Storage Batteries for EVs and Storage Battery Parts



Notes: USITC data has separate HTS numbers for EV-specific batteries and components: HTS 8507908000-Storage battery parts (except lead-acid type) and HTS 8507600010-LIBs for EVs of subheading 870390

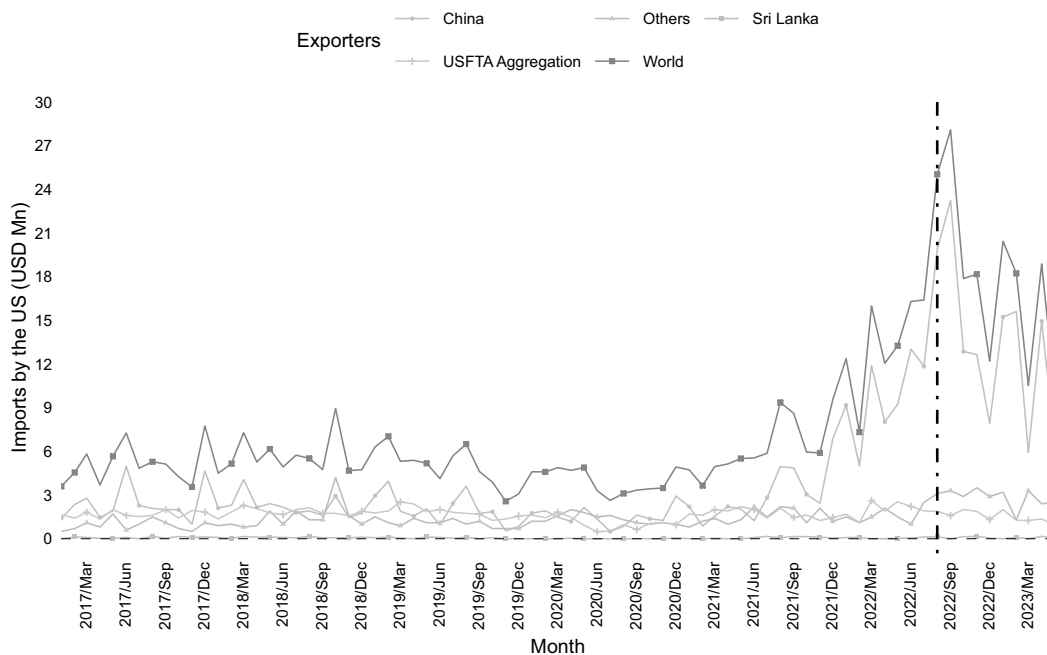
Source: Authors' illustrations using data from DataWeb: United States International Trade Commission (USITC)

Figure 3: Market Share of the Exporters of LIB Storage Batteries for EVs and Storage Battery Parts to the US in 2022



Source: Authors' illustrations using data from DataWeb: United States International Trade Commission (USITC)

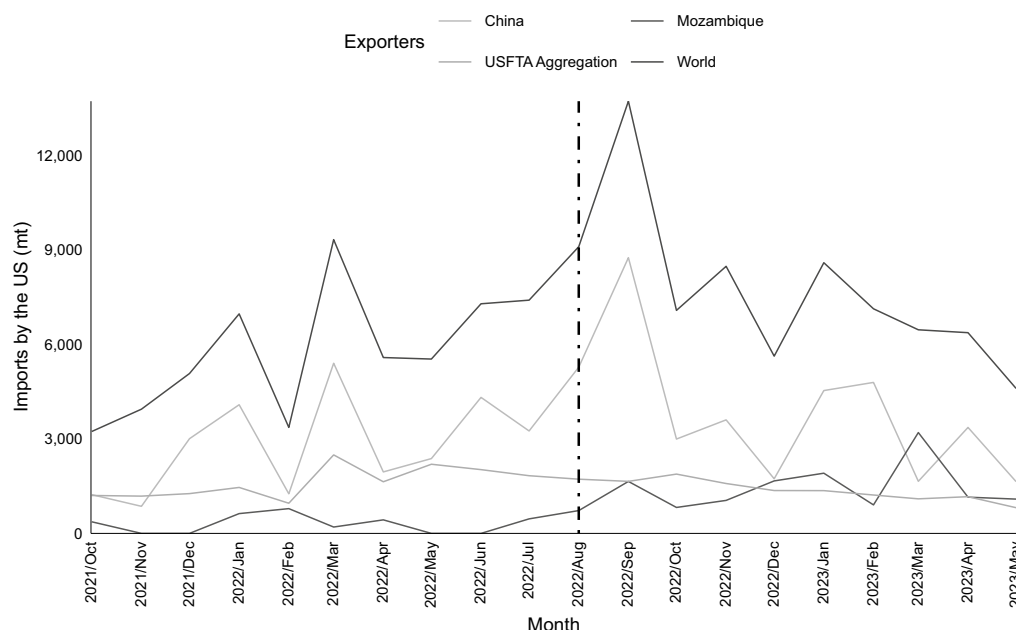
Figure 4: Value of Imports from the Suppliers of Graphite by the US including Sri Lanka: March 2017 - May 2023



Notes: The supplier group "USFTA Aggregation" comprises the countries where the US has FTAs or CMAs. The IRA consumer tax credits are applicable if the critical minerals are sources from US countries with FTAs. However, the IRA does not define the FTA, providing some flexibility to categorise newly formed Japan-US CMA under the eligible FTAs for the tax credit (Akhtar & Schwarzenberg, 2023). The vertical line depicts August 2022, the month the IRA was introduced.

Source: Authors' illustration using Trade Map data

Figure 5.1: Quantity of Imports from the Suppliers of Graphite by the US, including Sri Lanka: October 2021 - May 2023

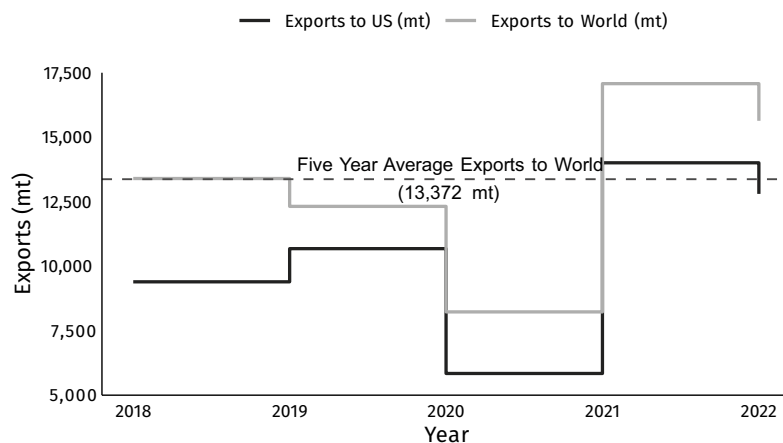


Notes: The vertical line depicts August 2022, the month the IRA was introduced.

Source: Authors' illustration using Trade Map data

It is noteworthy that following the introduction of the IRA in 2022, graphite imports by the US dwindled, primarily driven by decreased imports from China (as indicated in Figures 4 and 5.1). The imports from USFTA countries did not offset the drop in graphite imports. A marginal rise is seen in graphite exports from low-cost exporters such as Mozambique. A comprehensive econometric analysis could provide insights into whether the IRA exclusion of China influenced US graphite imports. It is plausible that due to uncertainties surrounding consumer tax credits, US-based anode producers ceased importing Chinese graphite. However, reshuffling supply sources will be time-consuming and hampered by the limited export capacity of USFTA countries in graphite. This outcome is unsurprising because China is the dominant global competitive graphite exporter. As shown in Figure 5.2, USFTA aggregation's total graphite exports were less than 17% of the US requirement to produce 1 Mn EVs.

Figure 5.2: Exports of Graphite by Countries having a FTA/CMA with the US



Notes: The five-year average graphite exports to the world by USFTA aggregation is just 13,372 mt. Assuming the US would produce one million EVs, the graphite requirement will be nearly 80,000 mt.

Source: Authors' illustration using Trade Map data

Two graphite product lines at HS-six digits can be identified in international trade data. Natural graphite in powder and flakes-HS 250410 and natural graphite excluding powder and flakes-HS 250490 (other graphite) are these natural graphite product lines. The global natural graphite trade is dominated by the HS 250410 product line, natural graphite in powder and flakes.¹⁰ The world exports of natural graphite in power and flakes in 2019 were USD 508.3 Mn, while other graphite exports were USD 50.0 Mn. Table 1 provides vital statistics for the graphite market in 2019. China dominates the exports of both product lines and owns 58.1% of HS 250410 exports, while Mozambique, the second largest exporter, owns 9.1% of the world market share. The lack of granularity of the trade data does not allow researchers to identify graphite exported for EV batteries. Graphite has many alternative uses in refractory, steel, pencils, lubricants, heat and fire protection, and energy storage (Box 1). Table 5 shows details of market shares of the three leading importers of downstream graphite products, like graphite blocks and paste (HS 380190) and graphite electrodes (HS 854519).¹¹ China is the leading exporter of these two products in the downstream graphite supply chain.

Sri Lanka is a tiny player in both product lines in the world market. In HS 250410, Sri Lanka's market share is just 0.9%, being the 11th largest supplier. Sri Lanka has exported 2,570.3 mt of natural graphite (HS 250410), while exports of other graphite (HS 250490) were just 34.4 mt (Table 4). Examining the competitive advantage of producing natural graphite requires investigating the unit price, existing tariffs in key markets, and comparative advantage. On average, Sri Lanka's monthly graphite exports to the US were 0.7% of the US total imports, and no visible realignment was evident in US demand for Sri Lanka in the post-IRA period. However, the growing demand for EVs will induce more demand for graphite in the future, and supply chain realignments will take time. Moreover, the US subsidy-based industrial policy diverts graphite trade away from China as the subsidy makes EVs with Chinese graphite more expensive.

The EU also plans to introduce sustainability requirements for EV batteries, making batteries sustainable throughout their entire lifecycle – from sourcing materials to their collection, recycling and repurposing (European Commission, 2022). Thus, this spreads optimism that Europe's attempt to lower imports from countries where graphite is mainly unsustainably sourced may open further opportunities for Sri Lanka. The magnitude of the trade diversion towards Sri Lanka and trade creation in favour of Sri Lanka's graphite will be determined by the relative cost advantage, tariff structure Sri Lanka faces, Sri Lanka's carbon footprint in graphite mining, and the supply capacity of Sri Lanka. According to the Ceylon Graphite Corporation, Sri Lanka has the purest form of graphite and is the only country in the world where crystalline graphite or lump (vein) graphite is available for commercial production (Baxter, 2022). Purity levels in these mines can go up to 99%, exceeding the average global purity level of 97%. According to data, Sri Lanka produced 4,300 mt in 2021, while the reported deposits are close to 1.5 Mn mt (Figures 6 and 7).

The EU also plans to introduce sustainability requirements for EV batteries, making batteries sustainable throughout their entire lifecycle – from sourcing materials to their collection, recycling and repurposing (European Commission, 2022). Thus, this spreads optimism that Europe's attempt to lower imports from countries where graphite is mainly unsustainably sourced may open further opportunities for Sri Lanka.

