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Place-Based Decarbonisation in Low and Middle Income Countries: A whole systems viewNazmiye Balta-Ozkan^a and Holger Dalkmann^b^a School of Water Energy and Environment, Cranfield University, Bedfordshire, UK^b Climate Compatible Growth Programme, University of Loughborough, UK and Sustain 2030, Berlin, Germany

Decarbonisation of transport is essential to the efforts to limit global temperature increase to under 1.5 °C as agreed in the Paris Agreement. According to the International Energy Agency (IEA), global emissions from transport were around 8 gigatonnes (Gt) in 2022 – an increase of three percent against the previous year (IEA, 2023). This sets a stark contrast against the annual 3% reduction target that is needed to be on track with IEA's Net Zero Emissions by 2050 (NZE) scenario. This is a significant challenge as transport emissions were increasing 1.7% per annum in the last 30 years, driven by a very strong demand for transport in emerging markets and developing economies. The latest Stocktake by the UNFCCC in September 2023 flags that the combined pledges of the 193 Parties under the Paris Agreement would put the world on track for around 2.5. degrees Celsius by 2030 (UNFCCC Secretariat, 2023). In 2021, 98% of the National Determined Contribution (NDCs) mentioned transport, but only 83% included transport measures and only 18% set specific CO₂ reduction targets for the sector (ITF, 2023).

Whilst at COP 26 in Glasgow, countries like China committed to reduce their emissions to net zero by 2060 and India announced for the first time a net zero target by 2070, it remains a key challenge for Low and Middle Income Countries (LMICs) to start the process of decarbonisation of their economies. The uptake of measures to reduce transport sector carbon emissions in LMICs has so far not been a priority. While there is a key responsibility for high income countries to take substantial action, the Paris goal cannot be achieved without LMICs acting on transport. A better understanding of how the decarbonisation of transport brings other benefits, ranging from energy security to improvements in air quality, could help to convince policy-makers and the wider public the urgency of taking actions.

The development and operation of low carbon transport systems are dependent on the availability of infrastructure systems, whether charging stations for electric vehicles (EVs) or hydrogen fuelling stations for heavy good vehicles (IRENA, 2022), acquitting them with an inherently place-based character. A place-based approach originates from environmental psychology discipline to recognise the impact of infrastructure developments on the local communities' pre-existing emotional attachments and place-related identity processes (Devine-Wright, 2009). Only by taking these social associations and meanings into account, a place-based decarbonisation may deliver faster and cost-effective progress towards carbon reduction in any geographical region (Goel et al., 2023). A further advantage of place-based approaches is their ability to join diverse policy goals (Devine-Wright, 2022), highlighting the potential for this concept to accommodate both the public's and decision makers' view points, desires and aspirations at different scales from national to regional and local levels. By embodying the historical, socio-economic, political, and geographical contexts, a place-based approach gives rise to decarbonisation outcomes that vary in pace, scale and nature. This special issue presents interweaving of these factors and processes through concepts, tools and models for six LMICs, including India, Bangladesh, Costa Rica, Egypt, Kyrgyzstan, and Ecuador. The studies present freight and passenger transport and the interaction and the interdependency of

transport decarbonisation pathways with energy systems and the wider policy and institutional landscape, using a mix of qualitative and quantitative methods.

Overview of articles: Informed policy action through more research

The role of freight in the decarbonization of transport is crucial but often receives less attention from policy makers and researchers. Therefore, the work from Gupta and Dhar (2022) focusing on the future of the freight sector in India is particularly relevant. Currently freight accounts for 7% of India's total CO₂ emissions and 42% of its petroleum fuel consumption. In their analysis, Gupta and Dhar combine stakeholder consultation and results from an energy-economic optimization model. His different scenarios highlight the need for strengthening multi-modal logistics policy in alignment with clean-energy-based electrification and strengthening national railway infrastructure for India to get on a Paris compatible pathway.

Electrification of vehicles is essential for the decarbonisation of road transport which accounts for over 15% of global energy emissions. According to the IEA's NZE scenario, sales of electric vehicles (EVs) need to make up 65% of total car sales by 2030 which has strong implications on the battery production capacity and demand for critical minerals (IEA, 2021). While the growth of EV sales to 14% in 2022, along with the announced battery production capacity give hope for progress towards the Net Zero Emissions by 2050 pathway (IEA, 2023), this special issue presents wider perspectives on the electrification of transport in LMICs. Of the three papers in this special issue, Abdullah-Al-Nahid et al. (2023) focus on electric four wheelers in Bangladesh, the other two analyses EVs as part of a wider planning and policy framework. Torkey and Abdelgawad (2022) develop a framework the planning of EV charging infrastructure as part of urban infrastructure planning in Egypt while Kondev et al. (2023) analyse and policy and institutional landscape for EVs in Kyrgyzstan.

