Battery-Electric Vehicles:

the Pathway to Pollution-Free Road Transport in the Global South and Mongolia?

Daniel Karthe [1, 2, 3*], Luisa F. S. Prates [1,2], Gantuya Ganbat [3], Minjeong Choi [1], Serena Caucci [1,2], Seoyoung Lim [4], Lulu Zhang [5,1], Lili Wang [6,7], Jack O'Connor [8], Christina Dornack [2], Alexey V. Alekseenko [1], Yubin Yang [1]

[1] United Nations University – Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), Dresden, Germany
[2] Faculty of Environmental Sciences, Dresden University of Technology, Germany
[3] Faculty of Raw Materials and Environmental Engineering, German-Mongolian Institute for Resources and Technology (GMIT), Ulaanbaatar, Mongolia
[4] Korea Environment Corporation (K-eco), Incheon, South Korea
[5] Leibniz Supercomputing Centre (LRZ), Garching, Germany
[6] United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT), Maastricht, The Netherlands
[7] School of Business & Economics, Maastricht University, Maastricht, The Netherlands
[8] United Nations University – Institute for Environment and Human Security (UNU-EHS), Bonn, Germany
*karthe@unu.edu

Abstract. The transport sector currently accounts for more than 21% of global greenhouse gas (GHG) emissions, largely attributable to road traffic. The Paris Agreement is therefore in jeopardy without its decarbonization. Currently, the transition to battery electric vehicles (BEVs) is the only technology that is fully market-ready. However, "zero tailpipe emissions" does not equal pollution-free transport. While BEVs eliminate local emissions from combustion, their environmental footprint extends beyond energy consumption. BEVs rely on large batteries requiring substantial amounts of raw materials, which have adverse effects on the environment during extraction and processing. The increased weight of BEVs can lead to higher particulate matter emissions from tire abrasion. End-of-life (EOL) batteries constitute hazardous waste unless treated in a safe, circular approach. Some advantages and challenges related to BEVs are greater in the Global South. Positively, air pollution prevention is a significant benefit in congested and highly polluted cities. The significant role of renewable energy sources in some of the Global South supports effective decarbonization. Negatively, raw material producing countries in the Global South bear much of the environmental burden of BEVs. Furthermore, EOL batteries constitute challenges for countries with poorly developed waste management, leading to considerable environmental pollution and health risks. Resource Nexus approaches can help guide sustainable pathways toward pollution-free road transport in the Global South.

Keywords: Battery electric vehicle (BEV), Energy transition, Lithium-ion battery (LIB), Pollution.

A. Lkhamsuren et al. (eds.), *Proceedings of the 3rd International Conference Resources and Technology (RESAT 2025)*, Advances in Engineering Research 284,
https://doi.org/10.2991/978-94-6463-928-5_10

1 Introduction: The transition to electric mobility –rationale, trends, and expected benefits

1.1 Decarbonization of road transport: a requirement for meeting the goals of the Paris Agreement

The transportation sector is among the largest energy users and still heavily dependent on fossil fuels. The climate footprint of the transport sector has continued increasing in the recent past, with road transport alone accounting for more than 12% of global GHG emissions, significantly more than shipping, air and rail transport combined (Statista 2025; World Resources Institute 2024). In the light of the Paris Agreement goal of limiting global warming to not more than 2°C above pre-industrial levels, it is imperative to significantly reduce the carbon footprint of the transport sector. The decarbonization of road transport is of particular importance in this context, not only because of its significant emissions but also due to the existence of several technologies that can contribute to decarbonization (Obergassel et al. 2021).

Several options exist for the decarbonization of road transport, including biofuels, synthetic fuels, hydrogen-based solutions and **battery-electric vehicles (BEVs)** (Yu et al. 2024). BEVs are considered the most feasible short-term approach to decarbonizing road transport as the technology is market-ready, and affordability has improved significantly in recent years. It is therefore not surprising that the transition to electric mobility forms a key component of environmental and transport policies in many countries (IEA 2024a; Patil et al. 2024). The fact that BEVs can build on hybrid and plug-in hybrid technologies means that electric propulsion and battery systems have already advanced considerably and that the transition from combustion engines to electric mobility can be managed smoothly (Yu et al. 2024).