10 Flake graphite is considered the most suitable form for processing into anode materials (based on The United States International Trade Commission, https://www.usitc.gov/publications/332/working_papers/gvc_paper.pdf)

11 It is possible that electrodes produced from synthetic graphite also categorised under this group.

Table 4: Graphite Exports in the World Market: Key Statistics for 2019

Variable	HS 250410 (Natural graphite in powder and flakes)	HS 250490 (Natural graphite excluding powder and flakes)
World Exports (Value)	508.3	50.0
World Exports (Quantity)	504,217.0	118,439.1
Share of global graphite trade (Quantity)	81.0	19.0
Top three exporters (Market share by value)	China (USD 295.6 Mn; 189,664 mt, 58.1%) Mozambique (USD 46.2 Mn; 161,937 mt; 9.1%) Brazil (USD 27.20 Mn; 17,902 mt, 5.4 %)	China (USD 30.5 Mn; 99,220 mt, 61%) Tanzania (USD 4.8 Mn, 10,850 mt, 9.6%) Mozambique (USD 3.4 Mn, 670.2 mt, 6.7%)
Sri Lanka (with world market share)	11 th largest supplier (USD 4.6 Mn, 2570.3 mt, 0.9 % by value)	17 th largest supplier (USD 0.08 Mn, 34.4 mt, 0.2% by value)

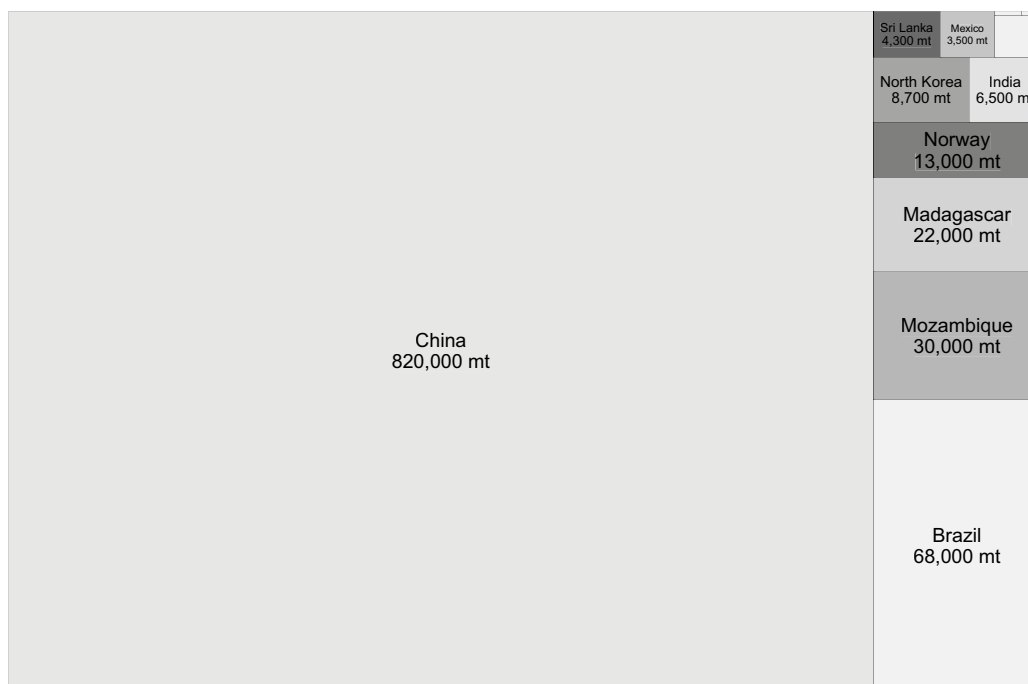
Note: Percentages are Market Share by Value

Source: Based on data from World Integrated Trade Solution (WITS)

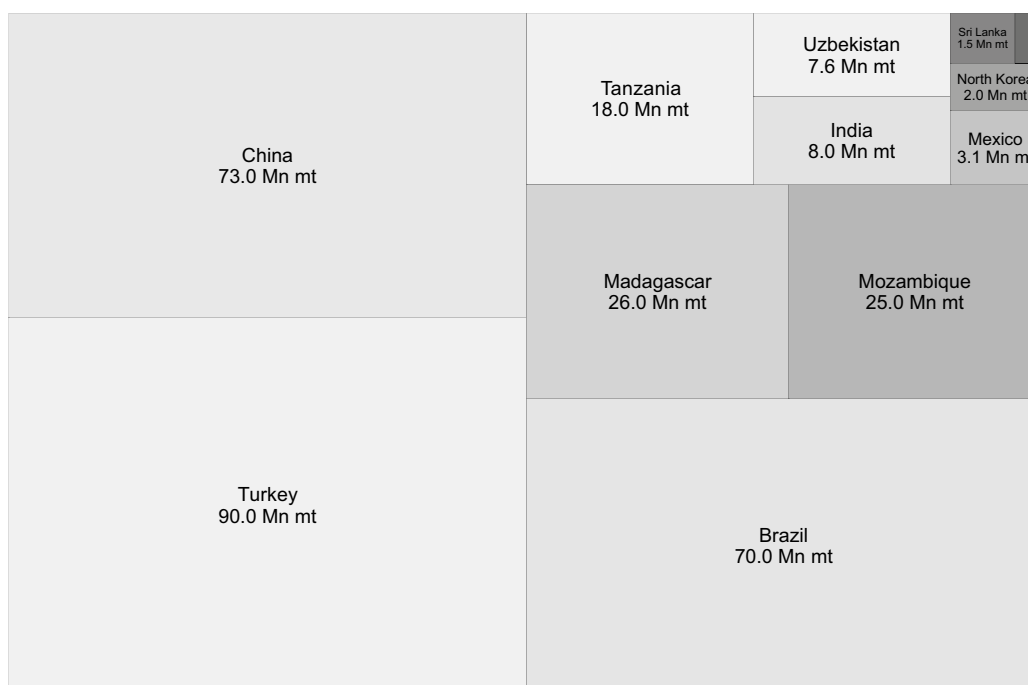
Table 5: Market Share of the Exporters of More Downstream Graphite Products

Product code	Product	World market (USD Mn)	Top three exporters	
			Country	Exports (USD Mn)
380190	Graphite (blocks, pastes, and plates)	648.6	China	293.6
			Mexico	50.4
			Germany	48.1
854519	Electrodes of graphite or other carbons	1,650.6	China	677.5
			Poland	166.2
			Norway	105.1

Source: Based on data from World Integrated Trade Solution (WITS)

Figure 6: Mine Production of Graphite by Country in 2021

Source: Authors' illustration using data from US Geological Survey (2022)

Figure 7: Deposits of Graphite by Country in 2021

Source: Authors' illustration using data from (US Geological Survey, 2022)

3. Methods and Data

The study follows a mixed methods research approach. The empirical analysis involves two primary components. The first section, a quantitative analysis investigates the graphite exporters' competitiveness, export trends, and market access. Moreover, a partial equilibrium model was used to roughly estimate the opportunities arising from the IRA. The second section explains a comprehensive qualitative analysis using KIIs, taking Sri Lanka's graphite sector as a case study. The trade indices used in the study and their domain of measurement are given in Table 6.

Table 6: Trade Indices and Domain of Measurement

Indices	Equation and description	Domain of measurement
1. Exports growth	$\frac{V_{t1} - V_{t0}}{V_{t0}} \times 100$ $V_{t1} = \text{Volume of graphite exports in year } t1$ $V_{t0} = \text{Volume of graphite exports in year } t0$	Growth of export value between selected two years
2. Revealed comparative advantage (RCA) index	$\frac{X_{cs} / X_c}{X_{ws} / X_w} \equiv \frac{X_{cs}/X_{ws}}{X_c/X_w}$ $X = \text{exports}$ $c = \text{country of interest}$ $s = \text{sector of interest}$ $w = \text{world}$	Relative exports share of a sector in the world in terms of total share. An RCA value above unity implies revealed comparative advantage
3. Market Penetration Ratio	X_{ijs} / M_{js} $X_{ijs} = \text{country } i\text{'s exports of } s \text{ to the country } j$ $M_{js} = \text{total import of } s \text{ to country } j$	Measures share of a country's exports in a sector to an importing country in that country's total imports in the particular sector
4. Trade Specialisation Coefficient	$(X_{ik} - M_{ik}) / (X_{ik} + M_{ik})$ $k = s = \text{sector}$ $M = \text{imports}$ $X = \text{exports}$	Measures trade specialisation. If the coefficient is around 0 it may suggest either weak competitiveness or a large share of intra-industry trade

Note: Modelling the trade diversion effect of IRA subsidies is complex, as the implications of subsidies generate indirect effects.
Source: Authors' compilation.

In the first implication, an EV with components and CRMs from China will be USD 7,500 more costly than a tax-credit-eligible model. Suppose an EV contains CRMs like graphite of IRA-eligible sources (non-China origin, processed in USFTA, or mined in USFTA countries) and components from a non-North American country. In that case, the tax credit eligibility is only USD 3,500. Thus, the tax credit is a subsidy to the CRMs and components originating (processed or extracted) from North American countries and for countries having FTAs with the US. A battery pack for an average car like the Nissan Leaf is USD 7,500 in the upper bound. So, a USD 7,000 tax credit is close to a 100% subsidy for an eligible battery pack. If the CRM content is considered separately, as shown in Table 2, the CRM content value of NMC type LIB is USD 1,710. Thus, the tax credit subsidy for the LIB is nearly 200%, as the tax credit for the mineral component is USD 3,500.

Under several assumptions, partial equilibrium analysis can estimate the trade impact of IRA subsidies. It should be noted that the estimates provide a direction of the trade flow rather than exact magnitudes, as estimates are done using assumptions. In this study, first, it was assumed that the subsidy would be close to 100%. The estimates take the value 99% as it is impossible to model a 100% tariff cut; as such, a tariff cut brings the price to zero. Second, it was assumed that all graphite imports by the US in the base year were used for EV battery production. In 2019, the US imported 50,197 mt of graphite for all purposes, including anode production. However, as mentioned above, the US needs 79,200 mt of graphite to produce 1 Mn EV batteries. Thus, a partial equilibrium stimulation with the above-mentioned assumptions provides rough guidance on the trade diversion effect of IRA subsidies on Chinese graphite exports. The partial equilibrium estimates were done for the following scenarios.

1) Scenario one: Assumes that only “foreign entities of concern” will be affected by the mineral content and component requirement. Then, natural mineral exporters from all the countries will benefit from diverted trade, as these countries can export graphite to be processed in the US or a country having an FTA with the US.

2) Scenario two: The EU follows the US IRA subsidies and excludes “foreign entities of concern”. Similar to scenario one, “non-China” natural graphite exporters will be benefited.

This study uses the in-built partial equilibrium modelling tool, the Single Market Partial Equilibrium Simulation Tool (SMART), in the World Integrated Trade Solutions (WITS) for the simulations to find the trade effect of IRA subsidies (Amjadi, Schuler, & Quadros, 2011; Laird & Yeats, 1986). The GTAP sectoral Armington elasticity of 1.8 was used for the Armington elasticity. More details on SMART simulations can be found in the studies of Wijesinghe and Rathnayake (2023).

Interviewing KII was used as the qualitative research approach to identify Sri Lanka's potential, constraints, and capacity to join EV battery manufacturing. A semi-structured interview guide was developed to obtain information on the feasibility of Sri Lanka engaging in the EV value chain, the costs involved and the policy environment. An understanding that the EV battery supply chain discussion is a multidisciplinary one pushed for a KII list with experts from various fields from almost all stages of the supply chain. The informants were purposively selected to cover technical operations, logistics and the commercialisation of products in the global market (Table 7). The interviews were conducted through one-on-one online meetings in English. The specific queries in the interview guides were framed to complement the informant's area of expertise. Each expert's opinion within their respective field of expertise was considered to produce an overview of Sri Lanka's current and potential involvement in EV production.

Table 7: Composition of Key Informant Interviews

Expert	Technical operations	Logistics	Commercial operations
Representatives from a large-scale graphite mining, processing, and export operation	√	√	√
Researchers of electronic vehicle battery cell production	√		
Academic in industrial logistics		√	√
Representative of the Export Development Board of Sri Lanka			√
Diplomat to a key producer of electronic vehicles and vehicle components			√

Source: Authors' compilation

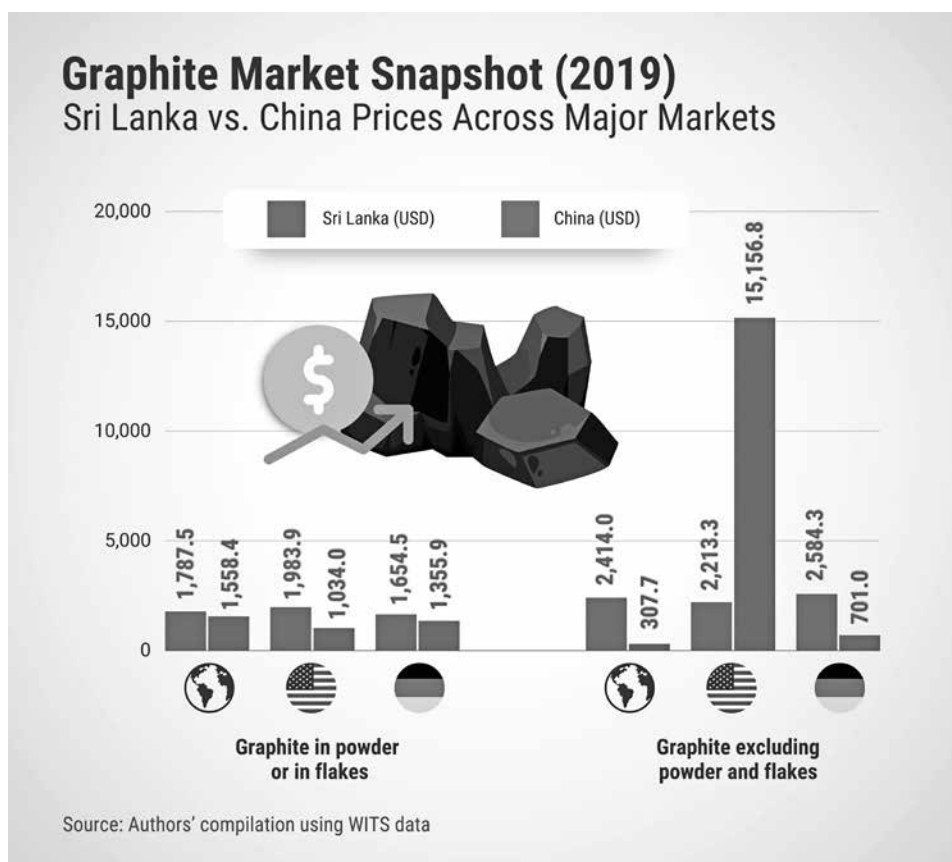
4. Results and Discussion

The results and discussion section is structured as follows. First, it discusses the competitiveness of graphite exporters, including Sri Lanka, assessed based on comparative unit prices in key markets. The revealed comparative advantages (RCA), market penetration, and existing tariffs on graphite exports are also discussed. Second, the impact of emerging industrial policy measures by the US on global graphite

In the global graphite export market, China commands substantial price competitiveness in the major export destinations such as the US and EU (Table 8). In contrast, Sri Lanka's graphite is relatively expensive worldwide.

exporters is discussed. Graphite exporters' potential gains from tariff cuts and trade creation/diversion caused by the US IRA are explained. Third, the results of the KIIs are presented, followed by a SWOT analysis of Sri Lanka's graphite exports for EV battery manufacturing. In discussing the results, the section prioritises Sri Lanka's position relative to that of other exporters.

