The Role of Clean Transportation in Advancing Energy Equity and Access

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AYODEJI
STEPHEN


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Energy equity ensures that all individuals have access to affordable, safe, and reliable energy while fairly sharing the benefits and risks of emerging technologies. It acknowledges the historical marginalisation of disadvantaged communities, who often face inadequate investment in clean energy infrastructure, pollution and limited access to energy-efficient housing and transportation. A system that enjoys energy equity extends economic, health, and social benefits to everyone, regardless of race, socioeconomic status, or physical ability. Currently, access to clean transportation systems is exceptionally unequal, resulting in a substantial portion of the population lacking affordable access to public transit or vehicles essential for job opportunities and obtaining necessary goods and services. Low-income groups bear the brunt of this inequality, spending most of their time and money on transportation, exacerbating their financial strain. These communities also frequently reside in areas that suffer disproportionately from health issues and other adverse effects, such as noise pollution and a higher incidence of fatal traffic accidents linked to transportation congestion and emissions. Access to affordable and reliable transportation remains a luxury rather than a norm. This lack of access isolates these communities, hindering their ability to thrive economically, socially, and environmentally.

Transportation equality and access have three categories, each addressing distinct aspects of fairness and access within the transportation system. Determining and considering these categories is essential to effectively tackling inequality and expanding clean transportation access. They provide a framework for understanding and addressing the diverse needs of individuals and groups. They are, horizontal equity and vertical equity. Horizontal equity emphasises fairness in sharing transportation resources and impacts among individuals and groups with similar abilities and needs. This approach calls for uniform treatment, ensuring that policies do not unduly favour one group over another. In this framework, fees and taxes should align with the benefits individuals receive unless there is a clear justification for subsidies or special adjustments. Vertical Equity (Income and Social Class) highlights the need to address disparities between groups with varying income levels and social standings. Policies are equitable when they actively support economically and socially disadvantaged populations, helping to counterbalance broader inequalities. Initiatives like affordable transportation options, discounted fares for low-income individuals, and

protections against excessive costs or risks for vulnerable groups embody this principle. Progressive policies that uplift disadvantaged communities are essential for fostering inclusion and justice in the transportation system. Vertical Equity (Mobility Needs and Abilities) aspect focuses on meeting the transportation needs of individuals with different mobility abilities and requirements.

It underscores the importance of designing systems and infrastructure that accommodate everyone, including those with disabilities or other challenges. Universal design principles, which create accessible and inclusive transportation options, are central to ensuring mobility-impaired individuals can travel with dignity and ease. To combat inequality and improve access to clean transportation, it is vital to consider and respond to all three dimensions of transportation equity. Horizontal equity assessments are typically more accurate when based on per capita comparisons rather than per-mile metrics while also incorporating adjustments to address user needs and abilities in line with vertical equity goals. For instance, when comparing two geographic regions or demographic groups with similar income levels and abilities, fairness would dictate that both receive equal annual per capita allocations of public resources. However, if one group or region faces economic, social, or physical disadvantages, additional resources should be allocated to compensate for those disparities. Likewise, suppose a specific group or type of travel activity generates higher costs. In that case, it should be subject to proportionally higher user fees or taxes to balance per capita subsidies unless there is a justified reason for providing extra subsidies to that group based on vertical equity considerations.

Transportation is often seen merely as a means to get from one point to another, but its impact extends beyond physical mobility. Historically, discussions on energy equity have centred on affordability and access to energy. However, energy equity encompasses much more, including environmental sustainability, accessibility, and social justice. Clean transportation broadens this perspective by integrating mobility into the energy equity equation.