The increasing awareness that fossil fuel reserves are finite led to the emergence of industrial-scale production of **biofuels**. First-generation or conventional biofuels are typically based on food-crops and include biodiesel and bioethanol. While the possibility of gradually scaling up their use by adding them in increasing fractions to conventional fuels like gasoline or diesel was considered promising, it soon turned out that a land use competition between food and biofuel production would be problematic. Subsequent generations of biofuel relied on other feedstocks including non-food plants, and waste products from forestry, agriculture and the food sector. While research is ongoing, second and later generation biofuels are currently not commercially competitive at large scales (Bisht & Pandey 2025). **Synthetic fuels** (also called e-fuels) are based on the production of synthetic molecules using electricity. Synthetic diesel, methanol, methane and hydrogen are some examples of e-fuels. While such fuels require only limited adjustments in powertrains, their production tends to be energy-intensive and thus costly. Moreover, their carbon balance depends highly on the source of electricity. Systems to produce e-hydrogen via electrolysis are currently the only mass-market ready systems for synthetic fuel production, but the disadvantage of low energy density and the need for significant compression remain obstacles (Pasini et al. 2023).

BEVs are currently considered the most promising short-term approach for decarbonizing light-duty vehicles (LDVs), but it is important to mention certain environmental challenges related to their production and end-of-life (see Fig. 1).

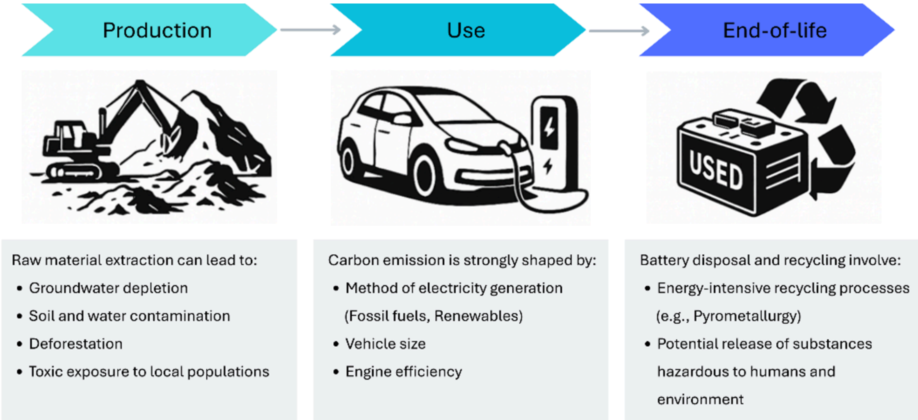

Fig. 1. Environmental challenges throughout BEVs' life cycle

- BEVs require rare earth elements for their electric engines and various raw materials for battery production (e.g., lithium, nickel, cobalt, graphite). The environmental impact of this raw material extraction is covered in section 2.1.
- The life cycle of BEV is divided into three main stages: production, use, and end-of-life. These three stages are relevant as they relate to specific environmental benefits and impacts (Verma et al. 2022). BEVs are more energy-intensive to manufacture than vehicles with internal combustion engines. Though BEVs have a lower carbon footprint than internal combustion engine vehicles over the full lifecycle, BEVs have 20-77% higher carbon footprint in production and end-of-life phase mainly because of the production of batteries (Kim et al. 2023) and the energy intensity of recycling processes such as pyrometallurgy (Zhou et al. 2020). Energy-efficient recycling methods such as hydrometallurgy and physical recycling can reduce the GHG emissions of electric vehicles (EVs) by about one third during the lifecycle (Lai et al. 2022; Qiao et al., 2017). Given the rapid advances in battery and recycling technology and the dynamic development of the global car market, it is meaningful to regularly update existing LCAs. The environmental benefits and carbon footprint during the use phase of BEVs are covered in section 2.2.
- BEVs create novel environmental and human health hazards when their traction batteries reach end-of-life. The implications for waste management and recycling are covered in section 2.3.

1.2 Global and regional trends

The global carbon footprint of road transport has continued to increase recently, reaching about 3.2 Gt CO_2 from LDVs and another 2 Gt CO_2 from heavy-duty vehicles (HDVs) in 2023 (Statista 2025b). The global LDV fleet currently consists of 1.5 million units and is predicted to reach about 2.0 billion vehicles in 2035 and 2.5 billion vehicles in 2050, driven almost exclusively by increasing car sales in developing economies (BP 2025). Despite the recent growth in electric mobility, it is predicted that the global stock of conventional vehicles and the carbon footprint of road transport will continue to grow for some time, leading to further increases in fossil fuel consumption and carbon emissions. The peak of fossil fuel consumption for road transport is expected in the late 2030s, but advanced policy and net-zero scenarios consider it possible by around 2030 (BP 2024; EIA 2021; IEA 2024b).

