10

E-Mobility for a Sustainable World: Unavoidable Automobility and Global South-North Perspectives

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People and freight movement accounts for 15 percent of global greenhouse gas emissions (1). Not all mobility or even automobility demand can be fully avoided as it is the mobility service that connects the point of demand and point of supply in an interdependent modern human society (see Figure 1 and Table 1). It is important then to consider how unavoidable automobility (mobility necessary to access services essential for human living) can be promoted bearing in mind the Sustainable Development Goals (SDGs), particularly SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all) and SDG 13 (take urgent action to combat climate change and its impacts) (2). Policymakers, spatial planners and service-delivery providers are the key actors to introduce any change related to mobility services, supplemented by information sharing to enhance user awareness and shape user behaviour (3). While digitalisation, information and communication, and interactive technologies may help in reimagining mobility services (4) their influence on the impact of mobility and energy demand on the environment is yet to be assessed (5).

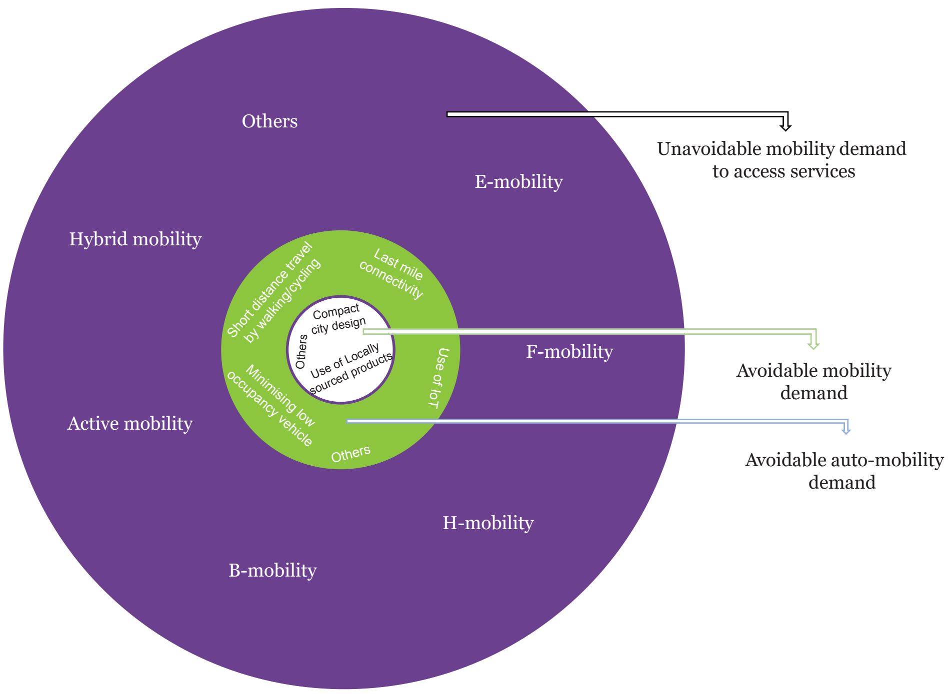
Mobility is not just for the physical transportation of passengers but for goods as well. Societies with a high interdependence through import-export of goods lead to an increased demand for automobility. Importantly, 90 percent of all global freight movement is by ships that run on fossil fuels (6).

North-South Binary

Existing literature on collective sustainable living (7) and eco-modern justice (8) highlights the need for mainstream research to go beyond traditional binary representations to show equity, such as North-South, rich-poor, developed-developing, or Annex I- Non-Annex I countries. The north-south binary, which emerged amid globalisation from traditional political economy literature (9), trade literature (10), and geography (11), needs to be reframed in the wake of the global sustainability discourse and different economic levels across social groups. This paper views the Global South and North not as geographic regions but as 'social designations' for vulnerable communities due to political-social-economic factors in rich and poor countries (12).

Social inequity in mobility is connected to levels of wealth, poverty and capabilities. People with a lower level of travel demand may satisfy one or a combination of the following factors: unemployment, low income, have a low ownership of vehicles, live in settlements that are less served by modern travel modes and services, have a lower capability to join the skilled labour market (13), and lack decent living standards (14). This group with a mobility deficit or deprivation will vary depending on the level of equity and inequity within a country. Unlike cooking fuel use, which leads to biomass burning and has environmental impacts, the mobility of a poor social group can typically be categorised under active mobility service and hence has a minimal contribution to the environment (Global South perspective). This paper focuses on unavoidable automobility, or the Global North perspective that cuts across all countries.