In the global graphite export market, China commands substantial price competitiveness in the major export destinations such as the US and EU (Table 8). In contrast, Sri Lanka's graphite is relatively expensive worldwide. For example, China exported natural graphite (HS 250410) to the US at USD 1,034 per tonne in 2019.¹² The comparable price of Sri Lanka exceeded China's price by USD 950, bringing the price of a Sri Lanka-origin graphite to USD 1,984 per mt. Overall, data reveals China's price competitiveness in graphite. However, emerging exporters such as Mozambique and Madagascar export graphite at a cheaper price, where the unit price is nearly a fourth of China's graphite price (Table 9).



¹² The 2022 prices are given in the appendix.

Table 8: Price Fetched by Sri Lanka and China for Graphite Products in Major Markets: 2019

Product	Product code	Market	Sri Lanka (USD)	China (USD)
250410	Graphite in powder or in flakes	World	1,787.5	1,558.4
		US	1,983.9	1,034.0
		Germany	1,654.5	1,355.9
250490	Graphite excluding powder and flakes	World	2,414.0	307.7
		US	2,213.3	15,156.8
		Germany	2,584.3	701.0

Source: Authors' compilation using WITS data

The RCA index in Table 9 reveals China, Mozambique, Brazil, Madagascar, Canada, Austria, and Sri Lanka have a relative productivity advantage in exporting natural graphite.¹³ Mozambique, Madagascar, and Sri Lanka have higher RCA values due to the disproportionate importance of graphite exports compared to the individual country's total exports. In addition, Brazil, Canada, and China have RCAs exceeding the unity, which implies a relative productivity advantage in exporting graphite. However, export data in Table 9 are likely to be misleading due to graphite re-exporters. For example, the US is not mining graphite within the country, and almost all exports from the US are re-exports. Consequently, the RCA values may not reflect the true productivity advantage.

The trade specialisation measure might help to understand the net exporters with surplus production. Figure 8 shows the trade specialisation coefficient for major graphite exporters between 2018 and 2022. Brazil, Canada, China, Madagascar, Mozambique, and Sri Lanka are net exporters with less intra-industry trade in the graphite sector. Significantly, China is expanding intra-industry graphite trade due to increased demand for low-cost graphite for EV battery production. The US, Japan, the Netherlands, and Germany were net importers in 2022, while the intensity of intra-industry trade grew with time. Thus, actual competition for natural graphite exports exists between Brazil, Canada, China, Madagascar, Mozambique, and Sri Lanka. Among these, China faces increased trade barriers in the US market, whereas Madagascar and Mozambique are emerging as low-cost producers attracting investors in the mining sector.

Overall, China stands as the dominant player in the global natural graphite market with a revealed productive advantage and cost advantage- as shown by the unit price of exported graphite. However, the other low-cost producers like Madagascar and Mozambique also compete by price. For example, although a low-cost producer, China seeks potential sources of low-cost ores abroad, mainly in countries like Mozambique and Madagascar. China started importing a substantial volume of graphite from Madagascar and Mozambique in 2018. While the imports from the world grew by 118% during the four years between 2018 and 2022, China's imports from Madagascar and Mozambique grew by a remarkable 129% and 485%, respectively (Table 10). The rising labour and energy costs in graphite production as well as the rising cost of compliance with environmental protection regulations prompt China to look for alternative graphite sources for its domestic graphite mining and processing industries (Tsuji, 2022).

China is expanding intra-industry graphite trade due to increased demand for low-cost graphite for EV battery production. The US, Japan, the Netherlands, and Germany were net importers in 2022, while the intensity of intra-industry trade grew with time.

¹³ It should be noted that, although RCA is used to measure the revealed productivity advantage, external trade policies widely affect the RCA value. Thus, RCA is not a true measure of innate productivity advantage of a nation.

The market penetration ratio measures the relative strength of an exporter relative to competitors in each market (Figures 9 and 10). Although China was the top global graphite exporter in 2022, its market share in the world market contracted by 6.3 percentage points compared to 2018. Notably, low-cost graphite exporters Mozambique and Madagascar intensified their market penetration in the world market by 8.3 and 5.3 percentage points, respectively, during the said period 2018-2022. Analysis of market penetration by the exporters in the primary graphite importing market also shows the gradual increase of the market penetration by Mozambique and Madagascar. Mozambique expanded its market share in Chinese graphite imports, or the market penetration grew from 22% to 59% during 2018-2022

A plausible reason behind Sri Lanka's underperformance might be a lack of price competitiveness and the importing countries' emerging demand for low-cost graphite sources.

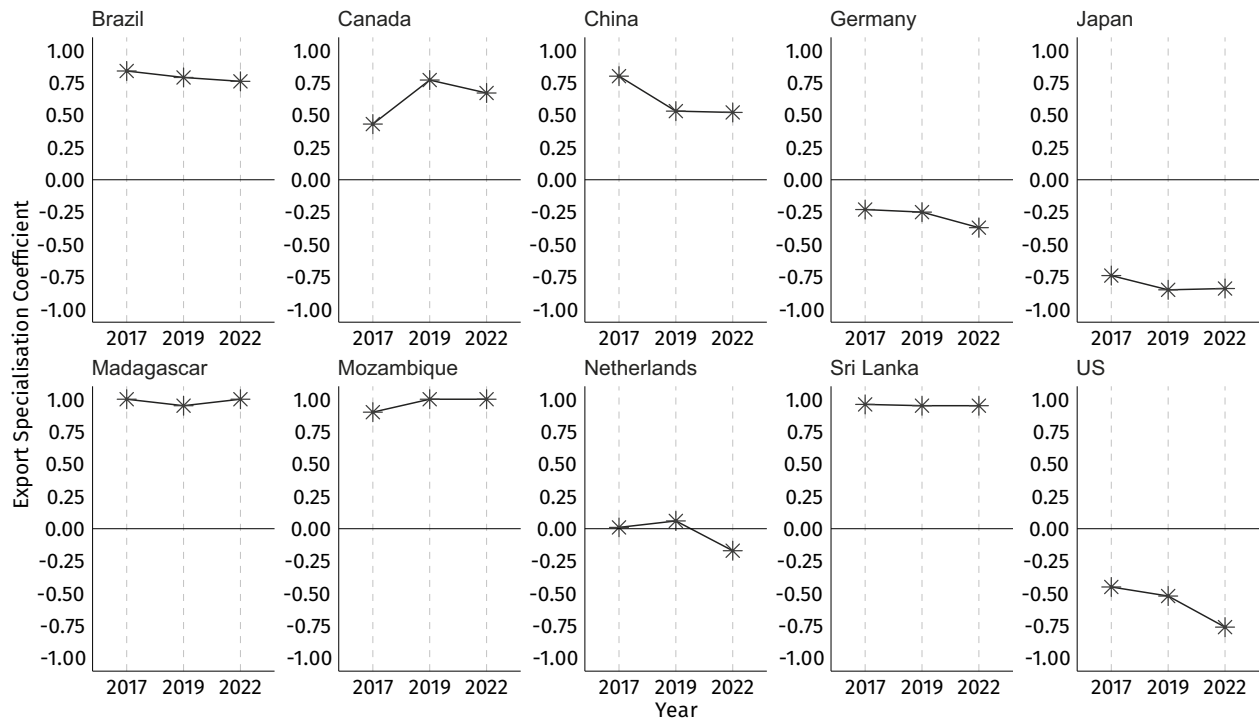
at the expense of the market penetration of Japan, contracting it by 22.3 percentage points. Even China lost its market share to Mozambique and Madagascar during 2018-2022 in some graphite import markets. In the EU, China lost 8.3 percentage points of market share, while Mozambique and Madagascar gained 3.3 and 6.1 percentage points, respectively. Similarly, China lost 3.8 percentage points in the Japanese market while Madagascar gained 2.8 points. However, China spread its dominance in export destinations such as South Korea and the US, deepening market penetration by 10.4 and 34.7 percentage points in 2018-2022. In the US market, Canada lost market share by 32.5 percentage points.

Data reveal that low-cost exporters like Mozambique and Madagascar benefit from the increased demand for graphite. In the EV battery market, cost reduction is pivotal in the quest to make EVs affordable to general consumers. Thus, it is natural that EV battery makers buy graphite from low-cost suppliers. Indeed, this trend challenges Sri Lanka's ambitions for market expansion, provided Sri Lanka is not currently cost-competitive. When considering the market penetration, Sri Lanka has lost market penetration in almost all major markets except Japan, where a slight gain of 0.5 percentage points is evident from 1.4% to 1.5%. Globally, Sri Lanka's market penetration dipped from 0.9% to 0.8% during 2018-2022. The market share loss is the biggest in the US market, shrinking from 1.6% to 0.4%. A plausible reason behind Sri Lanka's underperformance might be a lack of price competitiveness and the importing countries' emerging demand for low-cost graphite sources.

Table 9: Sri Lanka in the Global Natural Graphite (HS 250410) Supplier Network: Key Indicators for 2019

Country	Quantity (mt)	Value (USD Mn)	Unit price (USD/mt)	Share (quantity)	Share (value)	Revealed comparative advantage (RCA)
China	189,664.0	295.6	1,558.4	37.6	58.1	4.4
Mozambique	161,937.0	46.2	285.4	32.1	9.1	361.0
Brazil	17,902.7	27.2	1,519.4	3.5	5.4	4.5
Germany	14,994.2	26.3	1,753.4	3.0	5.2	0.6
Madagascar	53,958.4	19.6	363.8	10.7	3.9	272.0
US	6,115.8	18.5	3,024.9	1.2	3.6	0.5
Canada	12,396.7	17.1	1,377.6	2.5	3.4	1.5
Netherlands	9,198.9	10.5	1,136.8	1.8	2.1	0.7
Japan	924.6	8.4	9,086.6	0.2	1.7	0.4
Sri Lanka	2,570.3	4.6	1,787.5	0.5	0.9	14.4
Total	504,722.5	508.3		100.0	100.0	

Source: Authors' compilation using WITS data

Figure 8: Fluctuation of Export Specialisation Coefficient of Major Graphite Exporter: 2017 - 2022