A key driver for the decarbonization of road transport is electrification. Globally, the number of BEVs has increased since 2010, with an acceleration of the electrification trend in the 2020s. More than 58 million BEVs are currently used worldwide (IEA 2025a; see Fig. 2). Some countries in the Global South have been relatively fast with the uptake of EVs. Ethiopia, for example, has introduced policies for the transition to electric mobility that include a ban on the import of privately-owned LDVs that are based on fossil fuels (CNN 2025; Nnene et al. 2025). Several countries in the Global South including Sri Lanka, Egypt and Cape Verde have plans to phase out vehicles with internal combustion engines (ICCT 2020). However, except for China, most countries of the Global South have been far slower in adopting BEVs than countries of the Global North (IEA 2025a). Mongolia, where the market for battery-electric vehicles is still in its infancy, is a good example. Over the past 35 years, the import of affordable used cars has played a key role in the local market. Prohibitively high prices of BEVs during the 2010s, very limited charging infrastructure (mostly in and around the capital city) and the country's unique geography with very long distances between population centers are additional challenges. Moreover, given Mongolia's high reliance on coal for electricity production, BEVs do not result in significant climate benefits. For this reason, the transition to electric road transportation was not a political goal in the past, and Mongolian statistics do not distinguish BEVs from other types of LDVs. According to news reports, 498 BEVs were on the road in 2022 (Montsame 2022). The number of BEVs gradually increased, and as of 2024, the Mongolian Ministry of Road and Transport indicated a BEV fleet of 1.670 (MoRT 2024). The Government of Mongolia has recently set a goal of reaching approximately 20.000 BEVs by the end of 2026 (Mongolia Inc. 2023). Given the recent market entry of several Chinese EV producers, it is likely that EV registrations will increase faster in the future. Despite the challenges for the electrification of passenger vehicle fleets in the Global South, research has also shown that the transition to electric mobility can create unique business opportunities and support sustainable socio-economic development (Prates et al. 2025).

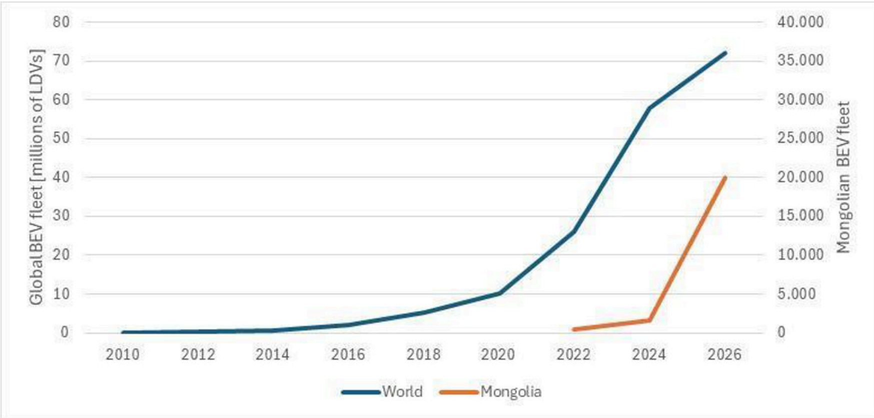

Fig. 2. Development of BEV fleets globally and in Mongolia. Global data: based on IEA 2025a; Mongolian data: own compilation (see text)

2 Electric vehicles – the key to pollution-free mobility in the Global South?

2.1 Raw material extraction impacts in the Global South

The transition to BEVs holds great promises for reducing GHG emissions and improving urban air quality. However, the environmental and socio-economic costs of raw material extraction, particularly in the Global South, raise significant concerns. BEV batteries rely heavily on critical raw materials such as lithium, cobalt, nickel, and graphite, i.e., resources that are predominantly extracted in countries with vulnerable ecosystems and often weak environmental governance (Backhaus 2021).

The extraction of these materials brings severe local environmental impacts. Open-pit lithium mining, for instance, can deplete groundwater reserves in arid regions of South America, particularly in the “Lithium Triangle” of Argentina, Bolivia, and Chile, where indigenous communities have raised concerns about water rights and ecosystem degradation (Schlosser 2020). Similarly, cobalt mining in the Democratic Republic of the Congo (DRC), which accounts for over 70% of global production, has been linked to soil and water contamination, deforestation, and exposure of local populations to potentially toxic chemical elements (Amnesty International 2017).

Moreover, mining operations in these regions are often associated with poor labor conditions and informal mining practices. Artisanal cobalt mining in the DRC frequently involves child labor and lacks basic safety standards, highlighting the ethical dimensions of the global battery supply chain (Banza Lubaba Nkulu et al. 2018 and references therein).

Resource extraction for BEV batteries is concentrated in a small number of producing countries. According to the IEA's Stated Policies Scenario for 2035, China is projected to remain the dominant global supplier of lithium, cobalt, and graphite, while Indonesia will lead in nickel production (IEA 2025b). This creates supply chain dependencies that can exacerbate geopolitical tensions and expose Global South countries to economic volatility, especially when their economies are overly reliant on raw material exports without sufficient value addition.