Figure 1: Avoidable and Unavoidable Mobility Demand



Source: Conceptualised by authors based on J.Roy et al, and B. Ghosh (15)

Reimagining Mobility

E-mobility emerged as a supply-side option in low emission mobility solutions under the assumption that electricity supply can be from zero carbon sources (see Figure 1). The sustainable development framework, digitalisation, Big Data and internet of things (IoT) (16), provide an opportunity to reimagine the mobility of people and goods in a broader context, with the potential for new investment in infrastructure, service provision systems (17), and an overall enabling environment through policy incentives without compromising on human wellbeing or breaking sectoral boundaries.

Transforming service provision systems: Avoiding demand for mobility

Avoiding mobility is not an option for the Global South as such communities are already living with unmet mobility demands and low levels of wellbeing. It is, however, applicable to the Global North communities that are directly or indirectly dependent on automobility and unavoidable automobility; they are the major driver of global unavoidable demand for automobility.

Infrastructure design and promoting it appropriately as a "new normal status symbol" will play an important role in avoiding the demand for mobility. For instance, compact urban planning will help in avoiding mobility (18). Mobility service provision through collaborative mobility demand (19), and reducing vehicle ownership by increasing the occupancy of vehicles by increasing comfort in public transport system (20) helps avoid and reduce mobility demand. Cities that are experiencing growth and are developing their infrastructure have the potential to incorporate plans and designs to encourage low mobility, and thus low energy, demand.

Active mobility for a sustainable world

The Global South is mostly dependent on active mobility that is sustainable but is trapped at a low level of human wellbeing without access to opportunities. However, for the Global North, active mobility is now emerging as an alternative sustainable option to enhance human wellbeing for certain services that are available at short distances and thus provide healthy options and reduce emissions through modern digital and physical infrastructure design (21).

The purpose of mobility can be varied (see Table 1). Active mobility through walking or cycling has no direct adverse environmental emissions since no fuel is used, and so is perfectly compatible with sustainable mobility. The mobility of people and goods can be over a short, intermediate or long distance. Typically, active travel is for short distances, and motorised mobility is for long-distance travel.

Mobility can be to maintain various needs, such as accessing educational spaces or workplaces, entertainment and shopping, healthcare, leisure and tourism, and socialisation. Often, the movement of people and goods can be complementary or substitutes, providing scope to avoid the mobility need of one kind or the other (see Table 1). Digitalisation and IoT are transforming the service provision system and increasing substitutability in passenger and freight movements. For instance, online food ordering, telecommuting for work, online shopping, and E-education. One way of measuring progress in sustainability is the status of human health (a component

Table 1: Means for Mobility

Transport types	Physical movement			
	People (passenger km)		Freight (ton km)	
	Global growth rates over the period*			
Active transport	Not available		Not available	
Road transport	193.17% (2000-2017)		100% (1990-2003)	
Rail transport	16.27% (1995-2007)		20.13% (1995-2010)	
Air transport	1368.11% (1970-2019)#		1322.70% (1973-2019)	
Water transport	Not available		120% (1990-2003)	
Purpose (Distance to cover)	**Private**	**Shared**	**Domestic**	**International**
Short	Active mobility: Walk, Cycle/bike Automobility: 2W, 3W, 4W	Active mobility: Cycle/bike Automobility: 2W, 3W, 4W	Active mobility: Walk, Cycle/bike Automobility: 2W, 3W, 4W	Train, Bus, Airplane, Ship
Intermediate	Active mobility: Cycle/bike Automobility: 2W, 3W, 4W	Active mobility: Cycle/bike Automobility: 2W, 3W, 4W, Bus	Active mobility: Cycle/bike Automobility: 2W, 3W, 4W	Train, Bus, Airplane, Ship
Long	4W	4W, Train, Metro, Bus, Airplane, Ship	3W, 4W, Train, Bus, Airplane, Ship	Train, Bus, Airplane, Ship
Access to Services	**Physical movement (of people)**	**Digitalised platforms**	**Physical movement (of freight)**	
Education	High potential for reduction	High potential for increase	Marginal/No additional physical movement of freight needed	
Job	High potential for reduction	High potential for increase	Marginal/No additional physical movement of freight needed	
Entertainment services (opera/ movies/sports)	High potential for reduction	High potential for increase	No additional physical movement of freight needed	
Dine out	High potential for reduction	High potential for increase	Potential for some additional physical movement of freight needed	
Bank/ATM	Medium potential for reduction	Medium potential for increase	No additional physical movement of freight needed	
Shopping	Medium potential for reduction	Medium potential for increase	Should be complemented by physical movement of freight	
Salon	Medium potential for reduction	Medium potential for increase	Additional physical movement of freight may not be necessary	
Health	Low potential for reduction	Low potential for increase	Should be complemented by physical movement of freight	
Leisure activities (gym/ swimming etc.)	No potential for reduction	No potential for increase	No additional physical movement of freight needed	
Parties (outside house)	No potential for reduction	No potential for increase	No additional physical movement of freight needed	

