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Decarbonising road transport in Africa: Strategies for a just and sustainable transition

Significance:

Although Africa's transport sector emissions remain low, the continent's ongoing economic and social development and rapid urbanisation suggest it will witness substantial growth in vehicle usage. This will result in higher transport-related emissions and associated environmental, economic and social impacts. Therefore, it is critical to explore emissions reduction and climate-resilient strategies. This commentary highlights the status, strategies, technologies and cross-cutting issues that are essential in transitioning to a net-zero road transport sector in Africa. It also underlines the role of the enable-avoid-shift-improve-resilience (EASIR) framework in the holistic decarbonisation of transport and the multiple-level perspective in addressing the challenges posed by dominant frameworks and entrenched regimes.

Introduction

Climate change is significantly impacting various aspects of our lives, including health, agriculture, transport and biological diversity. For instance, unpredictable and extreme weather events, such as heat stress and floods, can result in damage to infrastructure, displacement of communities, loss of livelihoods, and increased costs for disaster response and recovery, in addition to adverse effects on agriculture and food security. Much of the climate crisis is caused by human-induced activities, particularly in the transport sector, which, if not addressed, will lead us to an unsustainable path.[1] The transport sector accounts for approximately 23% of global energy-related greenhouse gas (GHG) emissions, with road transport alone responsible for 75% of these emissions, predominantly from passenger vehicles such as cars and buses.[2] Between 1990 and 2022, global transport-related GHG emissions increased at an average annual rate of 1.7%, paralleling the growth rate of industrial emissions, and outpacing all other sectors. Carbon dioxide (CO_2) emissions from transportation reached an estimated 8 Gt in 2022 – a 3% rise from the previous year.[3] Emissions from transport are caused by the sector's heavy reliance on fossil fuels, which supply 90% of its energy needs.[2]

Africa contributes a modest 4% to global transport emissions, given its relatively small market and low motorisation rate (Figure 1).[4] On average, CO_2 emissions per person per year in Africa stand at just 0.8 t, which is significantly below the global average of 4.8 t. Despite this, Africa's ongoing economic and social development, alongside rapid urbanisation, suggest that the continent will witness substantial growth in vehicle usage. This growth is expected to result in a notable increase in transport-related emissions and the associated negative externalities, such as health impacts, in the coming years. Africa's transport emissions are already rising at an annual rate of 7%, a sharp contrast to the slower growth rates seen in other regions.[5] For example, the USA experienced less than a 1% annual increase in transportation emissions from 1990 to 2017, while the United Kingdom saw an increase of just 0.12% during the same period.[6]

The health and economic implications of current transport sector emissions are also substantial. For instance, globally, pollution from transport is linked to the annual loss of approximately 7.8 million lives and health-related costs estimated at USD1 trillion.[7] Even though Africa has the lowest motorisation rate in the world, its average (particulate matter) $PM_{2.5}$ emissions of 97.4 μg/m³ are disproportionally high relative to the world's average of 82.3 μg/m³.[6] These trends make it imperative to transition to a low-emission and net-zero transport system.

Africa faces unique challenges and opportunities within its transportation sector, given its diverse geography, rapidly growing urban populations, varying levels of infrastructure development, heavy reliance on imported used vehicles, and the use of low-quality fuels. Here we draw on a report[8] by the Network of African Science Academies (NASAC) and the InterAcademy Partnership (IAP) on decarbonisation of transport in Africa. While the broader transport sector, including freight, contributes significantly to transport sector emissions, the report – and this analysis – deliberately concentrates on passenger transport because of its immediate and wide-ranging impact on urban development, public health and social equity. We explore the state of decarbonisation in Africa's road transport systems, emerging strategies and technologies shaping this transition, and the critical policy and governance issues involved. We also highlight the importance of integrating considerations of justice and equity into transition pathways and argue that the multi-level perspective framework offers valuable insights for navigating the complex systemic changes required to achieve a sustainable and inclusive transport future for Africa.