2.2 Beyond tailpipe emissions: The influence of electricity mix and vehicle efficiency

The absence of tailpipe emissions from BEVs directly benefits ambient air quality but can also contribute to the reduction of GHG emissions. Air quality benefits tend to be particularly high in densely populated and congested cities of the Global South. On the other hand, a reduction of carbon emissions can only be achieved if a significant amount of electricity is produced from renewable sources (Sustainable Mobility for All 2021). The electricity sector currently accounts for 36% of global CO_2 emissions, and electricity demand has been growing at an annual rate of more than 2.5% recently (IEA 2024b). For the near future, annual increases of 4% are predicted, with the transition to electric mobility among the key drivers (IEA 2025a).

The examples of selected countries in Africa, the Americas and Asia illustrate the vast differences in sources of electricity generation across the Global South (Table 1).

Table 1. Source of electricity generation in selected countries of the Global South. Sources: Latest available information (2022 to 2024) from IEA (2023) and IEA (2025).

	Fossil fuels (coal, oil, natural gas)	**Renewables** (hydropower, biofuels, wind, solar photovoltaics, geothermal energy)
Africa	75.3%	23.7%
Egypt	87.8%	12.2%
Ethiopia	0.0%	100%
Asia-Pacific	65.5%	29.5%
China	64.8%	30.4%
Mongolia	90.2%	9.8%
Americas	49.6%	37.0%
Brazil	8.7%	89.0%
Mexico	74.2%	18.2%

Some countries in the Global South rely mostly or even entirely on renewable energy for electricity production. Brazil and Ethiopia are good examples, but a detailed look reveals major differences. More than 60% of Brazil's electricity production is based on hydropower, but biofuels, wind energy and solar photovoltaics also play major roles. The country imports a small share of its electricity.

Contrastingly, Ethiopia relies very heavily on a single source of renewable energy: hydropower accounts for 96.7% of the electricity production. The expansions of hydropower capacities have turned Ethiopia into an energy exporter (IEA 2023). However, these achievements are the result of several large-scale hydro projects initiated since 1991, which have serious geopolitical implications and could be a potential source of water conflicts with neighboring countries (Ayferam 2024).

China and Mexico are examples of countries that still overwhelmingly rely on fossil fuels but where renewable sources are utilized to a moderate degree. However, there are important differences in the composition of the fossil fuels mix and the dynamics of renewable energy sector developments. Whereas in China, coal is the dominant source of electricity (61.7%), Mexico predominantly relies on natural gas (61.0%) which causes lower CO_2 and other pollutant emissions. At the same time, Mexico has only recorded slow growth in renewable energy usage over the past two decades, whereas renewable energy capacities in China have increased more than threefold (IEA 2023).

Egypt and Mongolia are examples for countries that remain highly fossil fuel dependent. As a country rich in coal resources of various qualities, it is not surprising that coal forms the backbone of Mongolia's electricity production system, accounting for 85.8% of the produced electricity. Egypt, on the other hand, relies mostly on natural gas (79.2%) and oil (8.6%) for electricity production, both of which are based on domestic reserves and production. While Egypt has stagnated in the expansion of renewable energy, Mongolia has achieved moderate progress over the past two decades (IEA 2023).

CO_2 emission reductions achievable by electric mobility depend both on electricity sources and the size and efficiency of electric vehicles. For India and China, recent studies have demonstrated that the climate change mitigation potential of BEVs (1) tends to be greater for small vehicles, including two-wheelers (in which internal combustion engines are often inefficient, and for which the additional carbon footprint of batteries is minimal), (2) correlates with engine efficiency which varies considerably, and (3) depends on regional electricity sources. In both countries, regions with carbon-intensive electricity production were found to increase carbon emissions due to electrification of LDVs whereas regions with higher shares of renewable energy resulted in a decrease in carbon emissions. For China, Wu et al. (2019) report a carbon intensity of 0.68 $kgCO_2e$ for 1 kWh of electricity, with a range between 0.18 $kgCO_2e$ in Yunnan Province to 0.90 $kgCO_2e$ in Shandong Province. For India, Abdul-Mannan et al. (2022) report a carbon intensity of 0.93 $kgCO_2e$ for 2019/20 and an expected decrease to 0.676 $kgCO_2e$ by 2029/2030, which would lead to overall increases in carbon emissions by a growing fleet of LDVs unless their energy consumption is reduced. The authors highlight that regional electricity mixes differ, with low-carbon electricity in northeastern India already enabling a positive climate impact of EVs but higher shares of fossil energies negating these effects in other regions such as eastern and western India.