Note: #Total passengers carried
High potential: when services can be ordered/ booked online but no physical movement of people necessary to deliver the product/services
Medium potential: when services can be ordered/ booked online but physical movement of people necessary to deliver the product/services
Low potential: when only few options under the broader umbrella of services (e.g., health) can be ordered/ booked online

Source: Compiled by authors. *Calculated from World Bank and Global Energy Assessment (26) of multidimensional metrics used to measure human wellbeing) (22). Studies show life-cycle CO_2 emission reduced by 14 percent with each additional cycle trip and by 62 percent with each avoided car trip (23). But such a shift in active mobility is determined by the availability of and access to infrastructure. Active mobility cannot happen in an urban centre if the city is not walkable by design (24). Thus, the overall demand for mobility might decline if managed strategically. But unless well-managed, it can lead to an increase in energy use and emissions as well (25).

Table 2: Adoption of E-Vehicles by Types

E-vehicle types	Implementation in countries
E-bike (2W)	China (27)
E-rickshaw (3W)	India (28)
E-cars (4W)	Norway, Iceland, Sweden, Finland (29)
E-buses	China, India (30)
E-trucks (freight)	US (31)
Electric trains/ metros/ underground rails	Hamburg (Germany) (32)
Electric cruise boats	US, South Korea (33)
Electric tram	Kolkata, Mumbai (India) (34)

Source: Compiled by the authors

E-mobility for Unavoidable Mobility in a Sustainable World

How can unavoidable mobility needs be met in a sustainable world, immediately for the Global North and expanded in the future for the entire population? E-mobility, H-mobility (hydrogen fuel-driven mobility) and B-mobility (biofuel-driven mobility) can be the solution. The rise in the use of lithium-ion batteries has enabled E-mobility to become a major feature of decarbonisation (see Table 2).

In light duty vehicles, E-mobility through fully battery-operated vehicles instead of internal combustion engines are becoming a commercial reality faster than anticipated across the globe (35). This is due to changes in national policies, vehicle manufacturing companies adopting new business ventures, business prospects evolving due to change in company valuation, and innovation in mobility technologies (see Table 3).

In India, initiatives such as a massive expansion of metro-rail networks in multiple cities are promoting E-mobility. Rising liquid fuel costs and the ban on two-stroke engines are some of the factors that have driven a quicker e-mobility transition in India (36). Bangalore Metropolitan Transport Corporation (BMTC) provides feeder bus services to and from metro railway stations to ease the continuity of the mobility service. BMTC has also planned to provide electric bikes at five metro stations. A number of other experimentations that are being introduced, include bus rapid transit systems (Ahmedabad, Pune, Kolkata), electric rickshaws (New Delhi, Kolkata and various other cities), promotion of different modes of non-motorised transport (Bhubaneshwar, Ahmedabad).

In developing countries, E-mobility is being rapidly implemented in micro-mobility (E-autorickshaws, scooters, E-bikes), in transit systems (especially buses) and, to a lesser degree, in the electrification of personal vehicles through various E-mobility policies (see Table 3for policies in South Asian countries). India's large and growing two-wheeler market has benefitted from the policy attention on electric vehicles (EVs), showing a significant potential for increasing the share of electric two-and three-wheelers in the short term (37). Similar opportunities exist for China where e-bikes have replaced car trips and are reported to act as intermediate links in multimodal mobility (38). China's EV market grew by 118 percent in the first quarter of 2019 (see Table 2a) and is currently larger than the EU and the US combined (39). In Chile, as of 2014, only 136 vehicles (0.003% of the total fleet) are electricity-fuelled (40). It is also important for innovation and service delivery providers to provide adequate charging points to support the penetration of EVs. In Brazil, the Itaipu hydroelectric power plant has established an electric car sharing platform for its employees (41).