Decarbonisation of road transport in Africa

Decarbonisation refers to the process of reducing carbon emissions and transitioning to a zero-carbon or carbon-neutral economy.[9] Within the transport sector, it involves reducing carbon emissions associated with transportation activities by shifting from traditional internal combustion engine vehicles to cleaner alternatives such as electric vehicles; improving infrastructure to support sustainable modes of transportation, such as public transit, shared mobility, cycling and walking; and adopting compact and mixed-used development to reduce the socio-economic and ecological impacts of travel.[10] While most efforts towards decarbonisation of transport focus on electrification of transport and the potential of electric vehicles, decarbonisation is not synonymous with electrification. Electrification contributes to decarbonisation efforts by replacing carbon-intensive energy sources with cleaner electric energy sources. However, decarbonisation encompasses a broader set of strategies aimed at reducing or eliminating overall carbon emissions within sectors of an economy. Therefore, while the adoption of electric vehicles in the transport

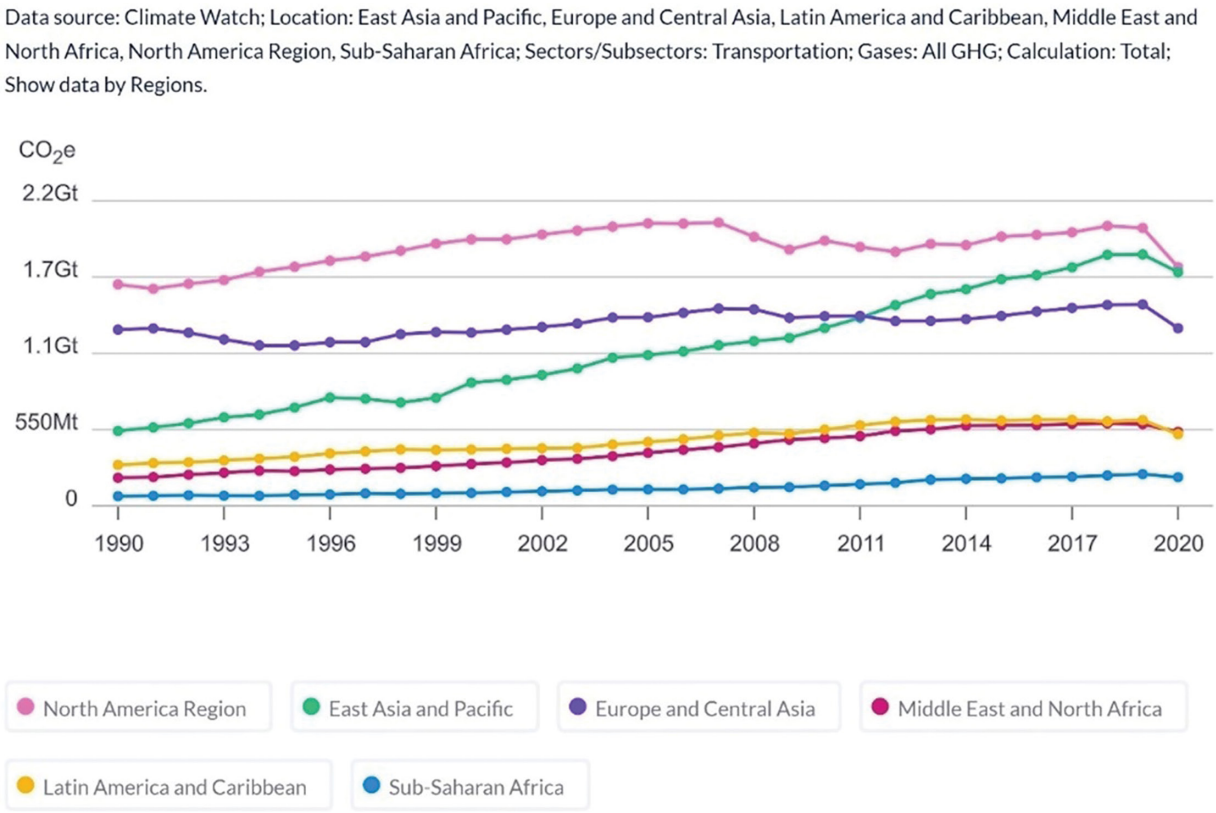

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Figure 1: Global transport emissions by region (1990–2020).

