Sustainable Manufacturing and Environmental Pollution Programme

BATTERY VALUE CHAINS

The challenges for e-mobility in South Asia

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Cover photo: Informal battery charging hub in South Asia, reflecting everyday realities of e-mobility. © H. Pacini, (2024).

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Highlights

TRANSPORT INEQUALITY AND INFORMAL SOLUTIONS

1.

Introduction

Energy poverty and the centrality of transportation

► In much of the Global South, less than 40% of the urban population had convenient access to public transport in 2019, leading to the proliferation of informal and affordable transport solutions such as shared vans, mini-buses, electric scooters, and bicycles.

↑ Image 1. Electric rickshaws and motorcycles compete for space in Dhaka's narrow streets, 2024

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While 750 million people worldwide still lack access to electricity, another 1.18 billion are energy poor (Min et al, 2024; IEA, 2024). The concept of energy poverty usually describes situations where households struggle to meet basic energy needs such as heating, lighting and transport. Indeed, in the context of low incomes, energy costs can negatively impact health and well-being (Martiskainen et al., 2021). A case in point is South Asia, where fuel used for various purposes is a major determinant of living standards. Due to low quality fuels, poor electrification and precarious infrastructure, the region has been recognized as one of the most susceptible to energy poverty (Chan and Delina, 2023; Abbas et al., 2021).

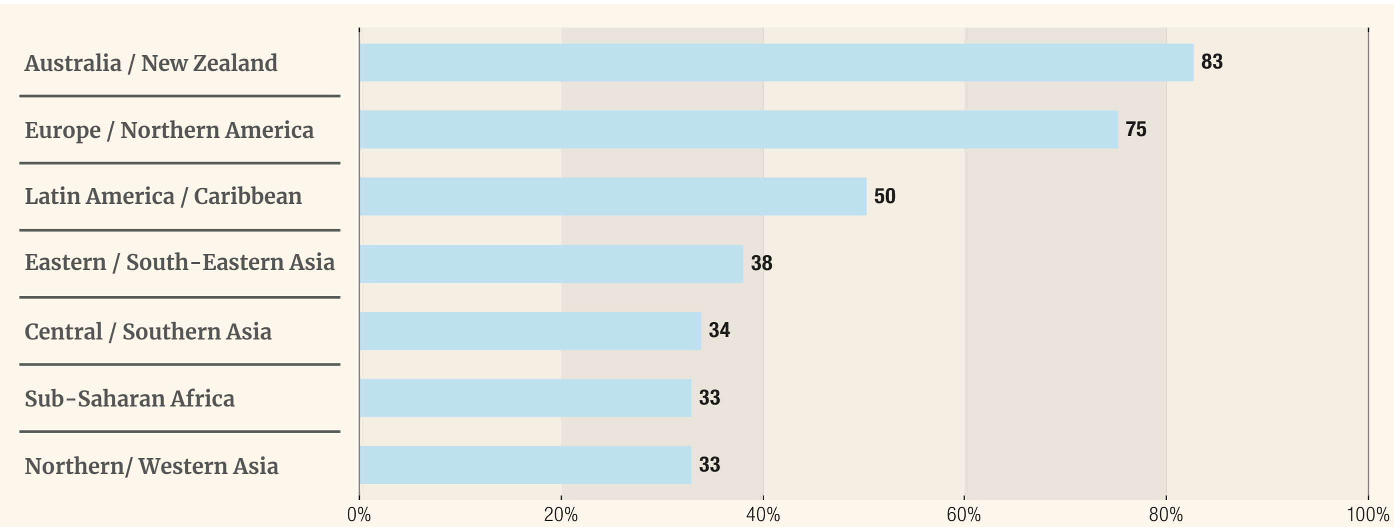
Access to 'safe, affordable, accessible and sustainable transport systems for all' is a fundamental human right – central to addressing energy poverty and is a key target of Sustainable Development Goal 11.2. Transport is needed for workers to commute, for markets to replenish store shelves and to ensure access to affordable housing and public services. Affordable transportation is essential for low paid and service workers often engaged in work that can mostly not be accomplished remotely. Yet, access to public transport varies considerably around the globe. As seen in Figure 1, less than 40 per cent of the urban population in much of the Global South had convenient access to public transport in 2019.