Table 3: Emerging E-mobility Policies in South Asian

Country	E-mobility policy	Targets/ Incentives
Afghanistan	No EV policy yet	-
Bangladesh (42)	Automobile Industry Development Policy 2021	10-year tax holiday, financial incentives, interest waiver on loans for local manufacturing and assembly of EVs. Global Environment Facility (GEF) announced plans to help Bangladesh accelerate their shift to zero-emissions electric mobility (in Nov 2021) Bangladesh Road Transport Corporation (BRTC) has taken the initiative to introduce 50 electric buses that will run in long routes like Dhaka-Chottogram.

Country	E-mobility policy	Targets/ Incentives
Bhutan (43)	Bhutan Electric Vehicle Initiative (2014)	To make the capital city, Thimphu, a clean Green Electric City Promotes EVs with tax incentives. EVs are exempt from sales tax, customs duty, and green tax. The country has an EV initiative including a GEF project for electric taxis. It has also discussed an EV road map for commercial vehicles (buses, urban trucks, and taxis)
India (44)	National Electric Mobility Mission Plan FAME II (April 2019 for 3 years)- Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles Phase II	Ensure at least 15% of the vehicles in the country are electric by 2030 The scheme is proposed to be implemented through the following verticals: a) Demand Incentives (upfront reduced purchase price of hybrid and electric vehicles to enable wider adoption, which will be reimbursed to the original equipment manufacturer by the Indian government) b) Establishment of network of Charging Stations (setting up of adequate public charging infrastructure) c) Administration of Scheme including Publicity, IEC (Information, Education & Communication) activities.
Maldives (45)	No EV policy yet	Global Environment Facility announced plans to help Maldives accelerate their shift to zero-emissions electric mobility (in its initial phase)
Nepal (46)	Environment friendly Vehicle and Transport Policy	Increase the share of EVs to 20% by 2020 and proposed subsidy schemes. But the market of the EVs dropped following the increase in 120%-140% of tax of combined excise and customs duties in the 2020-21 budget plan.

Country	E-mobility policy	Targets/ Incentives
Pakistan (47)	National Electric Vehicles Policy (2020)	Passenger EV sales to constitute 30% of new sales by 2030 and 90% of new sales by 2040; 2 & 3 wheelers EV sales to constitute 50% of new sales by 2030 and 90% of new sales by 2040; Buses EV sales to constitute 50% of new sales by 2030 and 90% of new sales by 2040; and Trucks EV sales to constitute 30% of new sales by 2030 and 90% of new sales by 2040 Incentives includes: 1% GST for EVs (down from 17%), 1% Import Duty on charging equipment, Lower electricity tariffs for EV charging stations, State Bank to offer lower rate financing to EV manufacturers
Sri Lanka (48)		Global Environment Facility announced plans to help Sri Lanka accelerate their shift to zero-emissions electric mobility (in November 2021)

Source: Compiled by the authors

The continued growth of E-mobility for land transport will require investments in electric charging and related grid infrastructure, which has a direct relevance in terms of SDG 7 and clean power generation capacity. To ensure fast EV uptake for climate benefit through market mechanism, three barriers must be overcome in the next 10 years: battery costs, availability of charging infrastructure, and clean power generation and distribution (49). Dedicated high power charging stations can reduce charging time (50). These have been installed in several countries that have a relatively large market for EVs, such as China, UK, US, and Germany.

While market mechanism is vital to advance electric mobility, adequate policy support is an absolute necessity to enable the shift. In Sweden and Germany, for instance, electric heavy-duty vehicles are incentivised by electrified traffic lanes (51). The larger penetration of EVs requires innovative business models like MaaS (mobility-as-a-service), but studies have shown concern that MaaS may not work in low density car-dependent cities as the distances to be travelled are too long, which may not enable easy sharing that can happen in dense places (52).