sector can help reduce carbon dioxide emissions, it does not fully address other challenges in Africa's transport sector, such as congestion, pollution, road safety, and the extensive land needed to support transport infrastructure. Thus, electrifying transport should be viewed as one part of a larger, more comprehensive strategy for creating sustainable transport systems in Africa, such as the enable-avoid-shift-improve-resilience (EASIR) approach discussed below.

Africa's evolving transport infrastructure, abundant renewable energy resources, shorter daily travel distances, and youthful workforce present an opportunity to implement advanced, low-emission technologies such as electric vehicles without the extensive modifications needed in more established transport systems. African countries have thus taken initiatives to decarbonise road transport, aligning their mitigation and adaptation targets and efforts with the nationally determined contributions under the Paris Agreement. Nationally determined contributions are commitments made by each country outlining their action plans for reducing national emissions and adapting to the impacts of climate change. These contributions are essential in achieving the global goal of limiting temperature rise to well below 2 °C, ideally aiming for 1.5 °C above pre-industrial levels, as outlined in the Paris Agreement.[11] For example, South Africa's nationally determined contribution includes a commitment to peak emissions between 2020 and 2025, plateau for a decade, and then decline in absolute terms.[12] As part of this commitment, the country is investing heavily in cleaner public transportation options, such as the electrification of its vehicle fleet and expansion of its bus rapid transit systems. Similarly, Ethiopia's nationally determined contribution highlights a target to reduce GHG emissions by 64% from the business-as-usual scenario by 2030.[13] This will be achieved through investments in electric railways, which are expected to reduce the reliance on diesel-powered trucks for freight and passenger transport. Furthermore, Morocco and Egypt are integrating renewable energy into their transport systems as part of their nationally determined contributions. Morocco's high-speed trains are already being powered by solar energy.[14]

African countries are further accelerating their transition to net-zero transport by adopting electric vehicles. Although the stage, scope and scale of electric mobility (e-mobility) development differ significantly among African countries, some nations are more advanced in their e-mobility transition. These include Côte d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Mauritius, Morocco, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Tunisia, Uganda, Zambia and Zimbabwe.[15] These countries have initiated policies and regulatory instruments or are executing pilot initiatives such as assembling and manufacturing electric vehicles, retrofitting internal combustion engine vehicles to electric propulsion, and setting up charging infrastructure. Among these countries, South Africa stands out for its comprehensive electric vehicle policy framework, which promotes both the production and use of electric vehicles. Additionally, South Africa is investing in research and development to enhance local expertise and capacity in the electric vehicle sector, including advanced research on retrofitting internal combustion engine vehicles to electric vehicles. Notably, researchers at Stellenbosch University are converting (retrofitting) Africa's popular para-transit vehicles, known as minibus taxis in South Africa, from diesel power to electric propulsion.[16] Retrofitting might provide a cost-effective and sustainable alternative for low-income owners of minibus taxis to transition to electric vehicles (Figure 2). Retrofitting also helps extend the life cycle of existing vehicles while significantly reducing their environmental impact, in line with the circular economy principles.[17] These scientists are not only involved in the mechanics of retrofitting, but are also calculating the energy needs, usage, vehicle charging behaviour and the environmental impact of retrofitted vehicles, resulting in a comprehensive understanding of their performance and sustainability to inform policy development.[16]