Access to reliable and affordable transport is essential not only for socioeconomic prosperity but also for environmentally friendly development. Transport accounts for 60 per cent of global oil consumption, 30 per cent of global final energy use and 23 per cent of CO_2 emissions (IEA 2021, 2020). Inadequate urban transport planning and management, exacerbated by the rapid proliferation of private vehicles, resulted in severe traffic congestion and harmful air pollution across the globe (UN-Habitat, 2000). Thus, creating reliable, affordable, and clean transport solutions is essential to addressing climate change in the long term.

In much of the Global South, where reliable public transit is lacking and many residents are unable to afford private transport, informal solutions naturally arise. These include a panoply of vehicles, such as shared vans and mini-buses, electric scooters (including tuk-tuk and three-wheelers), and bicycles. This brief note focus on the problem of lead-acid battery (LAB)-based vehicles in Bangladesh, an affordable solution which emerged in a context of economic necessity and high popular demand for short distance transport in the country, but with huge environmental and health impact.

↓ Figure 1. Percentage of urban population with convenient access to public transport, 2019

Source: UN Stats, UNSD.

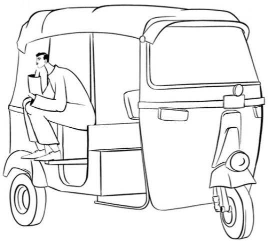


Highlights

ENERGY DEMANDS PERSIST DESPITE BAN

4 M 3-wheelers

4,600 MWh per day



▸ In 2022, 4M electric rickshaws in Bangladesh consumed 4,600 MWh/day for charging, despite a 2021 ban over safety concerns.

↑ Image 3. Standard Bangladeshi three-wheeler

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2.

The challenges of lead-acid battery vehicles

Across South and Southeast Asia, electric rickshaws (also known as "tuk-tuk" or EZ Bikes) feature prominently in the urban and peri-urban landscape. Across Asia-Pacific, the market for e-rickshaws is booming, with the three-wheeler market expected to almost quadruple from an estimated $2.71 billion[1] in 2023 to $10.26 billion by 2030. The vehicles are well-suited for navigating urban streets and have a longer range than non-electric versions (SMEP 2024a, 1). They generally have a range of up to 100 km, a seating capacity of 4-8, and a traveling speed of 30-35 km/hour, thus providing a low-cost informal transport alternative.

As of 2022, there were an estimated 4 million electric rickshaws in Bangladesh alone (Van der Straeten, 2022). While compressed natural gas is often used, many rely on LABs – a cheap and readily accessible lead-based battery for energy storage that can weigh up to 120kg per vehicle. Despite being formally banned in Bangladesh in 2021 because of safety concerns, three-wheel rickshaws are used as commercial transportation for the general population in urban centres like Dhaka (Pure Earth, 2021). The LABs are recharged at night, usually in collective garage stalls. As a result, most are unauthorized and unlicensed, yet remain widespread (SMEP 2024a, 2). Dependence on batteries adds strain to national energy grids due to high charging demands. Battery charging for the estimated 500,000 autorickshaws in Bangladesh consumes at least 4,600 MWh per day (Al-Amin and Sahabuddin, 2023).

Each e-rickshaw requires 4-6 LABs of at least 12 V. The batteries need to be recharged and eventually lose their ability to run. When new, the batteries can be recharged in eight hours, however, after approximately one year, it takes 10-12 hours to reach full charge (SMEP 2024a, 1). The LAB lifespan is only two years, with some lasting as little as 6 months. This further inflates demand for LABs. The global market for LABs is estimated at $45 billion in 2023 (Fortune Business Insights, 2024) and is growing at 12 per cent per year in Bangladesh. Around 50 battery factories in Bangladesh, 30 Chinese-owned, produce 500,000-600,000 units per year in the country (Pure Earth, 2021). The constant need to renew these LABs creates a constant flow of hazardous waste requiring end-of-life management.