Challenges

The increased emphasis on E-mobility through battery-operated vehicles is creating geopolitical issues in the energy sector and needs attention within the context of SDG 7.a (by 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology) and 7.b (by 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support). Countries like India are becoming importers of lithium batteries (used in EVs) in huge quantities given the lack of lithium, cobalt, and nickel reserves. In

Table 4: Regulatory Frameworks for Lithium-ion Battery Management

Regions	Framework	Treatment of Lithium-ion Batteries
EU	Battery Directive (2006)	Minimizing the negative impact of waste batteries, including lithium-ion batteries. Prohibition of disposal of industrial/ automotive batteries/accumulators to landfill or incineration Allowing the recycling and treatment of battery waste outside the EU if EU legislation for transport/transfer of hazardous waste are followed
US	Considered hazardous and are regulated under the Standards for Universal Waste Management (Electronic Code of Federal Regulations, Title 40, Part 273, US EPA).	The order strictly prohibits the disposal of batteries to landfills. However, the Federal Government standards do not include any directive about resource recovery from lithium-ion batteries waste. Some states in the USA are developing their own regulations that enforce producers to offer or fund battery recycling. These schemes are active in California, Minnesota, Iowa New York, Florida, Vermont, New Jersey, and Maryland.
China	Draft rules in 2017	Hold car manufacturers responsible for the recovery of new energy vehicle batteries and require them to set up recycling channels and service outlets where old batteries can be collected, stored and transferred to specialist recyclers.

Regions	Framework	Treatment of Lithium-ion Batteries
Japan	Law for the Promotion of the Effective Utilisation of Resources, 2000	Mandates that rechargeable batteries be classified for recycling, at the manufacturing stage, using a standardised three arrow recycling mark indicating battery type and primary metal components. On reaching end-of-life, these marked batteries are collected and recycled appropriately. The Law also sets lithium-ion batteries recycling target of greater than 30% and stipulates that all manufacturers and importers of batteries must have a recovery system for waste products
India	Draft rule- Battery Waste Management Rules, 2020	Explains in detail the responsibility of the battery manufacturer- from setting up battery-waste collection centres and take-back systems to affixing targets for battery-waste collection from two to seven years after the rules come into effect

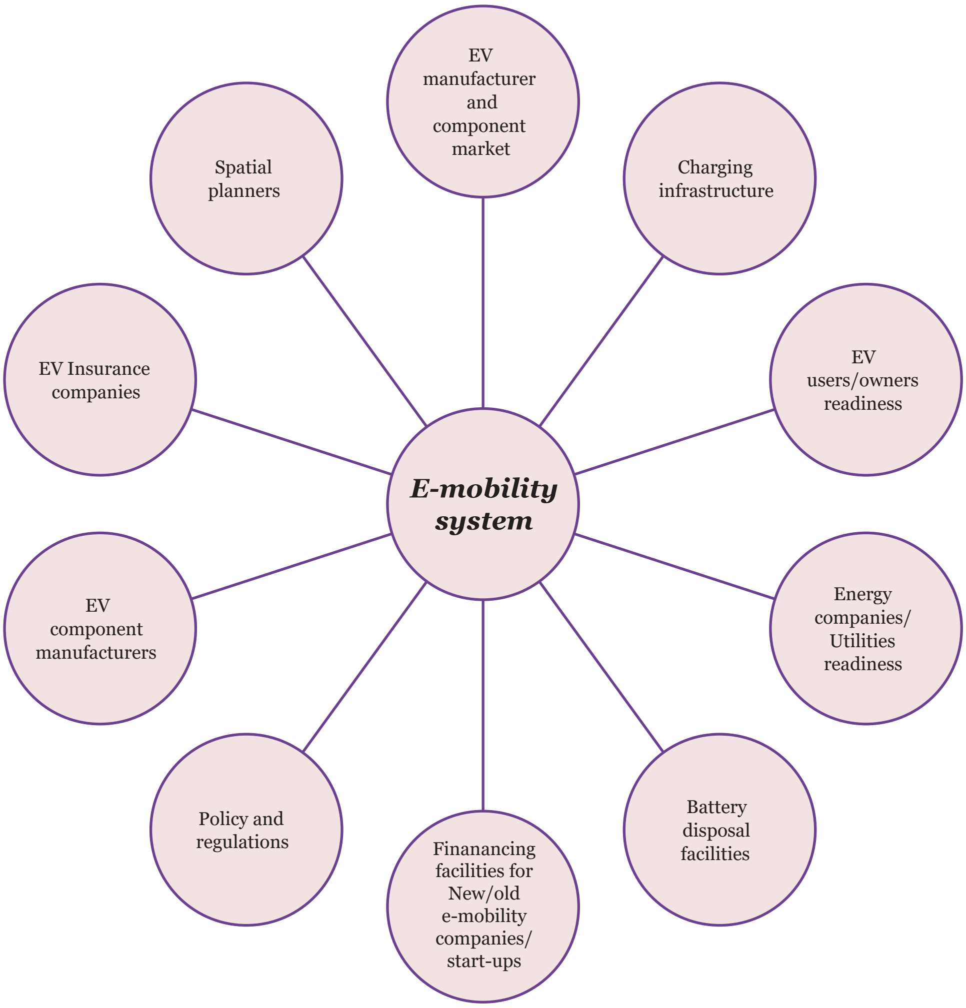
Source: Adapted from JMK Research & Analytics (57)