In addition to electrification, non-motorised transport is increasingly recognised globally for its benefits in reducing traffic congestion, lowering pollution levels, and promoting healthier lifestyles. In this vein, many African countries have adopted non-motorised transport policies. For instance, cities like Nairobi (Kenya) and Cape Town (South Africa) are implementing extensive bicycle lane networks and pedestrian pathways

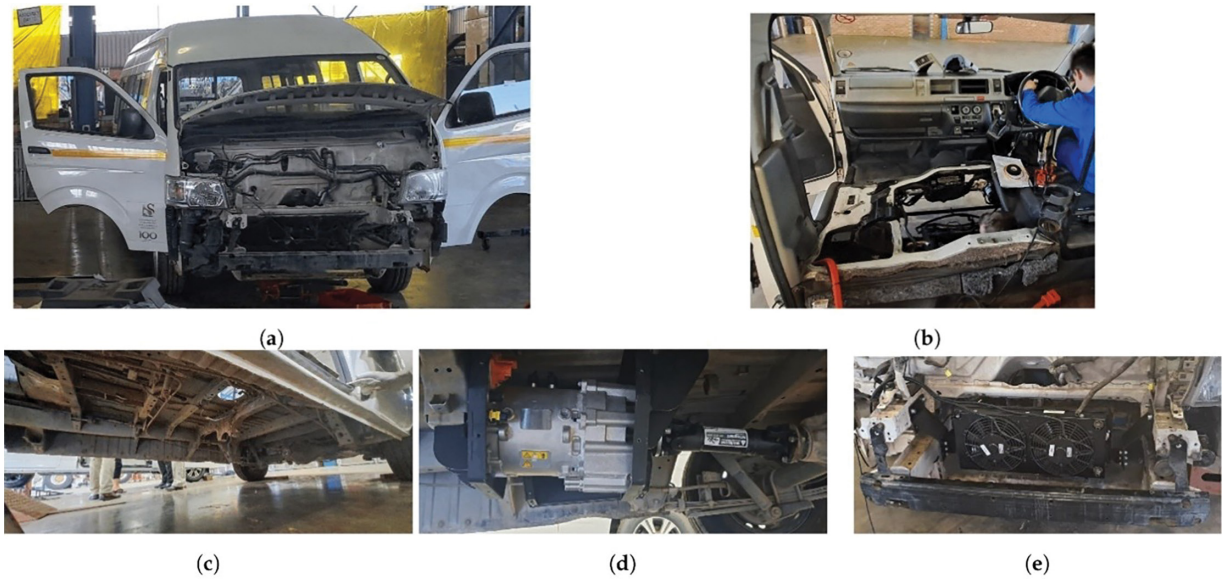

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Figure 2: Vehicle with combustion-related components removed. (a) Front view of the stripped vehicle. (b) Empty engine compartment. (c) Bottom view of stripped vehicle before electric motor and prop-shaft installation. (d) Electric motor with prop shaft (protective cover not shown). (e) Radiator for the electric motor coolant.

to encourage cycling and walking. Many countries are also implementing dense and mixed-use developments that enable the co-location of basic services such as a combination of retail, offices and residential areas, with the goal of reducing travel demand.

The enable-avoid-shift-improve-resilience framework

The enable-avoid-shift-improve (EASI) framework is broadly recognised for reducing emissions in the transport sector.[18] Established initially as the avoid-shift-improve (ASI) approach, the framework focuses on (1) strengthening the institutional and governance frameworks for policy development (enable), (2) reducing the need for motorised trips through smart land use and planning (avoid), (3) promoting the use of efficient modes of transport (shift) and (4) improving the efficiency and environmental performance of transport systems through enhanced vehicle, fuel and network operations and management technologies (improve). The NASAC-IAP study complements this framework by introducing a fifth pillar – *resilience* – transforming the EASI into the EASIR (enable-avoid-shift-improve-resilience) framework. The addition of resilience builds on a 2022 World Bank report which highlighted the resilience of the widely used transport modes in Africa, especially two-wheelers (motorbikes) and three-wheelers (tricycles or *tuk-tuks*), and their ability to overcome challenges, such as inadequate infrastructure, where they operate. Two- and three-wheelers are flexible and better at navigating complex rural terrain and overcrowded urban streets, and in moving people and goods from door to door with greater fuel efficiency. In addition to being fast, mobile phone penetration has made them easily accessible on-demand, especially in underserved rural communities.