1 Reference to "dollars" ($) means United States dollars, unless otherwise indicated.

← Image 2. Electric rickshaws (three-wheelers) navigating a street in Dhaka, Bangladesh, 2024

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Highlights

INFORMALLY RECYCLED LAB IN BANGLADESH

80%

▶ An estimated 80 per cent of lead-acid batteries in Bangladesh are recycled informally, often in unlicensed smelting sites called 'bhattis,' employing around 100,000 people. This process releases 15-20 per cent of the lead back into the environment, contaminating soil and water, and is a significant public health hazard, with 35 million children showing high levels of lead in their blood.

↑ Image 4. Woman without personal protective equipment (PPE) handling lead-acid batteries for recycling

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↓ Figure 2. Sectors that use ULABs in Bangladesh

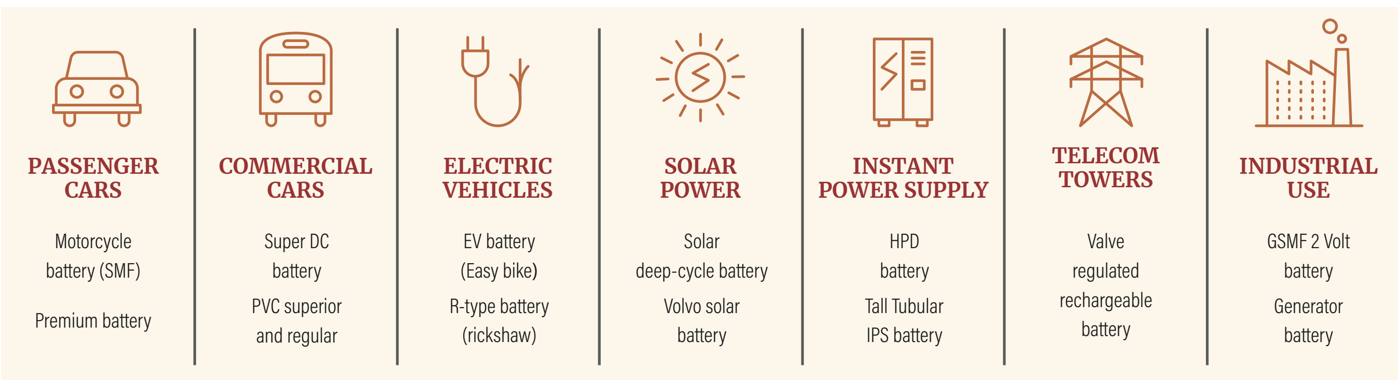
Source: Pure Earth (2020) as cited in SMEP (2024a).

After their use, the recycling of LABs requires extensive protective equipment to handle it safely (Pure Earth 2021). Lead metal can act as a neurotoxin in the body, and sulfuric acid in batteries creates skin lesions. Both lead to serious issues for children's cognitive and physical development. More than 80 per cent of lead in Bangladesh (the vast majority linked to batteries) is recycled through a network of informal ULABs recyclers without consideration for health and environmental hazards (UNEP, 2021).

Since Bangladesh has high import tariffs on both new and used lead-acid batteries, as well as an export tax on lead, the domestic price of lead in the country is higher than in the world markets (SMEP, 2024a). The high prices and barriers to trade mean most batteries are recycled domestically, so lead is reused in new batteries. There are an estimated 1, 100 recycling sites in the country, of which only six are in the formal sector. An estimated 80 per cent of batteries are informally recycled. Most of the recycling is done in unlicensed open pit smelting sites called "bhattis", employing a significant workforce of around 100,000 people. The small number of formal recycling facilities in the country is also a reflection of costs, as informal recycling is cheaper. Knowledge of lead's dangers to human health appears limited in the Global South, which helps to explain the lack of proper recycling facilities (Díaz-Criollo et al., 2019). Informal recyclers lack adequate equipment or safety, thus workers "face alarming risks of non-carcinogenic and carcinogenic toxicity-related disease (Jamal e al., 2024). The relative ease with which the lead metal in LABs can be smelted and recycled has led to widespread informal and unsafe recycling, which contaminates soil and water, at significant costs to public health (Pure Earth 2021; SMEP 2024a, 1). An estimated 15-20 per cent of the lead recycled in informal shops is released back into the environment (Pure Earth, 2024). The toxins can be spread through both air and water, polluting nearby areas (Otieno et al., 2022). In Bangladesh, an estimated 20 per cent of the population lives within five km of an informal smelting site. This proximity and the lack of child labor enforcement (ESDO, 2021) may explain why approximately 35 million children in Bangladesh have elevated lead levels in their blood (Pure Earth, 2024, UNICEF, 2024). Bangladesh loses an estimated $15.9 billion in GDP due to IQ loss caused by lead exposure in children.