2019-20, India imported 450 million units of lithium batteries valued at INR 6,600 crore (US$929.26 million) (53).

EV batteries typically lifecycle of about eight years and need to be replaced when capacity falls below 80 percent (54). This can be done in two ways—EV batteries can be repurposed for secondary applications or can be sent for recycling and for metal to be recovered from them.

Spent batteries contain toxic materials, and proper waste management is vital to avoid fires and soil and water contamination. Studies suggest that recycling and repurposing lithium-ion batteries can create a circular economy and reduce the dependence on resources and materials used to make these batteries (55). Multiple countries are establishing regulatory frameworks to manage lithium-ion batteries (see Table 4). India's draft Battery Waste Management Rules, 2020 outlines the responsibility of

Figure 2: Actor Network for E-Mobility



Source: Prepared by the authors

the battery manufacturer, ranging from setting up battery-waste collection centres and take-back systems to affixing targets for battery-waste collection. Recycling or reusing lithium-ion batteries for stationary energy applications is another potential way to manged end-of-life batteries. However, access to information on the health of lithium-ion batteries remains a challenge for recycling and remanufacturing batteries for a second life (56).

In India's intermediate means of transport (IMT) segment, which is dominated by hydrocarbons, the penetration rate of E-rickshaws is much lower than the potential. This is due to conflicts (social, political and legislative) with the hydrocarbon regime along with varying cultural bias for rickshaws despite the fast technology development in this segment. E-rickshaw technology is readily available but policy inertia, institutional preparedness, competition with the incumbent technology based on hydrocarbons are causing delays in transforming the IMT segment (58).

Importantly, a deep electrification in the transport sector may have an adverse impact on SDG 7 because increases in electricity demand can lead to an increase in prices, adversely affecting the affordability of modern energy for poor populations, unless pro-poor redistributive policies are in place (59). Decarbonising the transport sector will require significant integrated planning of transport and power infrastructure and the involvement of multiple social actors (see Figure 2) for systemwide benefits.

Conclusion

Considering E-mobility in the context of the climate goal (SDG 13) will likely conflict with the aims of SDG 7 (ensuring access to affordable, reliable, sustainable, and modern energy for all). Mobility-poor social groups can be categorised under active mobility service users and hence have a minimal impact on the environment. Social inequity in modern energy and mobility is connected to levels of wealth, poverty and capability. Viewing the Global South and North not as geographic regions but as 'social designations' for vulnerable communities provides a useful analytical framing—the Global South community has active mobility users with a minimum direct contribution to the environment but has less access to modern energy to meet the wellbeing needs. Global South as a social group that is living with low purchasing power, energy poverty and mobility deficit and is mostly dependent on active mobility, have the rights to enhance mobility and access to modern energy. At the same time, the automobility needs of the Global North have increased manifold in recent decades.

Mobility per se is not a problem, and can be better for health outcomes and overall human wellbeing (SDG 3) if it is in active mode. The overall demand for mobility can lead to an increase in energy use and emissions, unless managed properly. E-mobility is one solution.

Policymaking must keep abreast with this shift and to transform mobility practices. The growth in active mobility and its ability to replace automobility should be quantified to get an idea of avoidable and unavoidable mobility. Research must focus on the various social groups and particularly on the transition for the Global North. A systemic approach is needed to transition from fossil fuel-mobility to E-mobility in the Decade of Action.

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