Whenever electricity production is based on fossil fuels, further burdens such as soil and water contamination from coal mining and combustion have to be considered as additional environmental impacts (e.g., Alekseenko et al. 2025; Nottebaum et al. 2020; Sodnomdarjaa et al. 2024). Despite this, improvements of urban air quality can constitute a major benefit. Ulaanbaatar, the capital of Mongolia and home of about half of the country's population, is a good example. The city suffers from some of the worst air pollution worldwide, particularly during the long and cold winter seasons (Karthe et al. 2022). Even though coal combustion for heating purposes is the dominant source of air pollution across the city, air quality monitoring stations along the city's main roads exhibit significant contributions of road traffic, particularly during rush hours (Kim et al. 2025). Moreover, the increase in aerosol and NO_x concentrations in central parts of the city immediately after the lifting of COVID-19 restrictions underlines the relevance of road transport as a source of air pollution (Ganbat et al. 2022). Government plans to increase the EV fleet therefore have the potential to lower air pollution levels in some of the most frequented parts of the city.

2.3 The challenge of end-of-life batteries

While this transition offers environmental benefits, it also presents significant challenges, particularly concerning the management of EOL BEVs and their batteries, which contain hazardous materials posing risks to human health and the environment. Substances frequently contained in lithium-ion batteries (LIBs), which are currently the most common technology used for traction batteries, include lithium, cobalt, copper, nickel and lead (IEA 2024c; Prates et al. 2023; Zheng et al. 2023), substances that are classified as flammable, corrosive, irritant, toxic and carcinogenic according to the Globally Harmonized System of Classification, Labelling and Packaging of Chemicals (see Fig. 3).

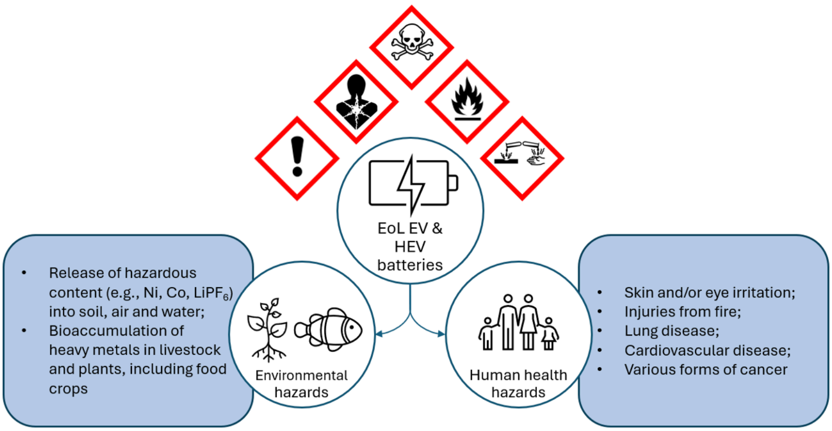

Fig. 3. Risks related to the improper disposal of NiMH and Li-ion batteries. Based on Prates et al. 2023

The potential threats posed by EOL vehicle batteries are exacerbated by three factors in the Global South:

- The export of used EVs with limited remaining battery lifetime from developed to developing countries can lead to the transfer of environmental burdens (Prates et al. 2023; UNEP 2020).
- Inadequate and informal waste management systems and a lack of comprehensive policies and regulations governing EVs and their batteries increase the risk that recycling and disposal are not implemented in a safe and sustainable way. This can result in environmental contamination and health hazards due to the release of toxic substances (Prates et al. 2023: Winslow et al. 2018). Such risks are exacerbated when EOL batteries are collected, recycled and disposed of by the informal sector, or by car service and repair shops that do not have access to proper recycling and disposal channels (see Fig. 4).
- State-of-the-art solutions to manage EOL batteries involve advanced technologies (e.g., recycling facilities combining pyrometallurgy and hydrometallurgy processes) which require not only high upfront investment but also technical expertise and a trained workforce to ensure safe handling, dismantling and recycling of EOL batteries (Hantanasirisakul and Sawangphruk 2023).

Fig. 4. Battery modules are tested, disassembled and stored in a significant number of repair shops across Ulaanbaatar. While some end-of-life modules are exported to Japan for recycling, there is no reliable information about the fate of the parts of this battery waste stream. Photo: Luisa F.S. Prates

3 Summary and Conclusions

The transition to electric mobility can be a key strategy for mitigating the climate and air pollution impacts of road transport. Technical advances, particularly in batteries, and increasing affordability of BEVs lead to increasing EV numbers in both the Global North and the Global South. While the carbon benefits of BEVs depend significantly on local electricity sources, but also on vehicle size and engine efficiency, the absence of tailpipe emissions benefits ambient air quality, particularly in regions experiencing heavy traffic and road congestion.