Yet, there are insufficient market incentives or enforced regulations to shift activity back to the formal sector; informal recyclers require little capital or equipment (Pure Earth, 2021). Moreover, civil servants lack the knowledge and skills to develop a sound environmental management plan for the sector; this is reflected in the lack of effort to enforce licensing among existing recyclers (ESDO 2021).

The problem does not exist in the Global North, where most LABs are mainly used to to start car engines, and formal recycling facilities and reverse supply chains handle them. With recycling rates as high as 99 per cent, LABs are the most recycled consumer product in the United States (Battery Council International, 2023). Research based on data from 14 countries shows a similar situation in the European Union (EU), where 97 per cent of LABs available for collection are recycled. Only a few are lost through export in used vehicles (IHS Markit, 2020). Moreover, EVs and energy storage systems in the Global North rely upon lithium-ion batteries (LIBs) and thus LABs are a diminishing environmental and health concern.



↖ Image 5. Abandoned LAB waste lying in open air in Mizarpur, Bangladesh, n.d.

© Pure Earth 2024.

↑ Image 6. Man breaking LABs for recycling in Tengal, Indonesia, n.d.

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← Image 7. Lead waste produced at an informal LAB breaking site, n.d.

© Pure Earth 2024.

← Image 8. Man smelting lead from informally recycled LABs, Pesarean, Indonesia, n.d.

↙ Image 9. Lead smelting pit in Tangail, Mirzapur, Bangladesh, n.d.

↓ Image 10. Workers pouring molten lead into ingot molds, Indonesia, n.d.