Abdullah-Al-Nahid et al. (2023) explores the future role of electric four wheelers in Bangladesh, with a view to inform current plans of the Bangladesh government in developing an EV policy. With currently about 10 percent of the country's GHG emissions coming from transport and their predicted increase by 116 percent by 2030, they evaluated policy options to reduce these future emissions. The authors developed an EV outlook for Bangladesh from 2022 to 2040 by applying the concepts of the additive linear programming mechanism. They estimated in their scenario that, with the inclusion of a 40% carbon tax, the forecasted number of EVs would reach around 3 million in the year 2040, while Internal Combustion Engine (ICE) vehicles would be no longer attractive.

A large body of literature on EVs can be broadly categorised into two categories of national policy perspectives and planning of charging infrastructure at distribution network level. While the former includes specific EV deployment targets or pilot studies that are funded by national governments or international organisations, the latter focuses how these targets may be operationalised by identifying the location of charging stations using optimisation techniques. Yet, in between these macro and micro perspectives lays the knowledge gap of how to plan EV charging infrastructure (EVCI) for cities. Torkey and Abdelgawad (2022) addresses this gap by developing a meso-level planning framework that can be utilised by cities, taking into account learning from global e-mobility frontrunners and urban planning such that EVCI responds to market dynamics. Four key lessons are identified: i) as EV adoption increases, public charging infrastructure becomes profitable for the private sector; ii) siting of charging stations near shared-mobility services improves revenue streams of EVCI, iii) EV-ready infrastructure system design is essential for cost-effective development of new cities, and iv) user awareness of EV onboard charger power limits is essential for a satisfying customer experience. The authors build on these insights to illustrate how EVCI can be developed in

five steps for two alternative cases: government-target-driven and international-best-practices-driven framework. This paper outlines how urban form and land use decisions can be used in locating different types of chargers (e.g. slow vs fast) spatially. The framework is applied to the new administrative capital of Egypt.

The study by Kondev et al. (2023) focus on the broader policy and institutional landscape for the acceleration of EV uptake, including the assessment of total cost of ownership (TCO) in the Central Asian region, specifically for Kyrgyzstan. With rich natural gas resources, both gasoline and electricity prices are lower than global median values in the country. While the authors find only one EV model, the Nissan Leaf, to have a lower TCO over five years than a similar size in ICEV, these calculations don't consider the costs of charging infrastructure and the avoided carbon emissions. As the average age of a passenger car is 16 years in Kyrgyzstan, the latter could improve the economics of TOC further. Maybe more importantly, the financial burden of per vehicle weekly fuel allowance (US\$25 to cover 300-350km range) could be reduced significantly if government vehicles were electric. To facilitate the adoption of EVs, the authors identify several measures including addressing misconceptions about EVs through public awareness campaigns, government's procurement of EVs, investments in the charging infrastructure as well as the development of organisational capacity across the EV supply chain. The development of alternative EV scenarios could be used to understand the impacts on the power grid which is closely linked to the driving patterns as well as the built environment conditions.

The other two papers focus on modelling of transport systems. The effectiveness of decarbonisation of transport via electrification depends on the utilisation of renewable energy for meeting the demands of fleet. Therefore, it is crucial to better understand the future power systems to ensure they can provide sufficient energy for the sector. The study by Victor-Gallardo and Quirós-Tortós (2023) argue that reductions in the cost of photovoltaic generation and battery storage improve the viability of distributed power systems. The authors analyse the implications of transitioning from a centralized to a distributed system to meet Costa Rica's transport electrification objectives of reducing emissions to net-zero by 2050. They developed a methodology to assess the future average price of electricity for two fundamentally different systems applying four different energy model scenarios for Costa Rica. They found that the future unit costs of solar and wind generation with energy storage infrastructure affect electricity prices more than other uncertainties. However, transitioning from centralized to distributed systems has economic implications for different power sector stakeholders, including incumbent energy firms, new distributed generation investors, and consumers.