However, the transition from LDVs with internal combustion engines to BEVs also creates a range of new environmental challenges that particularly relate to raw material extraction and processing, and to end-of-life vehicles and their batteries. Furthermore, whenever electricity production is based primarily on fossil fuels, climate benefits can be minimal or non-existent. These challenges particularly affect countries of the Global South as they are major raw material producers with underdeveloped waste management. Therefore, policies that promote the transition to electric mobility in the Global South should integrate the following aspects:

- Electrification strategies must be paralleled by a transition to renewable energy sources so that BEVs achieve net climate benefits.
- The introduction of BEVs must lead to adjustments in regulatory frameworks to prevent pollution shifting through used vehicle imports and ensure the establishment of safe and sustainable recycling and disposal strategies.
- As the transition to battery-electric mobility is a global phenomenon, international cooperation and knowledge exchange are fundamental to supporting the establishment of sound management systems.

Ultimately, the assessment of environmental implications of the transition to electric mobility must go beyond carbon emissions. The application of a Resource Nexus perspective (Brouwer et al. 2023) can guide such transitions by ensuring that the environmental footprint is considered holistically and that environmental challenges related to raw material extraction, vehicle and battery production, and end-of-life are integrated.

Acknowledgments. This article builds on an expert exchange within United Nations University (UNU) that was facilitated by the Kaleidoscope initiative under the Vice Rectorate in Europe (ViE). The authors would like to thank Prof. Dr. Xiaomeng Shen and the communications team at UNU-ViE for the respective efforts. The support of German Academic Exchange Service (DAAD) which provides funding for the doctorate of Ms. Luisa Prates in the Graduate School Scholarship Programme (GSSP) is thankfully acknowledged. The authors would also like to thank Korea Environment Corporation (K-eco), which has provided funding for the project "Nexus Approaches to battery waste management for sustainable e-mobility transition: insights from Germany (NABATE)" and supported the fellowship of Ms. Seoyoung Lim and the internship of Ms. Yubin Yang at UNU, all of which are greatly appreciated.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Abdul-Manan, A.F.N., Gordillo Zavaleta, V., Agarwal, A.K., Kalghatgi, G., Amer, A.A.: Electrifying passenger road transport in India requires near-term electricity grid decarbonisation. Nature Communications **13**, 2095 (2022). DOI:10.1038/s41467-022-29620-x
2. Alekseenko, A.V., Machevariani, M.M., Bech, J., Karthe, D.: Pollution of coal mine soils: global reference concentrations of chemical elements. Environmental Earth Sciences **84**, 286 (2025). DOI: 10.1007/s12665-025-12160-0
3. Amnesty International (2017): Time to recharge: Corporate action and inaction to tackle abuses in the cobalt supply chain. Online at https://www.amnesty.org/en/documents/afr62/7395/2017/en/, last accessed 2025/05/30
4. Ayferam, G.: Perspectives on the Geopolitical Implications of Post-1991 Ethiopia's Hydropower Development. African Journal of Politics and Administrative Studies (AJPAS) **17**(1), 1027-1053 (2024). DOI: https://doi.org/10.4314/ajpas.v17i1.50
5. Backhaus, R.: Battery Raw Materials - Where from and Where to?. ATZelectronics worldwide **16**, 38–43 (2021). DOI: https://doi.org/10.1007/s38314-021-0678-8
6. Banza Lubaba Nkulu, C., Casas, L., Haufroid, V., De Putter, T., Saenen, N.D., Kayembe-Kitenge, T., Musa Obadia, P., Kyanika Wa Mukoma, D., Lunda Ilunga, J.M., Nawrot, T.S., Luboya Numbi, O., Nemery, B.: Sustainability of artisanal mining of cobalt in DR Congo. Nature Sustainability, **1**, 495–504 (2018). https://doi.org/10.1038/s41893-018-0139-4
7. Bisht, G.S., Pandey, S.: Biofuels for a Sustainable Future: Generations, Technologies, and Key Challenges in Renewable Energy. Bioenergy Research **18**, 43 (2025). DOI:10.1007/s12155-025-10842-y
8. British Petroleum (=BP): bp Energy Outlook 2024 edition. British Petroleum, London (2024)
9. Brouwer, F., Caucci, S., Karthe, D., Kirschke, S., Madani, K., Mueller, A., Zhang, L., Guenther, E.: Advancing the resource nexus concept for research and practice. Sustainability Nexus Forum **31**, 41–65. (2023) DOI:10.1007/s00550-024-00533-1
10. CNN (2025): EVs are starting to overtake gas-powered cars in a surprising place. Online at https://edition.cnn.com/2024/08/17/climate/ethiopia-evs-gas-car-ban-climate/index.html, last accessed 2025/05/30
11. Ganbat, G., Lee, H., Jo, H.W., Jadamba, B., Karthe, D.: Assessment of COVID-19 Impacts on Air Quality in Ulaanbaatar, Mongolia, Based on Terrestrial and Sentinel-5P TROPOMI Data. Aerosol and Air Quality Research **22**(10), 220196 (2022). DOI:10.4209/aaqr.220196
12. Hantanasirisakul, K., Sawangphruk, M.: Sustainable Reuse and Recycling of Spent Li-Ion Batteries from Electric Vehicles: Chemical, Environmental, and Economical Perspectives. *Global Challenges* **7**(4), (2023). DOI:10.1002/gch2.202200212
13. International Council on Clean Transportation (=ICCT) (2020): Growing momentum: Global overview of government targets for phasing out sales of new internal combustion engine vehicles. Online at https://theicct.org/growing-momentum-global-overview-of-government-targets-for-phasing-out-sales-of-new-internal-combustion-engine-vehicles/, last accessed 2025/05/30
14. Internation Energy Agency (=IEA) (2023): Energy Statistics Data Browser. Online at https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=WORLD&fuel=Energy%20supply&indicator=TESbySource, last accessed 2025/05/30