The resilience pillar thus underlines the need to create and enhance the durability and adaptive capacity of transport systems, including infrastructure to withstand extreme-climate events such as heat stress and floods, ensuring their long-term sustainability and functionality. This is particularly crucial considering the increasing vulnerability of road transport infrastructure in African countries to climate-related disasters. For instance, floods, which often intensify with heavy rainfall and poor drainage systems, have led to widespread damage to roads and bridges in African countries, disrupting essential transportation networks, not to mention the loss of lives and economic activities.[19] Similarly, heat stress poses a significant threat to African roads as high temperatures can cause asphalt to soften and deform, leading to the formation of ruts and potholes that pose risks to road users.[20] These issues highlight the urgent need for climate-resilient transport infrastructure in Africa.

Just transition and equity considerations

Transitions to a net-zero economy require comprehensive policy frameworks that reflect the diverse socio-economic, cultural and environmental contexts of affected communities. It is essential to not only identify who benefits from decarbonisation policies, but also to understand who bears the costs – particularly in terms of affordability, access, employment and spatial mobility. In line with just transition principles, the shift must be equitable, inclusive and people-centred. Policies should therefore be designed to address the specific impacts of decarbonisation on different societal segments, especially vulnerable populations, including women, persons with disabilities, older persons and rural residents.[21]

In many African countries, informal transport systems such minibuses and motorcycles provide crucial mobility services, particularly for low-income populations. Decarbonisation strategies that overlook these actors risk marginalising them or pushing them out of work. A just transition approach would consider tailored support for informal sector workers, such as targeted incentives to acquire electric vehicles and training programmes to equip internal combustion engine vehicle mechanics with the skills needed to service electric vehicles. More generally, policymakers should take a holistic approach to transport decarbonisation by prioritising clean and affordable public transport, rather than primarily focusing on incentivising private vehicle ownership.

As most transport-related emissions are tied to energy usage, equity considerations also intersect with environmental justice. Africa is a major supplier of critical minerals such as cobalt and lithium, which are essential for electric vehicle batteries and the energy transition more broadly. Yet extraction often takes place under exploitative conditions, with little local benefit. For example, cobalt mining in the Democratic Republic of Congo has been linked to labour and human rights violations, including the employment of children[22], while lithium extraction can deplete water sources and displace rural communities. A just transition approach would therefore ensure ethical supply chains, benefit-sharing mechanisms and stronger environmental safeguards. These measures are necessary to avoid reproducing the spatial and social inequalities that have long shaped African transport systems.

The challenge of entrenched regimes and dominant frameworks

Perhaps the biggest challenge to decarbonisation of transport in Africa, as is elsewhere, is addressing entrenched regimes and dominant frameworks. The multilevel perspective framework, as discussed by Frank Geels[23], provides a structured approach to understanding the challenges facing transitions to sustainability by examining socio-technical transitions across three key levels: niche innovations (where radical innovations emerge), the socio-technical regime (representing established practices and rules) and the socio-technical landscape (the broader contextual factors) (Figure 3).

Socio-technical landscape

The socio-technical landscape encompasses macro-level trends and external pressures that influence regimes and niches.[23] In the context of Africa's transport decarbonisation, this landscape includes global environmental goals, international economic conditions and societal values towards sustainability. In this case, the Paris Agreement and the Sustainable Development Goals (SDGs) represent the most significant external factors that have placed pressure on African nations to transition to cleaner energy sources. However, in emerging and least developed economies such as those in Africa, these pressures need to be counterbalanced by local economic challenges and developmental priorities that sometimes make it difficult to prioritise decarbonisation over immediate development needs.