Source: Illustration based on authors' calculation

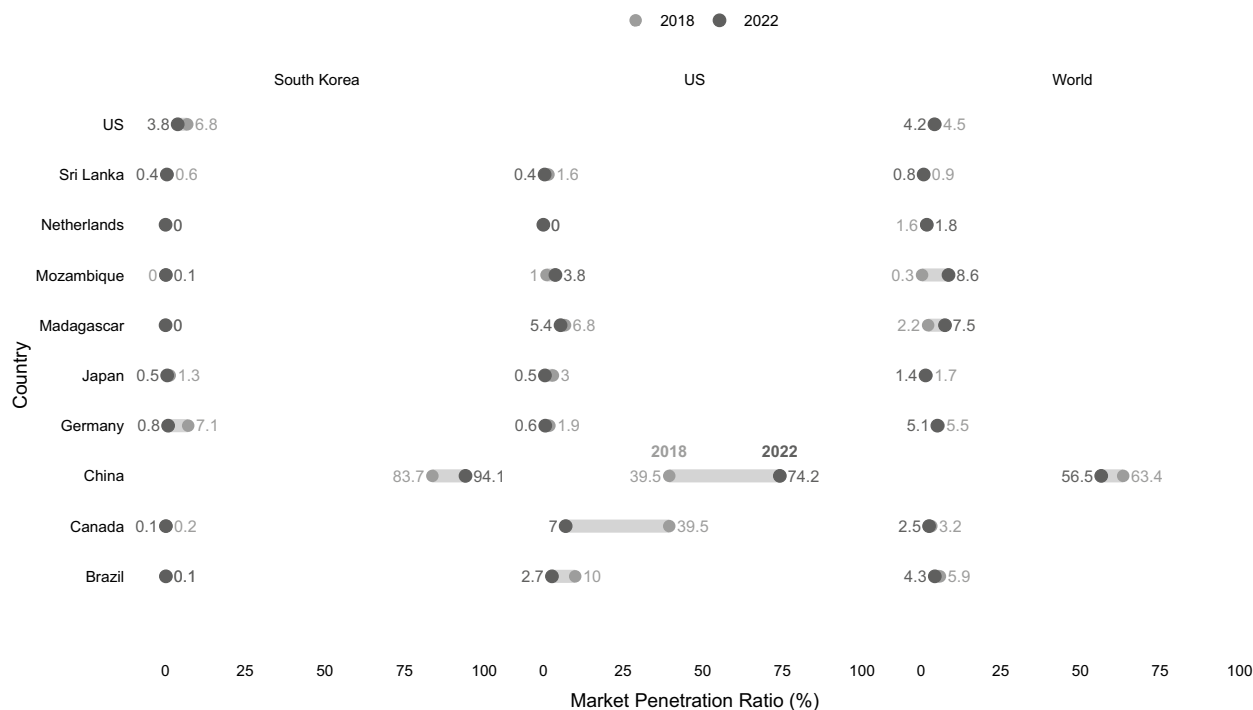
Table 10: Export Growth to China, US, and the EU 2018 - 2022 by Major Suppliers (%)

Supplier	Exporting market					
	World	US	South Korea	Japan	China	EU
World	22.9	188.3	60.8	-16.3	117.7	36.0
China	9.5	442.0	80.6	-19.7	NR	11.3
Mozambique	3,219.6	983.1	8,800.0	-25.0	485.1	89.6
Madagascar	311.6	130.5	—	1,526.0	129.0	192.1
Germany	14.0	-18.2	-82.4	0.0	-14.0	NR
Brazil	-10.6	-22.1	56.9	48.5	-55.6	-3.4
US	13.6	NR	-9.9	-16.2	17.1	-97.5
Canada	-4.0	-48.9	-25.6	18.0	30.6	-10.8
Netherlands	38.8	-100.0	-100.0	—	-99.0	—
Japan	-3.3	-52.5	-31.3	NR	-78.5	64.1
Sri Lanka	8.3	-22.8	2.3	14.6	-68.5	-44.7

Note: NR denotes Not Reported

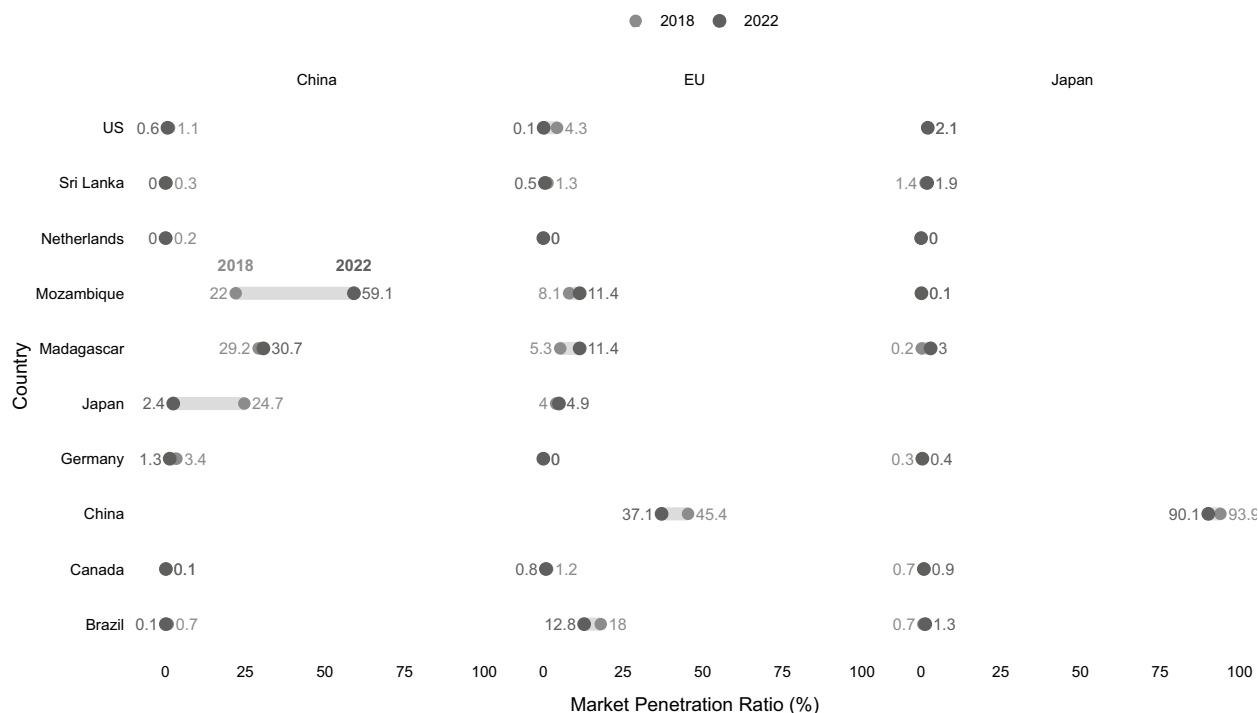
Source: Authors' calculations using Trade Map data

Figure 9: Change in the Market Penetration Ratio of Major Graphite Exporters: Export Destinations are South Korea, the US, and the World



Source: Illustration based on authors' calculations

Figure 10: Change in the Market Penetration Ratio of Major Graphite Exporters: Export Destinations are China, the EU, and Japan



Source: Illustration based on authors' calculations

All in all, existing unit prices, comparative advantage, surplus production, and market penetration trends signal fierce competition for exploiting the emerging opportunities for “non-China” graphite among the low-cost graphite suppliers outside China. Among these, Madagascar and Mozambique are better poised to supply low-cost “non-China” origin graphite in adequate quantities. However, with the global demand growth scenario, low-cost mining opportunities will be exploited faster, fading the cost advantage for Madagascar and Mozambique. The World Bank estimates the global graphite demand to be 4.5 Mn annually by 2050. The cumulative quantity is as much as 68 Mn mt, recording a marked surge in demand by 500% compared to the production level in 2018 (Hund, Arrobas, Fabregas Masllovet, Laing, & Drexhage, 2020). Therefore, while currently not cost-competitive, Sri Lankan graphite could see significant potential in the future, provided that the battery chemistry does not deviate significantly from LIBs, which is a reasonable assumption (Grey & Hall, 2020). If Sri Lanka manages to expand mining to unutilised graphite deposits, increase mining capacity, achieve scale of economies and further cut costs, Sri Lanka’s competitiveness may further increase. Notably, Sri Lanka’s graphite deposits are close to 1.5 Mn mt, hence its production capacity is substantial.

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Sri Lanka may also benefit from the emerging concerns on the socio-environmental impact of energy-transition-induced extractions on graphite suppliers such as Mozambique (Namaganda, Otsuki, & Steel, 2023). Concerns about the environmental sustainability of graphite mining, employment of child labour in the mines, and risk of governance and conflicts in the mining countries heighten the graphite supply chain vulnerability. Moreover, countries exposed to such vulnerabilities are susceptible to perceived unethical in the eyes of importers who are keen on sustainable sourcing. For example, the EU’s Joint Research Centre identifies Mozambique as a country with weak governance and low environmental performance. In addition, Mozambique and Tanzania are also categorised as high-risk countries for employing child labour (Mancini, Eslava, Traverso, & Mathieux, 2020). China and Brazil are deemed as countries with weak governance and low environmental performance. So far, incidents of child labour have not been reported in Sri Lanka, and in addition, the country is better ranked in the Fragile State Index. Thus, Sri Lanka has an opportunity to position itself as a sustainable and responsibly mined graphite in the world market. Sri Lanka also enjoys preferential market access under Generalised Scheme of Preferences Plus (GSP+) in the EU. However, the preferential market access is not exclusive to Sri Lanka as graphite exporters like Madagascar benefit from the EU’s Everything But Arms (EBA) programme.

One crucial downside risk is that although Sri Lanka’s political vulnerability is lower and legal labour markets exist, and adverse macroeconomic problems will discourage investments in the EV battery manufacturing value chain. Implementing sound macroeconomic policies and guaranteeing protection for the investors’ assets can help de-risk the above-mentioned investment conditions. Preferential market access helps more in exporting value-added graphite products. As natural graphite is a raw material, unprocessed graphite product lines in the upstream value chain -HS 250410 and HS 250490- are not subject to tariffs in most major exporting countries. The only graphite-importing country with a positive tariff is China. China has 3% of Most-Favoured Nation (MFN) tariffs imposed for natural graphite products. Sri Lanka enjoys 50% of the margin of preference in the Chinese market under the Asia-Pacific Trade Agreement (APTA). Currently, there is a positive tariff for electrodes by Japan and the EU. Graphite in blocks and plates also faces positive tariffs in the EU, Japanese, and US markets. Only China has a history of exporting these products. Consequently, WITS reports tariffs applicable to China (Table 11).

Table 11: Existing Tariffs for Various Graphite Products in Significant Markets (2019)

Product code	Product	Major market	Tariffs faced by the exporters (%)			
			China	Sri Lanka	Mozambique	Madagascar
HS 250410	Natural graphite	China	-	2	3	3
		Japan	0	0	0	0
		EU	0	0	0	0
		US ¹⁴	0	0	0	0
HS 250490	Other natural graphite	China	-	1.5	3	3
		Japan	0	0	0	0
		EU	0	0	0	0
		US	0	0	0	0
HS 380190	Graphite (blocks, pastes, and plates)	EU	3.7	-	-	-
		Japan	3.2	-	-	-
		US	4.9	-	-	-
		Japan	3.3	-	-	-
		US	0	-	-	-
HS 854519	Electrodes	EU	2.7	-	-	-

Source: Authors' compilation using WITS data

Overall, world graphite trade in upstream product lines is almost frictionless except for China's 1.5%-3% tariff on exporters.¹⁵ However, downstream value-added products face significant positive tariffs in the EU and Japan. The ambitions to expand domestic production of EV batteries have inspired the protectionist tariffs. In natural graphite exports, Sri Lanka has preferential access to the Chinese market, while in the other markets, Sri Lanka faces zero MFN tariffs. However, as IRA subsidies lower the relative cost of "non-China-origin" graphite in the US market, creating new avenues of trade and trade diversions away from China are possible. As other suppliers will also gain, Sri Lanka is not the only beneficiary from this trade diversion. The partial equilibrium simulations estimate significant trade creation for graphite.

Significant beneficiaries of the increased demand are low-cost producers- like Madagascar- and natural trade partners of the US- Canada and Mexico. However, Canada and Mexico are likely to face supply constraints as graphite deposits are insignificant. In the partial equilibrium analysis, supply constraints were ignored, and supply was considered perfectly elastic. Given the export level in 2019, a subsidy proposed by IRA would raise Sri Lanka's graphite exports to the US by 66%. If the EU follows such a subsidy excluding China, Sri Lanka will gain 76% more exports to the EU (Tables 12 and 13). In the EU, competing exporters like Brazil, Mozambique, and Madagascar benefit more than Sri Lanka.

While partial equilibrium estimates of this nature indicate the general patterns of demand distribution among the competing graphite exporters, there are many limitations. Partial equilibrium estimates do not capture the increased demand due to the preference shift from ICE vehicles to EVs. In addition, a ban

¹⁴ Trump era tariff of 25% applied for artificial graphite but a waiver had been approved at that time due to the importance of graphite in the auto industry

¹⁵ It is noteworthy to mention that China and Sri Lanka started negotiations for a free trade agreement in the past. Lowering graphite tariffs further will likely increase Sri Lanka's graphite exports to China. Partial equilibrium simulation can estimate the impact of a tariff cut on existing trade in a base year. Taking 2019 as base year, this study estimates a 5.0% gain in exports of natural graphite (HS 250410) increasing exports from USD 0.033 Mn to USD 0.034 Mn. Product line HS 250490 will realise 6.8% gain in exports increasing the export value from USD 0.131 Mn to USD 0.141 Mn (Table A.4 in Appendix)

on ICE drastically increases EV battery demand. Globally, current exporters like EU countries, Japan, South Korea, and the US may reduce exports and import more, relying upon imports from net exporters like Mozambique, Madagascar, and Sri Lanka. Thus, the actual demand for graphite can be much larger than the partial equilibrium estimates. However, the increased demand for graphite from Mozambique and Madagascar remains the same if the graphite exporters exclude China from consumer tax credits. Against this backdrop, Sri Lanka will need to compete by further cutting down the production cost to boost graphite exports and attract and tap the potential of the increased demand.