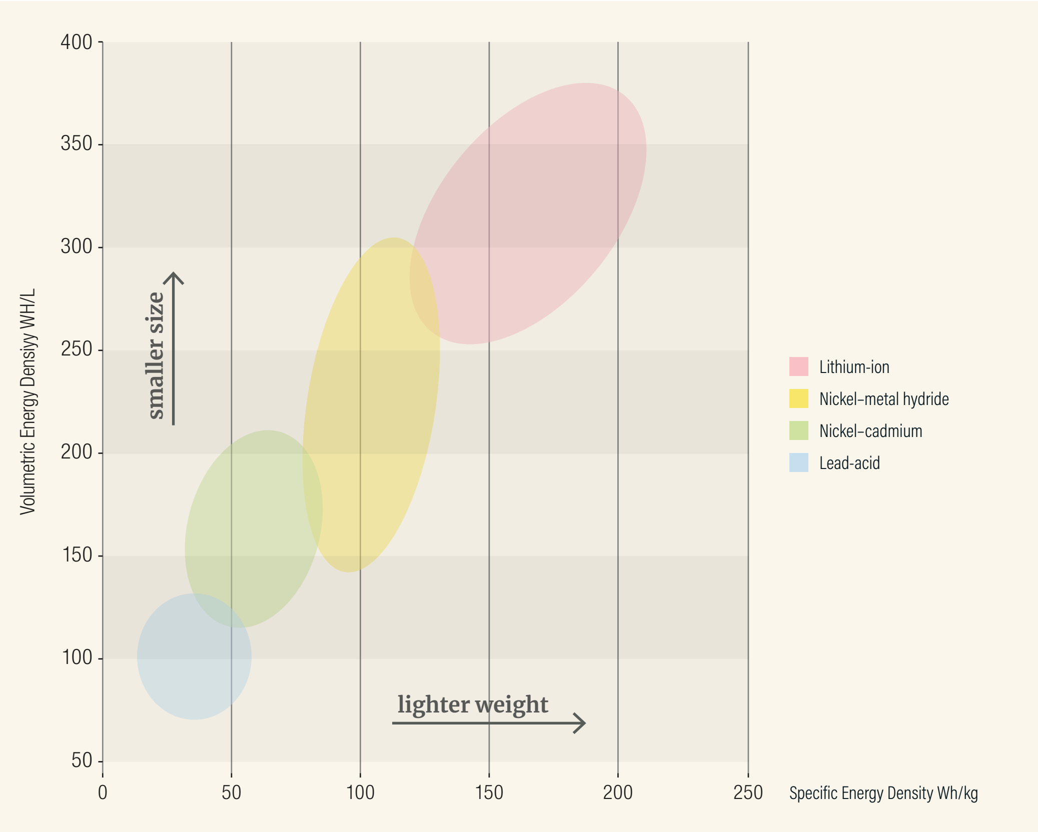


Figure 3. Comparison of energy density in battery cells

Source
Energy Technology/Wiley in: Kumar and Bhattacharjee (2024).

Note
Gravimetric energy density refers to energy stored per unit mass, while volumetric energy density measures energy stored per unit volume.

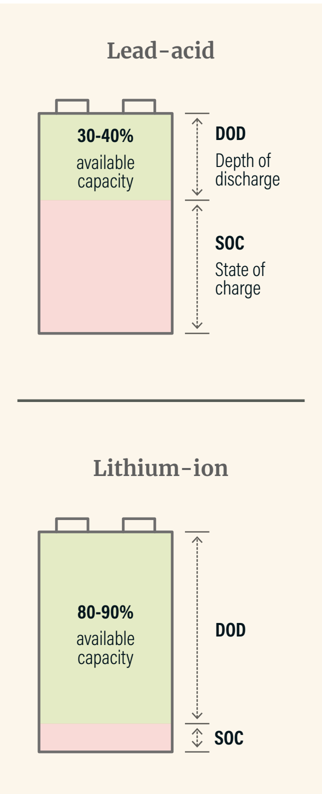


Figure 4. Lead-acid versus lithium-ion battery

Source: Bennett (2023).

Note: Battery available capacity in a daily cycle to prolong life: Always refer to the manufacturer's specifications and warranty requirements.

3.

Technology and cost considerations of lead-acid versus lithium-ion batteries

The energy density of different types of battery cells varies widely, with LABs and LIBs at the low and high ends of the spectrum. LIBs are the most efficient in that they have the highest volumetric and specific energy densities. Conversely, LABs have the lowest energy densities (Figure 3). A LIB performs better than a LAB of the same size and weight because it can store more energy for the same weight. In other words, it takes a larger and heavier LAB to accumulate the amount of energy stored in a LIB.

In terms of performance, the advantages of LIBs over LABs go beyond energy density, which can be up to six times higher. They require less maintenance and have lower environmental and health impacts, climate change and resource use (Yudhistira et al., 2022; Anuphappharadorn et al, 2014). They also offer significantly higher specific power, have a wider range of operating temperature, and a lifecycle that is double that of LABs (SMEP 2024a, 10). Figure 4 shows LIBs are far more efficient, able to use up to 90 per cent of their capacity before having to recharge, compared to just 30-40 per cent for LABs. In line with this, their lifespan is longer.

However, LIBs are far more expensive, presenting a serious obstacle to adoption in the Global South. Other things being equal, they have an estimated production cost of $150/kWh compared to $60 for LABs (SMEP 2024a, 10). Apart from weight considerations, this means that lead-acid systems can be three times cheaper. LABs are also a well-established technology, so their initial investment costs are lower in a wide range of applications, including off-grid energy storage (Paul Ayeng'o et al., 2018). Market factors, such as economies of scale and barriers to market access can also widen this gap, particularly in developing economies where high-end technologies are less available or more costly.