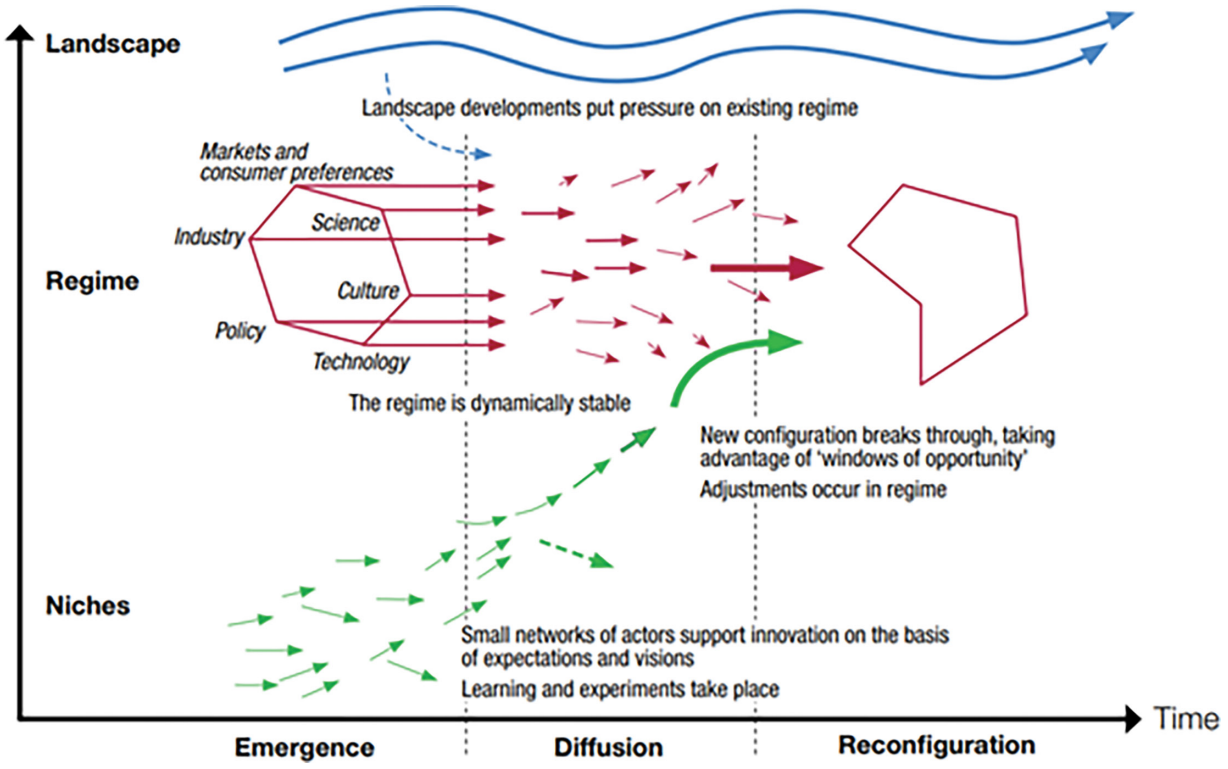
Socio-technical regime

The socio-technical regime consists of the dominant practices, rules and shared beliefs that stabilise existing systems.[25] Within this level, entrenched regimes and dominant frameworks pose the greatest threats to the decarbonisation of transport in Africa. Entrenched regimes include the political and economic structures that are deeply invested in the status quo. In this case, these would include existing political structures and powerful economic interests tied to the fossil fuel industry. These regimes benefit from the current fossil-fuel-based transport systems and can create significant resistance to change, for example, by lobbying against clean energy policies and investments that would promote decarbonisation. Additionally, the established transport infrastructure, including roads, fuelling stations and maintenance facilities, is built around fossil fuel vehicles. Shifting to electric or other clean energy vehicles requires substantial investment in new infrastructure, which entrenched regimes may resist due to high costs and the potential disruption to existing economic activities.[26]