In Ecuador, transportation accounted for 45% of total energy demand in 2020. Taking into account the vehicle type, number of units, service type and fuel allocation, Chiriboga et al. (2023) calculates useful energy demand of the transport sector in Ecuador under alternative scenarios. Higher efficiency of electric motors yields 12% lower useful energy demand of 21783 GWh in an optimistic scenario compared to baseline scenario by 2050. With current plans of an additional 1010 GWh renewable energy generation (67% of which from geothermal and 24% from wind) to be realised by 2030, it is shown that significant investment in power plants, transmission and distribution lines are needed to meet demand levels in the optimistic scenario.

Future research

The geographic spread and diversity of topics is testament to the complexity of the challenges LMICs are experiencing in decarbonising their transport sector. The studies presented in this special issue

highlight strong interaction and interdependencies between transport and energy systems in terms of both physical assets and the institutional landscape. They highlight the need for the adoption of a whole systems perspective for the evaluation of alternative transport system decarbonisation pathways and their dependency on and implications for energy systems, policy and institutional landscape. A relatively established literature on how transport systems may improve social equity and ‘mobility justice’ (Flipo et al., 2023) mostly focuses on the developed economies. The reported imbalances in the distribution of benefits of large transport infrastructure investments to the detriment of the least advantaged people in LMICs (Benevenuto and Caulfield, 2022), it is imperative for international organisations as well as national research and government institutes to consider the implications of transport decarbonization policies on all segments of the society so that a just transition is achieved.

Based on the studies included in this special issue, we identify three key areas for future research:

1. Data and modelling

Several studies have developed quantitative models to create scenarios and assess their implications for policy. However, lack of comprehensive datasets is a key limitation in many LMICs, noted by (Chiriboga et al., 2023) in their analysis in this special issue. This limits the capacity of researchers to adopt existing modelling frameworks for their country or develop new ones. Consequently, not only the opportunities for transport system decarbonisation may not be assessed fully, taking into account the local context, but also their impacts on the wider economy may be under or overestimated, creating a *doubly blind spot* for the policy. While there are initiatives like the Climate Compatible Growth Programme which aims to create starter kits for national energy and transport models by providing some basic datasets¹, there is a need for more granular and detailed local transport datasets. In particular, there is a need for more research on transport models in LMICs, in particular to better understand the social and economic impacts of transport decarbonization (Dixon et al., 2023). Via a comparative evaluation of ten existing transport models, the authors note the lack of entirely fit-for-purpose transport sector modelling tools for LMICs. Given the urgency of taking actions, they recommend the following:

- Forming partnerships between research institutions and international organizations to produce a suitable customized model
- Aligning efforts across stakeholders to produce a standard open-source model rather than proliferation of proprietary tools
- Sustaining parallel efforts to improve the availability of ‘data starter kits’ compatible with the model requirements
- Scaling up capacity building efforts to empower a cadre of transport sector analysts in LMICs

Advancements made in the fusion of multi-source heterogeneous data (e.g. smart card and bike-sharing trip data) and utilisation of computational methods (among others, Kinra et al., 2020; Yang et al., 2022) may also help with addressing this knowledge gap.

2. Freight transport

While freight transport has already account for more than 40 percent share of global transport emissions with a strong annual growth rate (ITF, 2023), it is often seen as a “blind spot” when it comes to policy action (Council for Transport Decarbonisation in Asia 2022). In their paper, Gupta

¹ <https://climatecompatiblegrowth.com/starter-kits/> (Accessed on 18/1/2024)

and Dhar (2023) highlight the lack of research on freight transport and its future role for decarbonizing transport. Assessing the impact of electrification, the role of rail, optimizing logistics through AI and the potential role of autonomous vehicles are just some examples of where more research could guide future policy making and business decisions.

3. Transport and Energy Nexus

This special issue highlighted the need for a whole systems perspective to the decarbonisation of transport sector. In IEA's NZE scenario, electricity meets 45% of global transport sector demand in 2050 where almost all of the car fleet are made up of EVs (IEA, 2021). As global electricity demand doubles between 2020 and 2050, dual roles EVs can play in terms of meeting mobility demands as well as providing power back to grid via Vehicle-to-Grid (V2G) systems (Mehdizadeh et al., 2024) have been well recognised by the transport scholars. Recent studies present greater integration of transport and energy nexus thinking whereby the investment decisions for the location of charging stations follow traffic flows (Rabl et al., 2024). This close interaction between transport and energy systems is emerging as a strong driver for the development of new business models like supermarkets installing and operating charging stations².