Clean transportation refers to various transportation methods and technologies that produce minimal or zero emissions of pollutants and greenhouse gases. It focuses on developing alternative fuels, innovative technologies, and improved public transportation services. The aim is to lower emissions, make transportation more energy-efficient, and ensure systems are easier to use and accessible to everyone. This concept encompasses various modes of transport, including electric vehicles (EVs), hydrogen fuel cell vehicles, and public transit systems powered by renewable energy sources such as solar, wind, and hydroelectric power. Key components of clean transportation include:

a. **Electric Vehicles (EVs):** These vehicles are powered by electric motors and batteries, producing no tailpipe emissions. They can be charged using electricity generated from renewable sources. Electric vehicles (EVs) are powered by electric motors and batteries. They are charged using electricity, which can be generated from renewable sources like solar or wind power. The key components of EVs include a large traction battery pack, an electric motor, a power electronics controller, a charging system, and a regenerative braking system. These elements work together to provide efficient and sustainable transportation.

b. **Hydrogen Fuel Cell Vehicles:** These vehicles use hydrogen gas to generate electricity through a chemical reaction in a fuel cell. Steam Methane Reforming (SMR) is the most common method for producing hydrogen, where methane (natural gas) reacts with steam under high pressure to produce hydrogen, carbon monoxide, and a small amount of carbon dioxide. Electrolysis, another method of producing green hydrogen, uses electricity to split water into hydrogen and oxygen. When the electricity comes from renewable sources like wind or solar power, the hydrogen produced is considered green hydrogen. Both methods have advantages and challenges, but they provide diverse options for sustainable hydrogen production. Hydrogen fuel cell vehicles (HFCVs) are powered by hydrogen gas, which is converted into electricity through a chemical reaction in a fuel cell. This process produces only water vapour as a byproduct, making HFCVs an environmentally friendly alternative to traditional internal combustion engine vehicles. The key components of HFCVs include a hydrogen fuel tank, a fuel cell stack, an electric motor, and a power electronics controller. Hydrogen gas is stored in the fuel tank and supplied to the fuel cell stack, where it reacts with oxygen to generate electricity. This electricity powers the electric motor, which drives the vehicle's wheels. The power electronics controller manages the flow of electricity and ensures efficient operation. Using hydrogen as a clean energy source, HFCVs contribute to reduced emissions and a lower carbon footprint.

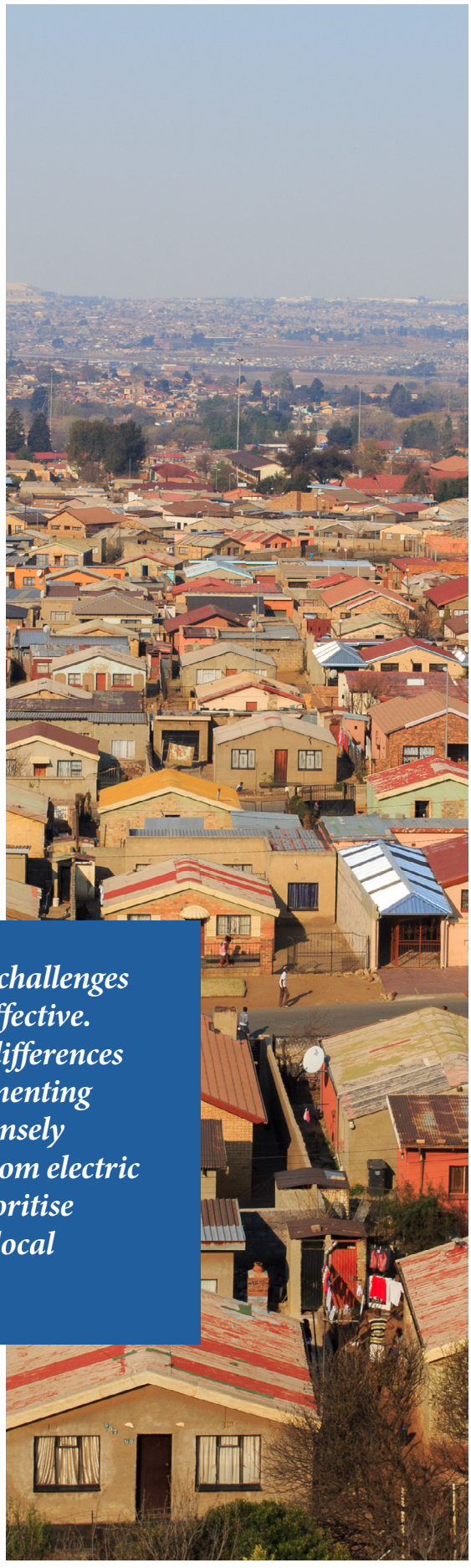
c. **Public Transit Systems:** Clean transportation also involves the development and expansion of public transit systems, such as buses, trains, and trams, powered by renewable energy sources. These systems can reduce the

number of private vehicles on the road, which can, in turn, result in lower overall emissions.