15. International Energy Agency (=IEA): Global EV Outlook 2024 - Moving towards increased affordability. IEA, Paris (2024a)
16. International Energy Agency (=IEA): World Energy Outlook 2024. IEA, Paris (2024b)
17. International Energy Agency (=IEA): Batteries and Secure Energy Transitions. IEA, Paris (2024c)
18. International Energy Agency (=IEA): Electricity 2025 – Analysis and forecast 2027. IEA, Paris (2025a)
19. International Energy Agency (=IEA): Growing geopolitical tensions underscore the need for stronger action on critical minerals security. IEA, Paris (2025b)
20. Karthe, D., Lee, H., Ganbat, G.: Fragmented Infrastructure Systems in Ulaanbaatar, Mongolia: Assessment from an Environmental Resource Nexus and Public Health Perspective. In: Iossifova, D.; Gasparatos, A.; Zavos, S.; Gamal, Y. & Long, Y. (Eds.): Urban Infrastructuring - Reconfigurations, Transformations and Sustainability in the Global South, pp. 15-34. Sustainable Development Goals Series. Springer, Singapore (2022). DOI:10.1007/978-981-16-8352-7_2
21. Kim, H. C., Lee, S., Wallington, T. J.: Cradle-to-gate and use-phase carbon footprint of a commercial plug-in hybrid electric vehicle lithium-ion battery. Environmental Science & Technology **57**(32), 11834-11842 (2023). DOI:10.1021/acs.est.3c01346
22. Kim, M., Ha, Y., Kim, J., Lee, J.Y., Kim, Y.P., Natsagdorj, A., Kim, C.: First real-time size distribution measurements of aerosol particles in Ulaanbaatar, Mongolia. Atmospheric Environment **345**,121052 (2025). DOI:10.1016/j.atmosenv.2025.121052.
23. Mongolia Inc.: Mongolia unveils ambitious plan to Increase electric vehicle adoption to 20,000 (2023). https://mongoliainc.com/8757/, last accessed 2025/05/30
24. Mongolian Ministry of Road and Transport (=MoRT): Challenges and future measures to increase the use of electric vehicles (2024). https://www.unescap.org/sites/default/d8files/event-documents/Session2.1_MORT.pdf, last accessed 2025/05/30
25. Montsame: There are only 492 electric vehicles in Mongolia (2022). Online at https://montsame.mn/en/read/293612, last accessed 2025/05/30
26. Nnene, O.A., Senshaw, D., Zuidgeest, M., Mwaura, O., Yitayih, Y.: Developing Low-Carbon Pathways for the Transport Sector in Ethiopia. Climate **13**(5), 96 (2025). DOI:10.3390/cli13050096
27. Nottebaum, V., Walk, J., Knippertz, M., Karthe, D., Batbayar, G., Pötter, S., Lehmkuhl, F.: Arsenic distribution and pathway scenarios for sediments and water in a peri-urban Mongolian small-scale coal mining area (Nalaikh, Ulaanbaatar District). Environmental Science and Pollution Research **27**, 5845–5863 (2020). doi:10.1007/s11356-019-07271-8
28. Obergassel, W., Lah, O., Rudolph, F.: Driving towards transformation? To what extent does global climate governance promote decarbonisation of land transport? Earth System Governance **8**, 100098 (2021). DOI:10.1016/j.esg.2021.100098.
29. Pasini, G., Lutzemberger, G., Ferrari, L.: Renewable Electricity for Decarbonisation of Road Transport: Batteries or E-Fuels? Batteries **9**(2), 135 (2023). DOI:10.3390/batteries9020135
30. Patil, G., Pode, G., Diouf, B., Pode, R.: Sustainable Decarbonization of Road Transport: Policies, Current Status, and Challenges of Electric Vehicles. Sustainability **16**(18), 8058 (2024). DOI:10.3390/su16188058
31. Prates, L., Karthe, D., Zhang, L., Wang, L., o'Connor, J., Lee, H. & Dornack, C. (2023): Sustainability for All? The challenges of predicting and managing the potential risks of end-of-life electric vehicles and their batteries in the Global South. Environmental Earth Sciences 82:143. DOI:10.1007/s12665-023-10806-5.