The pace and nature of electrification of transport in LMICs will undoubtedly be determined by global developments in the EV markets. Since the publication of these papers, the EV market conditions in North America have changed significantly. In December 2022, the US Government passed the Inflation Reduction Act to offer rebates to households for vehicles whose final assembly location is North America and meet critical mineral and battery component requirements³. Given the large size of the North American EV market, car manufacturers that don't meet assembly or battery requirements may lose out unless they offer similar levels of cost reductions to be competitive. The European Union is expected to launch a similar investment package. How these global developments may influence the pace and nature of transport electrification in LMICs as well as their location as a manufacturing base for these industries are yet to be seen. Yet, as the second-hand EV market is in its infancy in the developed economies, it may be some time that these vehicles make their way to the LMICs such as Kyrgyzstan. One may expect that faster electrification of passenger cars in the global North may help with the acceleration of EV uptake globally through these second-hand vehicle markets. However, this sets a stark contrast against embedding circular economy principles in EV ecosystem. The reusing, refurbishing and recycling of old EV battery packs in second life applications like stationary energy storage or other gadgets (e.g. e-scooters) has the potential to improve resource efficiency and develop new business models (Chirumalla et al., 2024; Eleftheriadis et al., 2024). In the UK for example, the government has allocated £29 million funding to its Faraday Battery Challenge programme⁴. How these developments may influence the second-hand EV markets and the pace of electrification of transport in LMICs is an area that requires further research. The development of a supply chain that has the technical capability to assess the condition of EV batteries in LMICs or the development of global standards and certification schemes like

² <https://about.sainsburys.co.uk/news/latest-news/2024/12-01-2024-sainsburys-launches-smart-charge-new-ultra-rapid-service> (Accessed on 18/1/2024)

³ <https://www.irs.gov/credits-deductions/credits-for-new-clean-vehicles-purchased-in-2023-or-after> (Accessed on 18/1/2024)

⁴ <https://www.faraday.ac.uk/six-projects-reshaping/> (Accessed on 18/1/2024)

‘battery passports’ (EP, 2023) is essential to mitigate the risk of them becoming a *dumping ground* of inefficient batteries and vehicles (Ciminale et al., 2023).

While it is not known how the interplay of second-hand markets and price competitiveness between the EV manufacturers⁵ may facilitate the affordability and accessibility of EVs in the LMICs, the need for investment in the development of charging infrastructure and the generation, transmission and distribution of power to meet these additional demands is imperative. It may be that those countries that have the capacity in their networks may emerge as the front runners of EV markets. Local governments can play important roles in the development of EV charging infrastructure. While some research highlights how tax and revenue competition between the local authorities may result in overcrowding effect (Tao, 2024), local authorities’ zoning and planning decisions determine where new demands for energy infrastructure may emerge and what scale of network reinforcement is needed. With the advancement of more EVs on the roads, today’s car parks will turn into *energy storage parks* in the future that can provide services to energy balancing and ancillary services markets. This means that transport and land use planners can play more active roles in the management of energy network constraints at local levels⁶. A closer collaboration between transport and land use planners and energy network operators can facilitate avoiding bottlenecks in power transmission and distribution networks and defer the need for reinforcement through the sizing and location of energy storage parks in cities and towns which is relevant for LMICs as well as the global North.

Notwithstanding the importance of interactions and interdependencies between transport and energy sectors, we argue that the intersection of transport and digital technologies has been largely ignored. The mobility-as-a-service (MaaS) concept offers the potential of on-demand mobility by utilising existing transport systems in efficient ways. While the complex web of interactions across private, public and semi-public actors in developed economies pose particular challenges for their development (Alderete-Peralta and Balta-Ozkan, 2024), its potential to support the provision of low carbon mobility in LMICs is yet to be seen given the substantial differences in modal split and high dependence to informal transport in those countries. Given the fast adoption of smart phones in LMICs, future research could look into how policy, regulatory, legal, organisational, financial, operational integration of formal and informal modes, behavioural, cyber security and societal issues interact and influence the development of MaaS in LMICs.

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⁵ <https://sustainabilitymag.com/renewable-energy/how-byd-has-beaten-tesla-and-could-dominate-global-ev-sales> (Accessed on 18/1/2024)

⁶ In the UK, some distribution network operators procure flexibility services where the consumers are incentivised to shift their demands to other off-peak periods in geographically defined areas

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