4.

Critical minerals and battery value chains

The costs of materials are a large determinant of a battery costs and account for about 75 per cent of production costs in the case of LIBs (Örüm Aydin et al., 2023). LABs rely on lead, a cheap metal primarily sourced from galena, cerussite, and anglesite ores. In contrast, LIBs rely on a diverse range of expensive minerals. Lithium, extracted from minerals like spodumene, petalite, and lepidolite or lithium brine, is a key component of the electrolyte and cathode materials. Other critical minerals include graphite for anodes, cobalt and nickel for cathodes, and manganese for both cathodes and anodes. The cost difference between the two types of batteries is significant in the Global South, largely due to reliance on imported minerals. This partly reflects the lack of LIB production (and recycling) facilities in those economies.

↓ *Source*
International Renewable Energy Agency (IRENA) (2023).

Table 1. Mining of critical minerals by producing economy

27 Co Cobalt	%
Dem. Republic of the Congo	70
Indonesia	5.4
Russian Federation	4.8
Australia	3.2
Canada	2.1
Cuba	2%
Philippines	2%
Others	10.5

29 Cu Copper	%
Chile	23.6
Peru	10
Dem. Rep. of Congo	10
China	8.6
United States	5.9
Russian Federation	4.5
Indonesia	4.1
Australia	3.7
Zambia	3.5
Mexico	3.3
Kazakhstan	2.6
Canada	2.4
Poland	1.7
Others	16.1

66 Dy Dysprosium	%
China	48.7
Myanmar	23.1
Australia	7.6
United States	2.9
Canada	2.7
Others	15

6 C Graphite	%
China	64.6
Mozambique	12.9
Madagascar	8.4
Brazil	6.6
Others	7.5

77 Ir Iridium	%
South Africa	88.9
Zimbabwe	8.1
Russian Federation	2.9
Others	0.1

3 Li Lithium	%
Australia	46.9
Chile	30
China	14.6
Argentina	4.7
Brazil	1.6
Others	2.2

25 Mn Manganese	%
South Africa	35.8
Gabon	22.9
Australia	16.4
China	4.9
Ghana	4.7
India	2.4
Brazil	2
Ukraine	2
Côte d'Ivoire	1.8
Malaysia	1.8
Others	5.3

60 Nd Neodymium	%
China	45.8
Australia	23.1
Greenland DENMARK	8.2
Myanmar	7.4
Brazil	4.4
India	2.1
Others	9

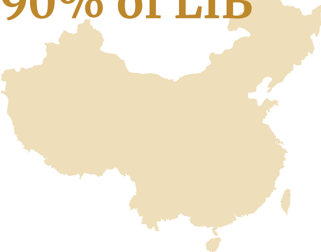
28 Ni Nickel	%
Indonesia	48.8
Philippines	10.1
Russian Federation	6.7
New Caledonia FRANCE	5.8
Australia	4.9
Canada	4
China	3.3
Brazil	2.5
Others	13.9

78 Pt Platinum	%
South Africa	73.6
Russian Federation	10.5
Zimbabwe	7.8
Canada	3.1
United States	1.7
Others	3.3

Highlights

CHINA'S LIB DOMINANCE AND SOUTH ASIA'S DEFICIT

China produces 90% of LIB



▸ Over 90% of all lithium-ion battery (LIB) production is concentrated in China, reflecting its strong industrial policy, while countries in South Asia face a 96% import dependency on LIBs, running a $3 billion trade deficit in 2023.

The high initial costs associated with transitioning to battery technology are primarily linked to the mineral concentration in a few key mining regions outside of South Asia. Table 1 illustrates that a limited number of developing economies dominate the mining landscape. China leads in the production of lead, producing 1.9 million metric tons, which accounts for over 40 percent of global output (US Geological Survey, 2024). It also produces about 65 percent of graphite. African economies play a significant role in mining critical minerals, with the Democratic Republic of the Congo producing 70 percent of the world's cobalt and South Africa accounting for 35 percent of manganese production. Nickel mining is concentrated in Asia, with Indonesia and the Philippines together responsible for over 55 percent of production. In Latin America, Chile and Peru are key players in copper mining, contributing to over 30 percent of global output.