32. Prates, L.F.S., Schneider, C.P., Dornack, C., Guenther, E., Möst, D., Karthe, D.: Achieving the SDGs through a resource nexus approach: lessons from the African E-mobility transition. Discover Sustainability (2025). DOI:10.1007/s43621-025-01340-4
33. Qiao, Q., Zhao, F., Liu, Z., Jiang, S., Hao, H.: Comparative study on life cycle CO2 emissions from the production of electric and conventional vehicles in China. Energy Procedia **105**, 3584-3595 (2017). DOI:10.1016/j.egypro.2017.03.827
34. Schlosser, N.: Externalised costs of electric automobility: social-ecological conflicts of lithium extraction in Chile. Working Paper No. 144/2020 (2020). https://www.econstor.eu/bitstream/10419/222406/1/1703743695.pdf, last accessed 2025/05/30
35. Sodnomdarjaa, E., Knippertz, M., Karthe, D., Alekseenko, A.V., Ganbat, G., Römer, W., Lehmkuhl, F.: Resource conundrum in Mongolia: Soil contamination from coal and copper–molybdenum mining. Soil Use and Management **40**, e13025 (2024). DOI:10.1111/sum.13025
36. Statista: Distribution of carbon dioxide emissions worldwide in 2023, by sector (2025a). https://www.statista.com/statistics/1129656/global-share-of-co2-emissions-from-fossil-fuel-and-cement/, last accessed 2025/05/30
37. Statista: Distribution of carbon dioxide emissions produced by the transportation sector worldwide in 2023, by sub sector (2025b). https://www.statista.com/statistics/1185535/transport-carbon-dioxide-emissions-breakdown/, last accessed 2025/05/30
38. Sustainable Mobility for All: Electromobility in the Global South: An Equitable Transition toward Road Passenger Transport Decarbonization. Discussion Paper. The World Bank, Washington, DC (2021)
39. United Nations Environment Program (=UNEP): Used Vehicles and the Environment. A Global Overview of Light Duty Vehicles: Flow, Scale and Regulation. UNEP Economy Division, Nairobi (2020).
40. U.S. Energy Information Administration (=EIA): International Energy Outlook 2021 with projections to 2050. US Department of Energy, Washington, DC (2021)
41. Verma, S., Dwivedi, G., Verma, P.: Life cycle assessment of electric vehicles in comparison to combustion engine vehicles: A review. Materials Today: Proceedings, **49**, 217-222 (2022). DOI:10.1016/j.matpr.2021.01.666
42. Winslow, K.M., Laux, S.J., Townsend, T.G.: A review on the growing concern and potential management strategies of waste lithium-ion batteries. Resources, Conservation and Recycling **129**, 263–277 (2018). DOI:10.1016/J.RESCONREC.2017.11.001
43. World Resources Institute: Where Do Emissions Come From? 4 Charts Explain Greenhouse Gas Emissions by Sector, https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors, last accessed 2025/05/30
44. Wu, Z., Wang, C., Wolfram, P., Zhang, Y., Sun, X., Hertwich, E.: Assessing electric vehicle policy with region-specific carbon footprints. Applied Energy **256**, 113923 (2019). DOI: 10.1016/j.apenergy.2019.113923.
45. Yu, X., LeBlanc, S., Sandhu, N., Wang, L., Wang, M., Zheng, M.: Decarbonization potential of future sustainable propulsion—a review of road transportation. Energy Science and Engineering **12**, 438-455 (2024). DOI:10.1002/ese3.1434
46. Zheng, P., Young, D., Tairan, Y., Yunhao, X., Zheng, L.: Powering battery sustainability: a review of the recent progress and evolving challenges in recycling lithium-ion batteries. Frontiers in Sustainable Resource Management **2**, 1127001 (2023). DOI=10.3389/fsrma.2023.1127001

47. Zhou, L.-F., Yang, D., Du, T., Gong H., Luo, W.B.: The Current Process for the Recycling of Spent Lithium Ion Batteries. Frontiers in Chemistry **8**, 578044 (2020). DOI:10.3389/fchem.2020.578044