On the other hand, dominant frameworks are not limited to fossil fuel dependency but also include broader paradigms that shape transport planning and urban development. One such paradigm is the continued prioritisation of car-centric infrastructure, which promotes private vehicle ownership over collective or non-motorised mobility. Urban sprawl, inadequate investment in mass transit, and the marginalisation of walking and cycling infrastructure are all manifestations of this dominant mobility model. This results in fragmented cities, increased travel demand and spatial exclusion of lower-income populations. These frameworks are often embedded in institutional practices, engineering norms and planning cultures that sometimes resist alternative models such as compact, transit-oriented, and people-friendly urban design. As such, challenging dominant paradigms must involve not only energy and technological shifts, but also a reimagining of what constitutes desirable and equitable mobility in African cities and regions. This would also involve thinking about new economic frameworks (niche innovations) that can account for environmental externalities and long-term benefits.[25]

Niche innovations

Innovations and new technologies that can drive decarbonisation emerge at the niche level. However, these niches struggle to break through the barriers posed by entrenched regimes and dominant frameworks. Examples in this case include the challenges facing the adoption of clean transport technologies, such as the lack of adequate funding, due to entrenched regimes controlling most of these resources. Without significant investment, these innovations cannot scale up to challenge the dominant fossil-fuel-based transport systems. Moreover, policy frameworks tend to favour established regimes, creating regulatory hurdles for niche innovations. For example, subsidies and incentives are often skewed towards fossil fuels, while clean energy solutions face



Source: International Science Council's[24] adaptation of Geels[25] framework (reproduced with permission).

Figure 3: The multi-level perspective framework for complex sustainability transitions.

regulatory uncertainties and lack of support.[27] The multilevel perspective framework thus underlines the importance of destabilising existing regimes through pressures from the landscape level and radical innovations incubated in protected niches.[25] Within decarbonisation, this approach underscores the need for a holistic strategy that addresses not only the focus on technological advancements such as electric vehicles but also policy adjustments, institutional transformations, market preferences and stakeholder engagement, to facilitate sustainable transitions.

Conclusion

Decarbonisation of road transport is critical for mitigating climate change, adapting to its impacts and ensuring sustainable development. While Africa currently contributes a modest share of global road transport sector emissions, the continent's rapid urbanisation and economic growth forecast a substantial increase in vehicle usage and related emissions. Reducing transport sector emissions requires a holistic approach – as elaborated in the EASIR framework – and a deeper understanding of the dominant regimes and frameworks that continue to favour fossil fuel dependency.

Consequently, even though most research on the decarbonisation of transport, including in this commentary, has focused on supply-side interventions such as electrification, vehicle efficiency, modal shifts and infrastructure upgrades, deep decarbonisation requires addressing both supply- and demand-side dynamics. It is equally important to recognise that the fundamental objective of transport systems is to provide people and industries with access to services, goods and opportunities, thereby enabling the flow of resources essential to economic and social life. A just and effective decarbonisation of transport in Africa must therefore move beyond technical fixes to also incorporate demand-side analyses that explore how mobility needs are shaped by livelihoods, spatial planning and production systems. Demand-oriented strategies are essential to ensure that decarbonisation does not merely reproduce existing mobility patterns – such as replacing internal combustion engine vehicles with electric vehicles – thereby reinforcing path dependencies and risking maladaptation. Instead, decarbonisation efforts should focus on transforming these patterns in ways that align with broader development goals of promoting more equitable, efficient and development-oriented mobility systems. While these dimensions were beyond the scope of the NASAC-IAP report, and this commentary, they represent a vital agenda for future research and policymaking.

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Declarations

We write in our own capacity, and our views do not necessarily represent the views of our institutions or member organisations. We have no competing interests to declare. We have no AI or LLM use to declare. All authors read and approved the final manuscript.

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