d. **Active Transportation:** This includes non-motorized modes of transport, such as walking and cycling, which produce no emissions and promote healthier lifestyles. Active transportation refers to modes of travel that rely on human physical activity, such as walking, cycling, and using non-motorized vehicles like scooters and skateboards. This form of transportation is environmentally friendly and promotes health and well-being by encouraging physical exercise. Active transportation infrastructure includes sidewalks, bike lanes, pedestrian crossings, and trails, which are designed to ensure safety and accessibility for all users. By reducing reliance on motor vehicles, active transportation helps decrease traffic congestion, lower greenhouse gas emissions, and improve air quality. Additionally, it fosters a sense of community and enhances the livability of urban areas by creating more walkable and bike-friendly environments. Investing in active transportation infrastructure is key to sustainable urban planning and contributes to creating healthier, more equitable, and resilient cities.

e. **Alternative Fuels:** Clean transportation also explores alternative fuels, such as biofuels and synthetic fuels, which can be produced from renewable resources and have lower emissions than conventional fossil fuels. Alternative fuels are energy sources used to power vehicles that are not derived from traditional fossil fuels like gasoline or diesel. These fuels offer a more sustainable and environmentally friendly transportation option, helping reduce greenhouse gas emissions and dependence on finite resources. Standard alternative fuels include biofuels, produced from organic materials such as plants and agricultural waste, and natural gas, which can be used in compressed (CNG) or liquefied (LNG) forms. Propane, a byproduct of natural gas processing and petroleum refining, is another clean-burning alternative that produces fewer emissions than gasoline and diesel. Researchers and policymakers are continually exploring innovative solutions and technologies to advance clean transportation and achieve long-term environmental and energy goals.

Furthermore, clean transportation does more than reduce greenhouse gas emissions; it empowers communities by connecting them to opportunities previously out of reach. It is intricately tied to energy justice, especially in developing communities with unequal access to energy and transportation. Clean transportation systems can address the dual challenges of mobility and energy justice. It leverages renewable energy sources and prioritises accessibility. For instance, deploying electric buses in urban centres can greatly reduce greenhouse gas emissions while ensuring that even the most underserved communities can access efficient transportation. Moreover, these solutions can be tailored to local contexts, making them sustainable and impactful in the long term. The link between transportation and energy equity is very important yet often overlooked. Without equitable mobility solutions, efforts to improve education, healthcare, and economic opportunities in developing regions remain incomplete.



Developing regions often face unique challenges that make standardised solutions ineffective. Geographic, cultural, and economic differences require a tailored approach to implementing clean transportation. For instance, densely populated urban areas may benefit from electric bus networks, while rural regions prioritise solar-powered mini-grids to support local mobility.

Mobility Solutions Grounded in Community Needs

Understanding the unique needs and challenges of a community is the foundation of any effective mobility solution. This involves engaging with community members, conducting surveys, and analysing data to identify issues such as accessibility, affordability, safety, and convenience. One of the primary goals of community-centered mobility solutions is to ensure inclusivity and accessibility for all individuals, regardless of their physical abilities, age, or socioeconomic status. This can be achieved by implementing universal design principles in transportation infrastructure and vehicles to accommodate people with disabilities, the elderly, and children. Additionally, affordable transportation options, such as subsidised public transit fares, ensure that low-income individuals can access essential services and opportunities. Developing safe and well-maintained infrastructure, including pedestrian pathways, bike lanes, and well-lit bus stops, enhances the safety and comfort of all users.