Currently over 90 per cent all LIB production is concentrated in China, reflecting its strong industrial policy for EVs and batteries (Hira, forthcoming). In the absence of domestic industrial policy to incentivize manufacturing and recycling capacity, this exposes consuming countries to potentially higher costs and the risk import dependency. In addition to the costs of importation, LIBs are also more difficult to recycle and require new infrastructure that most countries in the Global South presently lack (UNCTAD, 2025 forthcoming).

Countries in South Asia are no exception, as data on trade in LABs and LIBs indicate. South Asia's trade in batteries for mobility applications reached $3.7 billion in 2023, with LIBs dominating the market at 90 per cent. This trade has surged in recent years, with exports quadrupling and imports soaring fourteenfold between 2013 and 2023. While this signals deeper integration in supply chains and rising demand for battery technologies, it also highlights heavy reliance on foreign imports. A net exporter of LABs, South Asia faces a starkly different picture with LIBs. Indeed, the region runs a trade deficit in this segment, with imports accounting for a staggering 96 per cent of trade in 2023. This deficit has worsened over the last decade, increasing by an average of 33 per cent per year from -$0.2 billion in 2013 to -$3 billion in 2023 (Figure 5).

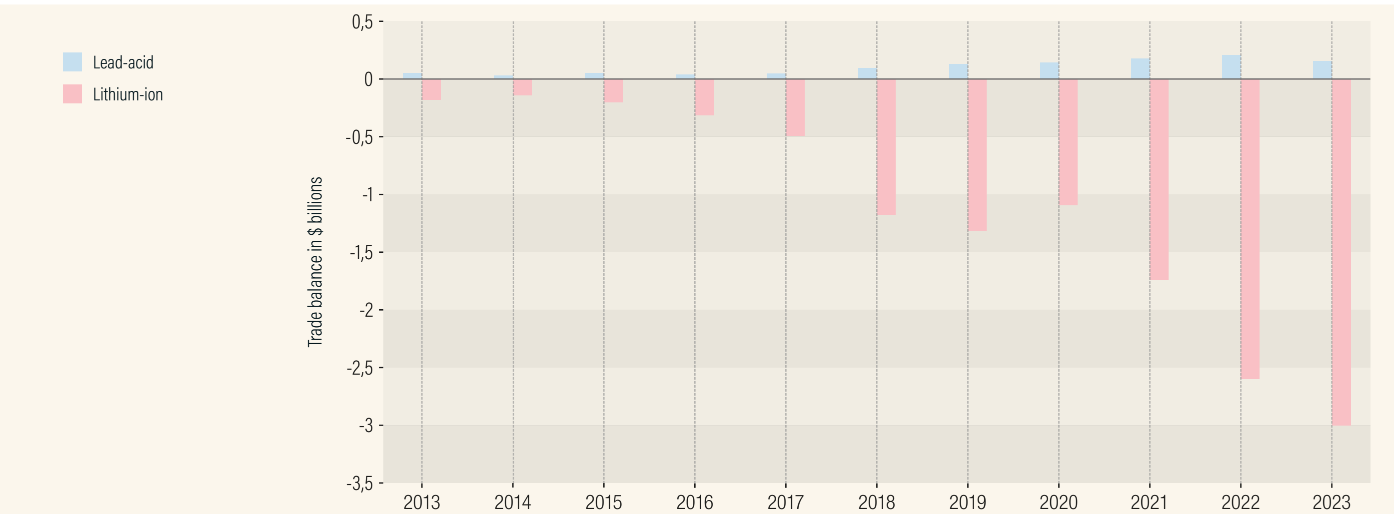
The challenges of battery supply chains demand a holistic approach to LAB substitution that balances technological and geopolitical considerations, particularly in South Asia. Indeed, proposed substitutes for specific metals in batteries are often identified without considering the performance trade-offs that would affect demand. For example, lithium iron phosphate (LFP) batteries are presented as an alternative to geopolitically-sensitive cobalt batteries (IRENA, 2024). However, their performance degrades at low temperatures (Belgibayeva et al., 2023), making them less suitable for cold climates.