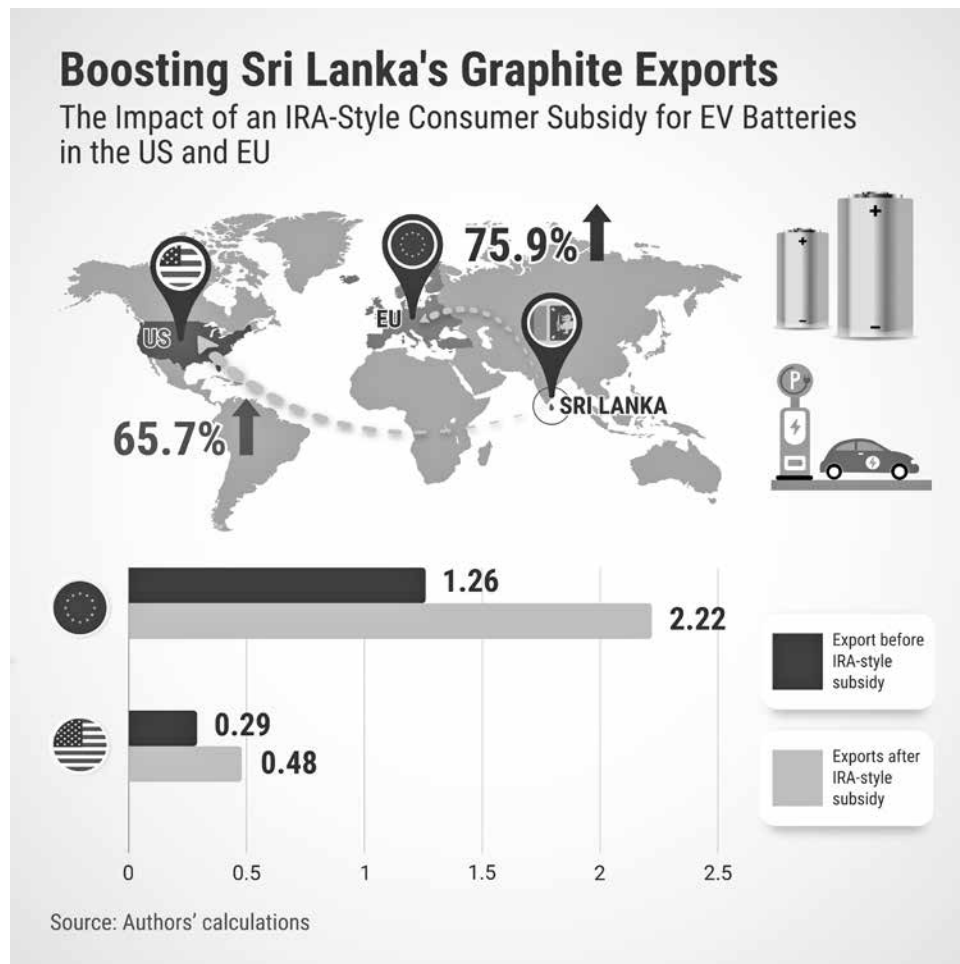


Table 12: Trade Creation Effect on Sri Lanka's Graphite Exports to the US and EU from an IRA-Style Consumer Subsidy for EV Batteries

Exporter	Export destination	Exports before (USD Mn)	Exports after (USD Mn)	Change (USD Mn)	Change (%)
Sri Lanka	EU	1.26	2.22	0.96	75.9
Sri Lanka	US	0.29	0.48	0.19	65.7

Source: Authors' calculations

Table 13: Trade Creation Effect “Non-China” Graphite Exports to the US and EU from an IRA-Style Consumer Subsidy for EV Batteries

Exporter	Export destination	Exports before (USD Mn)	Exports after (USD Mn)	Change (USD Mn)
Brazil	EU	19.8	34.6	14.9
Japan	EU	19.2	33.6	14.5
Mozambique	EU	15.3	26.9	11.6
South Korea	EU	14.8	26.0	11.2
Norway	EU	6.1	10.6	4.6
Madagascar	EU	5.8	10.2	4.4
Canada	US	14.20	23.53	9.33
Brazil	US	5.31	8.80	3.49
Mexico	US	4.84	8.02	3.18
Madagascar	US	3.11	5.16	2.05
Japan	US	1.97	3.26	1.29
Germany	US	1.13	1.87	0.74
Mozambique	US	0.92	1.53	0.61

Source: Authors' calculations

Increasing the complexity of the export basket by producing products with high technology content is known to spur economic growth. Sri Lanka's involvement in the EV battery supply chain is not a newfound concept. Various stakeholders have advocated for involvement in multiple stages of the supply chain since early 2000s.

Market analysis for the currently exported graphite products sheds some light on the export potential of Sri Lanka's graphite in the emerging global drive for electromobility. A discussion on the possible nodes in the EV battery manufacturing segment that Sri Lanka can join is also imperative for a few reasons. First, export diversification, a significant goal of Sri Lanka's export-led growth strategy, requires diversifying into new product lines. Second, industrial policy initiatives require identifying feasible product lines to be developed. Third, value-added graphite fetches a higher price in the world market, generates more employment in the country, and opens new avenues for further diversification of Sri Lanka's export basket. Increasing the complexity of the export basket by producing products with high technology content is known to spur economic growth. Sri Lanka's involvement in the EV battery supply chain is

not a newfound concept. Various stakeholders have advocated for involvement in multiple stages of the supply chain since early 2000s. Some of the potential value-addition stages are explored in this study, which are outlined below. These stages are further evaluated by factoring in constraints and opportunities in capacity, knowledge, technical know-how, and market and economic developments.

1. Mining and extraction
2. Mining and extraction → Processing and purifying
3. Mining and extraction → processing and purifying → cell component production (anode only)
4. Mining and extraction → Processing and purifying → Battery cell production (whole cell, import other minerals)
5. Mining and extraction → Processing and purifying → battery cell production → module production
6. Mining and extraction → Processing and purifying → Battery cell production → module production → Battery pack assembly

The current level of production and processing of graphite in Sri Lanka enables Sri Lanka to join the graphite-related EV battery manufacturing value chain in the second option. Sri Lanka's graphite is mined and then purified in commercial scale according to customer preference, although not specifically for EV batteries. According to a key informant, while operational mines produce only around 5,000 mt, current technology could set Sri Lanka for a hike in production volume to 350,000 mt annually. Additionally, the accumulated industry knowledge is substantial because of the knowledgeable incumbent local participants and their involvement in years of operation. Regrettably, although a customer base for Sri Lankan graphite has already been established, no local mining company supplies EV batteries specifically to an EV battery manufacturer. This means the possibility of missed opportunities for Sri Lanka.

Furthermore, exploring vein graphite mining is currently done by other stakeholders, including Ceylon Graphite Corporation, a mine-to-battery company focused on providing naturally high-grade vein graphite for battery anodes (Innovation News Network, 2022). Having produced graphite purity levels of 99.9997% from its K1 mine, their operations prove that environmentally less hazardous thermal purification can be used on Sri Lankan vein graphite to improve purity levels. The vein graphite at the mined stage has a higher purity level, which signals a bonus to Sri Lanka that the primary processing required for flake graphite is unnecessary. This compares well against competitors such as China, whose current purification practices use hydrofluoric acid instead of the process followed in Sri Lanka. Arguably, choosing only to mine and purify Sri Lankan graphite does not add much value to the supply chain and would rather provide minimal value to the country. Thus, the possibility of value addition in further downstream nodes of the manufacturing value chain should be explored.

Regarding the third option- the production of anode material from mined graphite- the stakeholders have strongly advocated Sri Lanka's production of anodes, and research concerning the use of Sri Lankan vein graphite is well underway. A mining firm is keen on directing investment into mining vein graphite for EV battery anode production. Other stakeholders, such as the National Institute of Fundamental Studies (NIFS) and the University of Moratuwa (UoM), are actively developing anodes for LIBs using Sri Lankan vein graphite. The research currently being developed here aims to find an anode to achieve specific properties. For example, when designing a LIB, two fundamental qualities must be assessed: the battery lifetime (in terms of distance travelled) and the lifespan, i.e. how many charge/discharge cycles a battery can have. The greater the either of these, the better the battery's performance. Among other issues, the battery weight and its environmental impact are subsequent considerations. The research currently conducted in Sri Lanka aims to prove the superior nature of specifically designed anodes that use vein graphite in terms of these qualities.

Additionally, producing the EV anode using Sri Lanka graphite on a commercial scale also faces considerable challenges. Though graphite anode components can be produced locally, the machinery for drilling and processing graphite specifically for anode production would have to be imported, which calls for substantial investment capacity.

The anode model, manufactured at a lab scale with vein graphite mined in Sri Lanka, is under testing and has already been granted intellectual property rights for the constitution of the batteries. However, chemical and thermal testing for all parameters must be conducted to test the battery to ensure it complies with industry standards. At present, Sri Lanka lacks a thermal testing laboratory, which makes this impossible, partly due to the prevailing import restrictions on technologies required. Additionally, producing the EV anode using Sri Lanka graphite on a commercial scale also faces considerable challenges. Though graphite anode components can be produced locally, the machinery for drilling and processing graphite specifically for anode production would have to be imported, which calls for substantial investment capacity. The capacity of the mined graphite veins is subject to debate among the experts. The investors are concerned with the limited capacity of the output. The existing technology

imposes a high production cost on Sri Lankan graphite, making it hard for local producers to compete with competitors from countries like China and Mozambique. Adopting newer mining technologies could see a hike in their capacity from 4,000 mt to 350,000 mt per year, enabling Sri Lanka to supply processed graphite to manufacturers like Tesla.

Alternatively, another potential value addition suggested by a key informant was through a patent for the design of an improved battery containing vein-graphite anodes. Research conducted by Sri Lanka proves to be beneficial to foreign producers. It is not uncommon for EV manufacturers to outsource their research. In 2020, Tesla Inc., a leader in EV battery technology, agreed to fund a Canadian research facility focused on LIB development. Through this, Tesla has supported battery research by the facility, listing these companies as co-inventors in at least six potential applications since 2017 (Shirouzu & Lienert, 2020).

However, using Sri Lankan graphite for anodes as a filler material can be challenged with an alternative material: graphene. A key informant representing graphite-related manufacturing suggested producing graphene as a value-added intermediate, acting as an active material, meaning it would be used in the electrochemical charge/discharge reaction. It was argued that graphene production for electrodes in EV batteries would set the ground for a better opportunity for value addition. However, the quantity needed per battery would be lower than the graphite requirements. While graphene utilisation for EVs has not been thoroughly explored, it may yield another opportunity for Sri Lanka to be involved in the EV battery supply chain. It could also be a technology worthwhile exploring in years to come.

Box 3: Graphene: The Wonder Material

An exfoliant of graphite, graphene is a single-atom-thick sheet of carbon forming a honeycomb lattice-like pattern. It earns its name as the wonder material owing to its unrivalled and superior properties, including its ability to conduct electricity has created a voluble discussion on its use in batteries, including those that are lithium-ion based. Acting as an active material in the battery, graphene can be used in the electrodes of lithium-based cells- in the anodes of the LIBs, or in combination with sulphur cathodes in lithium-sulphur batteries- chiefly due to its chemical stability and high electrical conductivity. This addition will allow the electrode to be lighter, and thus more suitable for higher energy and power densities. The high carbon added to the active materials in the electrodes can also give the battery an extended life, while its high electric conductivity can significantly improve battery performance.^a

The global graphene battery market is expected to grow from USD 140.7 Mn in 2023 to USD 2 billion (Bn) by 2033, with a CAGR of 31%. The graphene market expands across North America, Europe, Asia, and the Middle East & Africa. The EU in particular has established its interest in this material, enforcing the EU Graphene Flagship to promote graphene research. With a budget of Euro (EUR) 1 Bn, it operates with the aim to become a global leader in terms of graphene and related 1-dimensional material research.^b

In terms of global exports, close to USD 944.5 Mn of graphene (under HS Code 380190) was exported, of which China exported the largest proportion, valued at USD 570.8 Mn. With the largest share in the graphene market, China exported 120,000 tonnes in 2022. Countries that followed included Malaysia, the United Arab Emirates, the Russian Federation, and Germany.

Research about graphene is, however, inconclusive as still uncertainty exists to some extent in terms of its practical uses and its production on a commercial scale. Several key obstacles lie in the way of commercial adoption, including the relatively high cost of graphene. In 2020, single-layer graphene was sold at EUR 230 per centimetre-squared, while graphene oxide cost EUR 140,000 per kg.^c This may be due to the high costs of processing graphite to graphene

and scarce availability in large amounts necessary for large-scale production.^{a,d} Therefore, it is posited that wide-spread application is somewhat restricted by the limited sustainability in terms of large-scale production and handling. Despite this, graphene-based materials are seen to be the most promising candidates for the future of next-generation energy storage devices and electromobility.^a

Sources:

- a Lavagna, Luca, Giuseppina Meligrana, Claudio Gerbaldi, Alberto Tagliaferro, & Mattia Bartoli. 2020. Graphene and Lithium-Based Battery Electrodes: A Review of Recent Literature. *Organic/Inorganic Hybrid Materials for Fuel Cells and Advanced Batteries* 13(18).
- b IMARC Group. (2023). Graphene Battery Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2023-2028 (Market Report 6293596; Issue 6293596). IMARC.
- c Bartoli, M., Giorcelli, M., Jagdale, P., Rovere, M., & Tagliaferro, A. (2020). A Review of Non-soil Biochar Applications. *Materials*, 261.
- d Witharana, S. (2023, July 18). Sri Lanka's Potential to Join the EV Battery Supply Chain [Institute of Policy Studies of Sri Lanka, Interviewer].

Producing the whole cell, as in the fourth option, would provide more lucrative opportunities to improve value addition. Still, from a pragmatic standpoint, it is inapt than its former options for a few reasons. First, other components critical minerals required, such as lithium, nickel, and cobalt, are not available in Sri Lanka, and global competition exists to secure these minerals. Thus, battery cell production would involve Sri Lanka importing these materials from countries such as Chile and Indonesia. The ability of a nascent industry to face the fierce global competition regarding raw materials to secure adequate supplies and manage supply chain vulnerabilities arising from trade and industrial policies of the exporting countries is doubtful. For example, Indonesia, one of the leading countries with nickel endowments, banned nickel exports. Second, as mentioned before, Japan and South Korea are leaders in cell component production. Battery cell production is highly concentrated, with the top three producers in 2021- CATL (China), LG Energy Solutions (South Korea), and Panasonic (Japan)- accounting for a bulk share (65% of the global production (International Energy Agency, 2022). In the EV battery cell production value added in 2019, US EV Sales, Japan and South Korea contributed USD 99 Mn and USD 40 Mn, respectively (Horowitz, Coffin, & Taylor, 2021). Out of 10 battery cell production locations for major EV models sold in the US, Japan and the Republic of Korea are involved in 6 as of 2017 (Coffin & Horowitz, 2018). Entering a market with a high concentration of this kind would be daunting, mainly because the existing players are established conglomerates with several decades of experience (International Energy Agency, 2022).

Without EV vehicle manufacturing in Sri Lanka, having an EV battery seemed less feasible. Sri Lanka's success will rely on attracting investments in EV vehicle assembly from Asian manufacturers targeting Asian consumers.

Conditions pertinent to other options are similar, but option six was the least likely because battery pack assembly usually occurs near the vehicle assembly location due to the logistics of (on transporting) battery packs, which are larger and heavier than cells or modules (Barman, Dutta, & Azzopardi, 2023). As a result, wider production sharing along the value chains is being restricted, reducing the ability to produce the battery pack in some other ies, separate from EV manufacturing. Without EV vehicle manufacturing in Sri Lanka, having an EV battery seemed less feasible. Sri Lanka's success will rely on attracting investments in EV vehicle assembly from Asian manufacturers targeting Asian consumers. The US industrial policy already incentivises locating EV manufacturing firms of Asian origin within the US, further impeding the value chain's fragmentation. As ICE vehicle manufacturing is an electorally pivotal manufacturing sector, most industrial countries tend to incentivise EVs to be produced within their own countries, with the fear of an electoral backlash from the EV manufacturing workers. The impact of industrial policy in the developed country on possible value addition is negative. As discussed

earlier, the US IRA provides subsidies for the domestic production of battery components. Such trade policy barriers undermine Sri Lanka's ability to produce downstream products along the EV battery manufacturing value chains.

It should be acknowledged that existing capacity constraints might affect Sri Lanka's positioning in the EV battery manufacturing value chain. Mass-scale production has decelerated partly due to the lack of competitiveness of Sri Lankan graphite in terms of cost. In Sri Lanka, to some extent, price differences occur because the graphite is mined from deep mines making extraction costlier. Chinese graphite comes from open-cast mining- a much easier operation, albeit environmentally hazardous due to acid use in processing.

Existing capacity is also underutilised, as several key informants mentioned that the untapped graphite reserves exist under jungle cover and areas in Anuradhapura. The underutilisation can partially result from increased environmental regulatory measures prohibiting the expansion of mining operations. The stringent environmental regulations create high barriers to entry, adding to the high entry costs and making it difficult for new companies to open mines. Once mined and processed, developing this graphite into anodes is also constrained. As with the battery development at the UoM, the process is made difficult by the import restrictions and curtailed research expenditure by the government, removing critical equipment and funding for development. Even if a battery is developed in Sri Lanka, it would be easier to commercialise it with proper safety tests. However, this is impossible at present in the absence of a thermal testing lab in Sri Lanka. A key informant spoke about the importance of encouraging research and development (R&D) efforts within Sri Lanka and recommended facilitating developers to gain intellectual property rights.

Based on the quantitative analyses and KIIs, two SWOT analyses are reported in Tables 14 and 15. First, a SWOT analysis is done to evaluate Sri Lanka's potential to join more EV battery manufacturing upstream nodes. Mining, extraction, processing, and anode production are upstream nodes (Table 14). The second SWOT analysis considers the possibility of joining more downstream nodes such as cell, battery module, and battery pack production (Table 15). The SWOT analyses and summarises the study's findings to identify the most feasible nodes of the EV battery value chain that Sri Lanka can join. Due to logistic reasons, the battery module and battery pack assembly are the most remotely possible nodes. As mentioned before, battery packs are generally assembled where EV manufacturing occurs. In addition, national security concerns and supply chain resilience motivate significant economies to produce batteries domestically.

Sri Lanka faces a narrow opportunity to produce anodes as a value addition to high-purity graphite. Growing research and existing technical know-how in local universities might be instrumental in this process. However, the US industrial policy, too, exerts pressure on anode production as well as on producers to relocate/move to the US or North America to benefit from the IRA. Sri Lanka can capitalise on potential trade agreements with ASEAN economies to enter the emerging China-Thailand-Indonesia EV hub as an anode producer. Accordingly, as manufacturing substantially value-added graphite products is uncertain, Sri Lanka's most promising path towards integrating into the EV battery value chain is to supply battery-grade graphite.

Box 4: Policy Environment for EVs in Sri Lanka

In 2009, Sri Lanka amended its Motor Traffic Act to include EVs, marking the inception of increased state attention towards the sector.^a The momentum continued with the 2017 publication of Regulations for EV Charging Stations by the Public Utilities Commission of Sri Lanka. These regulations encompassed licensing procedures, charging rates, safety protocols, and other technical guidelines, underlining a commitment to fostering a robust EV infrastructure.^b The drive towards sustainability gained further traction through the recommendations outlined in the Presidential Expert Committee's report, "Sustainable Sri Lanka 2030 Vision and Strategic Path." The report advocated for tax reductions on EVs and the introduction of electrically powered public transport systems to offer sustainable energy alternatives for the transportation sector.^c

Aligning with these recommendations, the National Policy on Sustainable Consumption & Production for Sri Lanka, published in October 2019, set forth a policy goal aimed at promoting energy efficiency in various transport modes.^d Subsequently, in 2021, the Cabinet granted approval to a proposal by the Minister of Environment, calling for the preparation of a strategic plan to boost the adoption of EVs across Sri Lanka.^e Kumarage and Silva in their gap analysis study done in 2021 noted the main policy challenges of capacity and adaptability of current electrical infrastructure and institutions that must be taken into consideration when promoting EVs.^f The commitment to encouraging EV usage was further underscored by the Ministry of Labour and Foreign Employment Circular No: 02/2022 Scheme, which granted permits and licenses for Sri Lankans employed abroad to import EVs.^g

A noteworthy development occurred in September 2023 when the Cabinet approved a tariff exemption of up to USD 30,000 for importing EVs, providing a substantial incentive for their adoption. Furthermore, approval was granted for imposing a zero (0%) custom tariff on Cost, insurance and Freight (CIF) value when importing electric two-wheelers with a power grade up to 500 kilowatts (kW) and modern partially assembled semi-knocked-down (SKD) sets with an engine capacity up to 3,000 cylinder capacity (CC) for assembling plug-in hybrid EVs for investors who had reached an agreement to invest 50 million USD and upwards with Sri Lanka Board of Investments (Department of Government Information, 2023). The Department of Motor Traffic is actively engaged in testing and promoting EVs in various locations across the country, contributing to the ongoing efforts to embrace sustainable and eco-friendly transportation alternatives.^g

The Board of Investments of Sri Lanka lists 100% duty-free market access for all component items except rubber parts to enter into the Indian market under Indo-Sri Lanka Free Trade Agreement (ISLFTA), 100% duty-free market access for 60% of the total auto component items to enter into Pakistan market under Pakistan - Sri Lanka Free Trade Agreement (PSLFTA), and 100% duty-free market access to EU + market under EU GSP scheme as advantages for electrical vehicle component investments in Sri Lanka.^h

Sources:

- a Government of Sri Lanka. (2009). Motor Traffic (Amendment) Act, No 08 of 2009. Colombo: Department of Government Printing of Sri Lanka.
- b Public Utilities Commission of Sri Lanka. (2017). Regulation of Electric Vehicle Charging Stations. Colombo, Sri Lanka: Public Utilities Commission of Sri Lanka.
- c Presidential Expert Committee. (2019). Sustainable Sri Lanka 2030 Vision. Colombo: Presidential Secretariat.
- e Ministry of Environment of Sri Lanka. (2019). National Policy on Sustainable Consumption & Production for Sri Lanka. Colombo, Sri Lanka: Ministry of Environment of Sri Lanka.
- f Kumarage, A. S. and Silva, M.M.D. (2021). A Gap Analysis of EV Policies for promoting E-Mobility in Sri Lanka. East Asian Society of Transport Studies (EASTS). Hiroshima, Japan: East Asian Society of Transport Studies (EASTS).
- g Department of Motor Traffic. (2023 January 19). Protocol for Licencing of Electric Motorcycles. retrieved on 1st January 2024 from Department of Motor Traffic: https://dmt.gov.lk/index.php?option=com_content&view=article&id=89:2023-02-25-18-46-44&catid=8&Itemid=140&lang=en
- h Department of Government Information. (2023). Cabinet Decisions. Retrieved on 1st January 2024 from Department of Government Information: <https://www.dgi.gov.lk/news/cabinet-decisions?start=10>

Sri Lanka is in a relatively advantageous position to supply battery-grade graphite to the EU and US markets as a “non-China” origin sustainable graphite source. Substantial deposits, although relatively smaller compared to mining giants like China, Mozambique, and Madagascar, will see an enhanced value in the future due to high demand and the US and EU, and the previously explained concerns about over-reliance on graphite origin from China. Sri Lanka can position itself in the graphite for the EV battery market as a high-quality, sustainable, and responsibly mined, respecting labour and child protection accords- with less geopolitical risk for buyers like the EU and US. However, the advantages are in non-price, particularly strategic and sustainability domains deemed sensitive. It is imperative to explore price-competitive avenues to benefit from the global drive for securing graphite for EV batteries.