A portfolio strategy that incorporates multiple technologies and battery metal profiles can help ensure that countries with diverse resources and competitive advantages benefit from the transition to e-mobility. This approach can prevent potential bottlenecks in the value chain or technology that could lead to a regression to lead-acid systems. Leveraging these countries' domestic capacities would also ensure that demand is met efficiently, avoiding the creation of unsustainable trade deficits.

↓ Figure 5. South Asia's trade balance in battery technology, 2013-2023 ($ billion)

Source: Analysis based on data extracted from UN Comtrade (2024).

Note: Battery trade is measured using codes 850710 (lead-acid batteries) and 850760 (lithium-ion batteries) under the 2022 Harmonized Commodity Description and Coding System.



5.

Conclusion

Managing the LAB problem in Bangladesh

In Bangladesh, as throughout the Global South, the lack of a coherent approach to regulations across different ministries and levels of government managing road transport, hazardous waste, imports and exports impedes progress. Beyond creating a harmonized and coherent approach, there are a few key areas prime for intervention:

Firstly, promote the adoption of more sustainable equipment and practices in the recycling of LABs, including formalizing all three-wheel sectors, tagging and tracing batteries and incentivizing their collection for recycling, and prohibiting vulnerable populations, such as pregnant women and children, from working in recycling. Secondly, support the development of higher quality domestic and imported LABs, which would extend their lifecycle and reduce the need for recycling. Thirdly, support the transition to LIBs over time in e-rickshaws, through direct and indirect subsidies, including the reduction of tariffs on battery components and providing financial loans and microfinance systems to offset initial costs (SMEP 2024a, 21; SMEP 2024b).

During the transition from LABs, one focus is on production processes in supply chains. It is important to avoid policies that decouple domestic from international prices, such as import tariffs on batteries or export taxes on lead, which can lead to higher local lead prices, with the distortions spurring informality. SMEP (2020) suggests interventions such as materials substitution for less toxic inputs where possible; air and water effluent treatment; personal protective equipment for workers in primary production and recycling; formalized waste recycling and reuse; and generally improving training of civil servants and workers and the quality control of production processes. Improved and more rigorously enforced pollution standards must be supported by a multi-stakeholder approach.

Along the lines of circular economy thinking, the challenge is to upgrade rather than replace existing recycling systems, and introduce product take-back programs and "right to repair" regulations. Another solution would be to improve and formalize reverse logistics, especially recycling efforts, such as through a deposit refund scheme, stronger mandatory warranty periods to enhance battery quality and durability, an environmental tax for batteries, a single environmental standard agreed upon by government and private sector stakeholders, the development of a battery swap system for e-rickshaws, and a new hydrometallurgical recycling process. This would require significant government and private sector consensus, and in some cases, foreign investment and technology transfer. This should be accompanied by a vigorous public health campaign to raise awareness among workers about the risks of lead exposure. (Pure Earth, 2021).

A parallel strategy is to make better battery technologies more attractive to users. This could start with reducing any import tariffs or other policies that increase the costs of LIBs. Moreover, the reduction of costs in LIBs could be linked to strategies beyond transportation, including the development of remote renewable energy solutions in the Global South, particularly in the many areas where grid-access electricity is lacking or unreliable. In these areas, PV panel stations could help to recharge the batteries for electric rickshaws and other modes of transport. In the case of LIBs, the development of a stronger reverse logistics / recycling system is also particularly important. Recycling lithium batteries is more technically challenging than it is for lead, and many countries lack a functioning reverse logistics system for lithium (Wu et. al. 2022). This results in a context where spent LABs have a high buy-back price in formal and informal markets (due to their ease of recycling), while LIBs are often landfilled when batteries achieve end of life. Developing battery remanufacturing and recycling capacity for LIBs is a logical next step to extend their lifecycle and reduce costs in their production and disposal.

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