Table 14: SWOT Analysis for Sri Lanka’s Potential to Join Upstream Nodes of the EV Battery Value Chain (Graphite Mining/processing and Anode Production)

Strengths	Weaknesses
• High purity of vein graphite at the mining stage • Ability to exceed LIB battery grade purity through environmentally responsible thermal processing¹⁶ • High performance of natural graphite compared to synthetic graphite • Substantial deposits: reported deposits reach 1.5 Mn mt (US Geological Survey, 2022) • Preferential market access to the EU through GSP+ and margin of preference to China through APTA • Sri Lanka’s FTAs (Existing FTAs with India, Singapore, South Asia, and Pakistan. Sri Lanka has expressed interest/started negotiations for FTAs with Thailand, Bangladesh, Indonesia, and the Regional Comprehensive Economic Partnership (RCEP). • Existing revealed comparative advantage and surplus production • Responsible and sustainable mining.	• Less price competitiveness compared to China and emerging low-cost producers, Madagascar, and Mozambique • Relatively smaller mining capacity: annual production is nearly 5,000 mt only • Although substantial, the relatively small size of the known deposits • High operational cost compared to open-pit graphite mining practised by the major competitors. • Government royalty fees (9%)
Opportunities	Threats
• Global surge of demand for EV vehicles and EV battery	• The IRA-mandated subsidies incentivise investments for anode production in the US or North America¹⁷

¹⁶ Ceylon Graphite achieved 99.9997% purity in their K1 mine using thermal processing which is an environmentally sound process. (for more details refer <https://www.ceylongraphite.com/news/ceylon-graphite-achieves-99-9997-graphite-purity-exceeding-lithium-ion-battery-requirements/>)

¹⁷ The US battery capacity has overtaken Europe’s (for more details refer <https://source.benchmarkminerals.com/article/ira-supercharges-usas-gigafactory-capacity-pipeline-as-it-overtakes-europe-for-first-time>)

• Possible consumer tax credits-induced demand surge for EV batteries: possible trade creation • Exclusion of China from consumer tax credits: possible trade diversion. • Emerging Asian EV battery hubs: China-Thailand-Indonesia cluster • The EU and US drive for “sustainable and responsibly mined” graphite	• Trade and industrial policy of the EU and the US, based on national security concerns leading to deglobalisation of the EV battery value chain • Fierce competition for supply the demand for “non-China” sourced graphite by low-cost and investor-friendly countries in Africa, which possess large deposits that need less expensive mining • Declining market penetration of Sri Lanka graphite
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Source: Authors' compilation

Table 15: SWOT Analysis for Sri Lanka's Potential to Join Downstream Nodes of the EV Battery Value Chain (cell/module/battery pack production)

Strengths	Weaknesses
• A growing body of research on battery cell and battery production • High-purity and battery-grade graphite in substantial deposits • Preferential market access to the EU through GSP+ and margin of preference to China through APTA • Sri Lanka's FTAs (Existing FTAs with India, Singapore, South Asia, and Pakistan. Sri Lanka has expressed interest/started negotiations for FTAs with Thailand, Bangladesh, Indonesia, and RCEP • Preferential market access to the EU through GSP+ and margin of preference to China through APTA	• Logistically impractical and unfeasible to produce a battery pack without an EV manufacturing base • Lack of investment capacity. • Lack of required research facilities such as battery testing labs • Sri Lanka's graphite deposits are relatively lower, although substantial. Investors might consider it as a disadvantage • Government royalty fees (9%)
Opportunities	Threats
• Global surge of demand for EV vehicles and EV battery • Emerging Asian EV battery hubs: China-Thailand-Indonesia cluster • The EU and US drive for “sustainable and responsibly mined” graphite in EV batteries	• Investors are concerned with the recent debt default and capacity to meet the demand • Trade and industrial policy of the EU and the US based on national security concerns leading to deglobalisation of the EV battery value chain • EV battery and component production firms located in the US or North America to benefit from IRA subsidies • Fierce competition to secure other CRMs like lithium, cobalt, and nickel, which are not found in Sri Lanka

Source: Authors' compilation

5. Conclusion

The imperative to achieve net-zero emissions, national security considerations, and domestic political concerns related to the manufacturing sector drive the US to adopt a proactive green industrial policy. While the US employs discriminatory consumer subsidies to promote EV adoption, its industrial policy encourages establishing EV and EV component manufacturing within its borders. This strategic move aims to diversify the supply chain and lessen vulnerabilities by excluding China. Given this context, the rising demand for graphite, spurred by IRA subsidies and the decision to exclude China creates a void in the existing supply market as well as generates lucrative new prospects for graphite producers outside China.

Specifically, the mining and processing of graphite into battery-grade material represent the most viable product line/s for Sri Lanka to pursue. To mitigate risks stemming from the US industrial policy, Sri Lanka can explore mineral trade agreements with the US, which would stimulate additional investments in the country's mining sector.

Partial Equilibrium analysis shows that increased demand for graphite would see a major shift graphite exports from “non-China” sources to the US. While USFTA aggregation, Mozambique, Madagascar, and Sri Lanka are poised to gain from the trade creation, and are currently among the only few countries as surplus exporters. Thus, fierce competition between the surplus producers should be expected to supply the demand for “non-China” graphite. Considering market penetration trends, significant graphite deposits, relative productivity advantages, and cost efficiencies, Madagascar and Mozambique find themselves in a more advantageous position to capitalise on the growing demand for “non-China graphite.” Nonetheless, as significant importers endeavour to diversify their supply chains away from China to mitigate vulnerabilities, concerns about the environmental sustainability of extraction, issues related to child labour, and governance matters may undermine the graphite extraction/export prospects of such countries.

Sri Lanka holds considerable potential to benefit from the increasing demand in the future, albeit lacking cost competitiveness in the global graphite export market. Sri Lanka prides itself on producing high-quality graphite characterised by battery-grade purity, minimal environmental impact, and adherence to acceptable labour standards. Additionally, Sri Lanka possesses a comparative advantage in graphite production and enjoys an established mining sector with a consumer base.

The SWOT analysis conducted to assess Sri Lanka's potential involvement in EV battery value chains indicates that the most promising opportunities lie in the upstream segment. Specifically, the mining and processing of graphite into battery-grade material represent the most viable product line/s for Sri Lanka to pursue. To mitigate risks stemming from the US industrial policy, Sri Lanka can explore mineral trade agreements with the US, which would stimulate additional investments in the country's mining sector.

Value addition, such as anode production, could become a realistic option if Sri Lanka manages to attract investments directed towards North America in the post-IRA era. Sri Lanka can leverage its trade relationships with ASEAN nations to attract investments in anode production. Notably, Sri Lanka has an FTA with Singapore. In addition, Singapore attracts investments in EVs and research programmes attempt to innovate by introducing fast-charging batteries. Moreover, Singapore positions itself well as a node between raw material suppliers like Sri Lanka and the US through FTAs. Thus, in addition to joining mineral trade agreements with US' trade partners, Sri Lanka has the potential to leverage on existing trade agreements to join production value chains of EV batteries. Additionally, investing in R&D, such as establishing battery testing laboratories for local university researchers, will

enhance the country's technical expertise in EV battery component manufacturing. These initiatives will likely generate positive interest from potential investors and create high-quality job opportunities in the manufacturing sector. However, producing complete batteries within Sri Lanka seems infeasible due to logistical challenges and the global concentration of EV battery manufacturing in the hands of a few selected economies.

The green industrial policy initiatives by the developed countries bring intricate challenges as well, mainly to the CRM-extracting developing countries with fragile governing systems and weak institutions. In the US, the approach to achieving net-zero targets involves consumer subsidies instead of carbon taxes. This approach effectively shifts the environmental responsibility associated with clean energy production to the countries that supply critical minerals. Pursuing cost-effective mining operations with lenient environmental and labour regulations may result in significant environmental and social consequences in the countries extracting graphite. Future research efforts should concentrate on examining these adverse external effects.

Another caveat in investing in graphite-based EV battery industry is the ability of a drastic change in green technology of vehicles, such as Hydrogen-powered vehicles, to destroy the EV battery industry. Overreliance on exporting graphite for the EV battery market warns against being lured by the industry's lucrativeness onto a proverbial submerged iceberg. Although a significant deviation is unlikely, as predicted by the increased demand for critical minerals for EVs, over-concentration of export baskets around graphite-related products is not a sound industrial policy. Supply countries must strive for export diversification to avoid sudden drastic economic shocks from demand fluctuations.

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Appendix A:

A. Consumer Tax Credits from the Inflation Reduction Act (IRA)

The IRA of the US provides tax credits to EV consumers under two requirements.

A.1) Critical Mineral Requirement

An EV will be eligible for USD 3,750 tax credit if the applicable percentage of the value of the critical minerals contained in the battery must be extracted or processed in the US or a country in which the United States has a free trade agreement (FTA) or be recycled in North America. The applicable percentage of the value of the critical minerals contained in the battery varies by year, bringing it up to 80% in 2027.

Table A 1: Applicable Percentages for Critical Mineral Requirement

Year	Applicable percentage
2023	40
2024	50
2025	60
2026	70
2027	80

Source: US Department of the Treasury (2023)

ii) Battery Component Requirement

An EV will be eligible for a USD 3,750 tax credit if the applicable percentage of the value of the battery components must be manufactured or assembled in North America.

Table A 2: Applicable Percentages for Battery Component Requirement

Year	Applicable percentage
2023	50
2024	60
2026	70
2027	80
2028	90
2029	100

Source: US Department of the Treasury (2023)

However, by 2024, an eligible clean vehicle may not contain any battery components manufactured by a foreign entity of concern and, beginning in 2025, any critical minerals extracted, processed, or recycled by a foreign entity of concern.

B) The Eligible Countries US has Free Trade Agreements (FTAs), including Critical Mineral Agreements (CMAs) as Proposed Rules by the Internal Revenue Service (2023)

1. Australia
2. Bahrain
3. Canada
4. Chile
5. Colombia
6. Costa-Rica
7. Dominican Republic
8. El-Salvador
9. Guatemala
10. Honduras
11. Israel
12. Jordan
13. Korea
14. Mexico
15. Morocco
16. Nicaragua
17. Oman
18. Panama
19. Peru
20. Singapore
21. Japan (CRA)

Table A 3: Top Three Suppliers to EU, US, Korea, Japan and China: 2019

Market	Imports from world (USD Mn)	Top three suppliers	
		Supplier	Exports (USD Mn)
US	59.7	China	24.4
		Canada	14.4
		Mexico	5.4
EU	166.1	China	30.8
		Germany	25.7
		Brazil	20.0
South Korea	92.4	China	80.6
		US	6.8
		Germany	3.1
Japan	102.7	China	95.2
		US	2.3
		Sri Lanka	2.0
China	99.9	Mozambique	63.1
		Madagascar	21.4
		Japan	4.5

Source: Authors' compilation using WITS data

Table A 4: Top Three Exporters of Downstream Graphite Products: 2019

Product code	Product	World Market (USD Mn)	Top three exporters	
			Country	Exports (USD Mn)
380190	Graphite (blocks, pastes, and plates)	648.6	China	293.6
			Mexico	50.4
			Germany	48.1
854519	Electrodes of graphite or other carbons	1650.6	China	677.5
			Poland	166.2
			Norway	105.1

Source: Authors' compilation using WITS data

Table A 5: Tariffs by Sri Lanka on EV Battery Components: 2019

Product	Product Name	Effectively applied tariff rate (AHS)
250410	Graphite In powder or in flakes	10.71
250490	Graphite excluding power or flakes	12.5
260500	Cobalt ores and concentrates	0
282010	Manganese dioxide	0
282090	Manganese oxide (excluding Manganese Dioxide)	0
282200	Cobalt oxides and hydroxides; refined	0
282520	Lithium oxide and hydroxide	0
282540	Nickel oxides and hydroxides	0
283324	Sulfates of Nickel	0
283529	Phosphates	0
283691	Lithium carbonates	0
284290	Peroxoacids	0
380190	Graphite (blocks, pastes, and plates)	0
740311	Cathodes and sections of cathodes	0
810520	Cobalt mattes	0
850650	Lithium cells and batteries	13.8
850760	Lithium-ion accumulators	14.4
850790	Parts of electric accumulators	13.9
854519	Electrodes of graphite	0
870380	EV vehicles	15

Source: Authors' compilation using WITS data

Table A 6: Sri Lanka's Exports Gain if China Lowered Tariffs to Zero in an FTA

Code	Exports before (USD 1000)	Exports after (USD 1000)	Gain (USD 1000)	Change (%)
250410	32.641	34.258	1.617	4.95389234
250490	131.935	140.876	8.941	6.77682192

Table A 7: Graphite Prices Fetched by Sri Lanka and China in Different Markets: 2022

Product	Product code	Market	Sri Lanka (USD)	China (USD)
250410	Graphite in powder or in flakes	World	2,005	1,935
		US	2,896	2,666
		Germany	1,425	1,255
250490	Graphite excluding powder and flakes	World	2,632	431
		US	-	65,000
		Germany	2,667	702
		US	-	65,000
		Germany	2,667	702

Appendix B

The interviewed experts were asked the following questions about Sri Lanka's feasibility in entering the global EV value chain.

1. In terms of the production of EV batteries, what minerals and materials can Sri Lanka provide to the supply chain?
2. Researchers of this study explore the possibility of taking advantage of the graphite supply in Sri Lanka to enter the supply chain. Is this feasible?
3. How much graphite can Sri Lanka produce, and does it have enough to meet the demand for EV batteries?
4. What is the possibility of producing the whole LIB? do you think this is possible and a good idea, and why?
5. What would the timeline be like if Sri Lanka to begin production of EV batteries? How long does it take to set up production?

Sri Lanka's current involvement in the EV value chain is limited to exporting processed graphite and graphene to carbon-graphite components and lubricants manufacturers for the automobile industry in Japan, South Korea and Europe. Graphite anode components can be produced locally, though the machinery for drilling and processing graphite specifically for anode production would have to be imported. The capacity of the existing mined graphite veins is subject to debate among the experts. The investors are concerned with the limited capacity of the output. The existing technology imposes a high cost of production on Sri Lankan graphite, making it hard for local producers to compete with competitors from countries like China and Mozambique.

Adopting newer mining technologies could increase their current capacity of 4,000 mt per year to 350,000 mt per year, enabling them to supply processed graphite to Tesla's EV factory based in Hong Kong. In the case of the production of EV battery cells locally, machinery for the fabrication of the components and the raw materials for all components other than the graphite anode would have to be imported. Another import demand would be the testing equipment for quality control of the produced electric cells. A Logistics expert estimated that it would take around 5-10 years for Sri Lanka to enter and establish itself in the EV value chain by producing EV batteries.

Table B 1: Expert Opinions of Feasibility of Sri Lanka to Enter the Global EV Value Chain

Inquiry	Technical experts (n=2)	Experts in logistics (n=1)	Experts in investments (n=3)
Availability of mineral resources required for production	• Components for graphite anodes • Low annual output • Out-dated technology • Debated mine capacity		• Graphite, limonite, and quartz are the main imported minerals. • Limited mining scale
Ability to penetrate the global supply chain	• Currently export graphite and graphene • Higher cost of production • Limited capacity to enter the supply chain. • Expandable graphite and graphene oxide (a lighter alternative to steel) are potential products to be exported		• More competitive prices offered by competitors. • Positive impact by importers diversifying their raw material import sources. • Emerging market for clean energy • Investors are concerned with the recent debt default and capacity to meet the demand
Import requirements for manufacturing LIBs in Sri Lanka	• All machinery and components except anode • Thermal stability testing equipment		
Time requirement		• 5-10 years for establishment	

Information was gathered on the cost of production, both for current products and for a hypothetical operation of a commercial EV battery production facility. The informants were asked the following questions.

1. *What are the costs of starting a mine, and processing the graphite?*

2. *What are the costs of exporting graphite to a global market?*

3. *What would the costs be in this scenario if Sri Lanka produces the whole LIB?*

The graphite production process in Sri Lanka is cost-intensive due to the depth of operations. Sri Lankan graphite producers employ floatation to purify 94-95% pure vein graphite. The market price of a tonne of 98% purity Sri Lanka graphite is USD 1,600-2,200, according to the estimates of the mining experts. The same purity level is achieved by Chinese producers using acid-purification and the product is sold at about USD 800 per tonne, which puts local producers at a price disadvantage. Another factor driving this high price is the royalty payments based on value-added prices. Sri Lanka demands a royalty of 9% of the value-added invoice price per tonne of graphite shipped out of the country. Many importers impose zero levies on raw materials such as graphite. Therefore, shipping and shipping-related expenses constitute the cost of exporting raw and processed graphite.

Sri Lanka cannot currently commercially produce EV batteries locally. Such a production operation would require a team of multi-disciplinary experts, a very high capital cost to import and install required facilities and costly R&D activities. Overinvestment is a concern and a clear understanding about the limitations of Sri Lanka's ability to engage in the EV value chain and to compete with other graphite importers, is a must.

Table B 2: Cost of Production of Graphite, Export of Graphite Products and Estimated Cost of LIB Production

Inquiry	Technical experts (n=2)	Experts in logistics (n=1)	Experts in investments (n=2)
Cost of starting a graphite mining and processing operation	- Existing veins require deep mining, a high cost. - High cost for transport of material to and from deep mines		
Cost of exporting raw graphite and graphite products			- Many importing countries impose zero tariffs on raw materials. - Very high royalty value payments
Cost of producing LIBs locally	- Lack the capacity for commercial-scale production. - Require new machinery for extraction and processing. - Costly R&D - Potential for intellectual property rights transfers	- Need multi-disciplinary experts involved for - Should not over-invest on value chain.	

The experts were asked the following questions on the policy environment of the graphite industry and a hypothetical future industry in LIB production.

1. *What constraints exist in terms of policy for mining for graphite?*
2. *Are there any policies for managing natural resources, including those relating to the environment, that must be considered if producing or which may hinder Sri Lanka's ability to produce more graphite?*
3. *What can be done in terms of policy to encourage EV supply chain involvement in Sri Lanka?*
4. *Some countries, such as Indonesia, impose export bans to encourage foreign firms to invest in processing factories within Sri Lanka. Should Sri Lanka do this?*
5. *How do we encourage foreign buyers to buy Sri Lanka graphite? Will forming trade agreements with countries that are producing LIBs be helpful?*
6. *Does Sri Lanka currently have any trade agreements for graphite with foreign buyers?*

Sri Lanka imposes heavy regulations on geological excavations, especially for mining operations. Environmental concerns also exist over the excavating of new mines, especially in forested areas. Obtaining licences for graphite mining and shipping is a lengthy process and acts as a barrier to the entrance of new businesses. The existing operations have steady operations with skilled staff and mature business networks. The state interest in EVs or LIB production is not high. Foreign investors wishing to operate such operations within the country will have to operate under local laws and regulations concerning the mineral mining and manufacturing industry. The lack of a robust mineral extraction policy is a factor that dissuades investments.

Sri Lanka needs state commitment towards the EV value chains, such as incentives for investors through the Board of Investments and conducive policies. Changing the current method of charging the royalty rate based on value-added invoice price to a more producer-friendly pithead price would reduce the final price of Sri Lankan graphite in the world market. An export ban on the export of raw graphite could encourage the production of value-added graphite products. However, promoting EV component production requires investments more than an export ban. Sri Lanka has free trade agreements with India and Pakistan. A possible avenue of utilising the agreements to attract investments for EV component production is for investors from countries like Japan who currently pay a 35% tariff on EV batteries to open production facilities in Sri Lanka and import to markets in India and Pakistan. However, the current economic crisis and doubts about the capacity of the graphite mines in Sri Lanka have created unfavourable conditions for such investments.

Table B 3: Policy Environment, Constraints and Suggested Solutions

Inquiry	Technical experts (n=2)	Experts in logistics (n=2)	Experts in investments (n=2)
Policy constraints of the graphite industry	• Many regulations hinder operations and opening new mines • Environmental concerns • Low state interest towards LIB production • Environmental concerns	• High barriers to entry, very hard to obtain required licencing for new mining operations • Lack of local policies promoting engagement in eEV value chains	• Investors need to be able to operate under local manufacturing industry policy conditions • No well-developed local mineral extraction policies
Requirements to create a favourable policy environment	• Government commitment and investments • State sponsorship towards R&D of products	• Robust policies on electro mobility	• Provide incentives through Board of Investments • Royalty rate based on pithead value instead of value-added price
Usefulness of an export ban on raw graphite	• Export ban on raw graphite can be beneficial to promote production of value-added products		
Trade agreements on supply chain penetration			• Existing FTAs with India and Pakistan conducive for the export of EV products

Appendix C

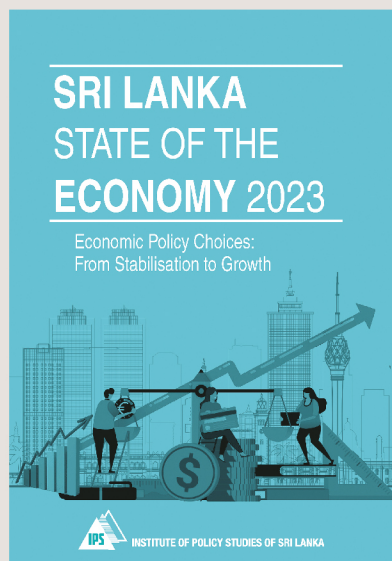
Table C 1: Effectively Applied Tariff Rates for EVs and Components for Selected Trading Partners

HS Code	Product	Partner	Weighted average tariff (AHS)
250410	Natural graphite in powder or in flakes	World	12.23
250410	Natural graphite in powder or in flakes	China	15
250410	Natural graphite in powder or in flakes	India	0
250410	Natural graphite in powder or in flakes	Japan	15
250490	Natural graphite (excluding in powder or in flakes)	World	14.97
250490	Natural graphite (excluding in powder or in flakes)	China	15
250490	Natural graphite (excluding in powder or in flakes)	India	0
260200	Manganese ores and concentrates	World	
260400	Nickel ores and concentrates	World	
260500	“Unrefined” raw cobalt ores and concentrates	World	0
260500	“Unrefined” raw cobalt ores and concentrates	India	0
282010	Manganese oxides, Manganese dioxide	World	0
282010	Manganese oxides, Manganese dioxide	India	0
282090	Manganese oxides (excluding manganese dioxide)	World	0
282090	Manganese oxides (excluding manganese dioxide)	India	0
282090	Manganese oxides (excluding manganese dioxide)	Japan	0
282200	“Refined” cobalt oxides and hydroxides	World	0
282200	“Refined” cobalt oxides and hydroxides	India	0
282520	Lithium oxide and hydroxide	World	0
282520	Lithium oxide and hydroxide	India	0
282540	Nickel oxides and hydroxides	World	0
282540	Nickel oxides and hydroxides	India	0
283324	Sulfates, alums, peroxosulfates	World	0
283324	Sulfates, alums, peroxosulfates	India	0
283529	Phosphates	World	0
283529	Phosphates	China	0
283529	Phosphates	India	0
283529	Phosphates	Japan	0
283691	Lithium carbonates	World	0
283691	Lithium carbonates	China	0
283691	Lithium carbonates	India	0
284290	Salts of inorganic acids or peroxyacids	World	0
284290	Salts of inorganic acids or peroxyacids	China	0
284290	Salts of inorganic acids or peroxyacids	India	0
284290	Salts of inorganic acids or peroxyacids	Japan	0
380190	Graphite or other carbon in the form of pastes, blocks, plates or other semi-manufactures	World	0

380190	Graphite or other carbon in the form of pastes, blocks, plates or other semi-manufactures	China	0
380190	Graphite or other carbon in the form of pastes, blocks, plates or other semi-manufactures	India	0
740311	Copper in the form of cathodes and sections of cathodes	World	0
740311	Copper in the form of cathodes and sections of cathodes	China	0
740311	Copper in the form of cathodes and sections of cathodes	Japan	0
750110	Nickel mattes	World	
750120	Nickel oxide sinters and other intermediate products of nickel metallurgy	World	
810520	"Refined" unwrought cobalt	World	0
850650	Lithium, cells and batteries	World	14.57
850650	Lithium, cells and batteries	China	15
850650	Lithium, cells and batteries	India	0
850650	Lithium, cells and batteries	Japan	15
850790	Plates, separators and other parts of electric accumulators, n.e.s.	World	9.67
850790	Plates, separators and other parts of electric accumulators, n.e.s.	China	13.5
850790	Plates, separators and other parts of electric accumulators, n.e.s.	India	0
850790	Plates, separators and other parts of electric accumulators, n.e.s.	Japan	15
854519	Electrodes of graphite or other carbon, for electrical purposes	World	0
854519	Electrodes of graphite or other carbon, for electrical purposes	China	0
854519	Electrodes of graphite or other carbon, for electrical purposes	Japan	0
870360	Other vehicles, with both spark-ignition internal combustion piston engine and electric motor as motors for propulsion, capable of being charged by plugging to external source of electric power	World	14.42
870360	Other vehicles, with both spark-ignition internal combustion piston engine and electric motor as motors for propulsion, capable of being charged by plugging to external source of electric power	Japan	14.42

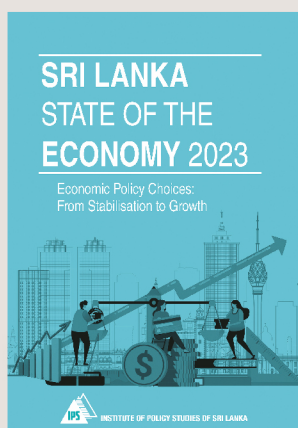


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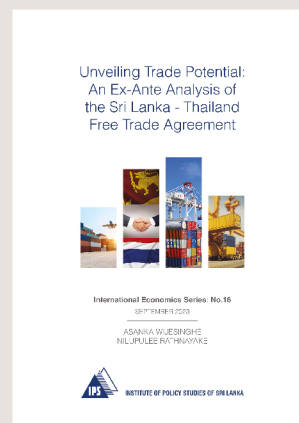
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