A study by the Wellbeing Services County, LAB University of Applied Sciences and LUT University revealed the impact of sustainable mobility in Lahti, Finland. The study entailed a set of pilots implemented at a workplace in Lahti, offering various sustainable commuting options. These included employer-subsidized commuter tickets, employer-provided bicycle benefits for commuting, and shared electric city bikes and scooters for travel during the workday. The study collected data through short surveys before and after the pilots and thematic interviews during implementation. Results showed

that the pilots were successful in introducing more sustainable ways of mobility. The study highlighted the importance of sustainable mobility in reducing CO2 emissions and promoting physical activity and health among the working-age population.

While global frameworks and technologies are vital, their effectiveness depends on adapting them to local contexts. For example, a clean transportation solution suitable for densely populated urban centres may not be effective in remote, rural areas. Hyper-localized applications, such as solar-powered tuk-tuks in Southeast Asia or electric water taxis in coastal African regions, demonstrate how localised adaptations of global technologies can meet specific community needs.

One central pillar of sustainable and equitable clean transportation systems is community involvement. Effective mobility solutions require active community engagement and participation. This can be facilitated through public consultations and workshops to gather input from community members and stakeholders on transportation projects and policies. Establishing community advisory boards provides ongoing feedback and guidance on mobility initiatives. Participatory planning methods, such as town hall meetings, design workshops, and community surveys, can provide insights and encourage a sense of ownership among stakeholders. For instance, community-driven bike-sharing programs in East Africa have successfully improved mobility by incorporating local input into the design and implementation phases.

Sustainability is key in developing mobility solutions that benefit the community and the environment. Investing in green public transit options, such as electric buses and trains, reduces greenhouse gas emissions and improves air quality. Promoting active transportation modes, such as walking and cycling, by creating safe and convenient infrastructure and programs encourages healthier lifestyles. Encouraging shared mobility services, such as car-sharing and bike-sharing, reduces the number of private vehicles on the road and decreases traffic congestion.

Technology and innovation are essential in enhancing mobility solutions and addressing community needs. Implementing innovative transportation systems that use real-time data and analytics optimises traffic flow, reduces congestion, and improves transit services. Developing user-friendly mobile apps that provide real-time information on transit schedules, routes, and availability makes it easier for community members to plan their journeys. To ensure the effectiveness of mobility solutions, it is essential to measure and evaluate their impact on the community.

Establishing performance metrics assesses the success of mobility initiatives in terms of accessibility, affordability, safety, and environmental impact. Continuously gathering feedback from community members identifies areas for improvement and makes necessary adjustments. Providing regular reports on the progress and outcomes of mobility projects maintains transparency and accountability. By grounding mobility solutions in community needs, we can create transportation systems that are inclusive, sustainable, and responsive to each community's unique challenges and opportunities.

The Ripple Effects of Clean Transportation Designed to Enhance Energy Equity and Access

1. **Energy Poverty Reduction:** Energy poverty, characterised by the lack of access to affordable and reliable energy services, is a significant barrier to economic development and quality of life. Clean transportation solutions, such as electric vehicles (EVs) and public transit systems powered by renewable energy, can alleviate energy poverty by providing cost-effective and sustainable mobility options. For instance, electric buses and trains reduce the dependence on expensive and polluting fossil fuels, making transportation more affordable for low-income communities.

2. **Improved Accessibility with Renewable Energy-Powered Transit:** Clean transportation systems are designed to be inclusive and accessible to all segments of society. Public transit networks powered by renewable energy, such as solar or wind, can be expanded to reach underserved and remote areas, ensuring everyone can access essential services like education, healthcare, and employment. Developing bike-sharing programs and pedestrian-friendly infrastructure also promotes active transportation, reducing the need for private vehicles and enhancing mobility for all.

3. **Economic Opportunities Generated via Clean Transportation Initiatives:** The transition to clean transportation creates new economic opportunities, particularly in the renewable energy and green technology sectors. The manufacturing, installation, and maintenance of clean transportation infrastructure generate jobs and stimulate local economies. Moreover, community-based initiatives, such as grassroots transport cooperatives and off-grid transport solutions, empower local stakeholders and foster economic resilience. These initiatives provide affordable and sustainable mobility options and create income-generating opportunities for marginalised communities.

4. **Reducing Environmental Inequities:** Environmental inequities, often called environmental justice issues, arise when disadvantaged communities bear disproportionate pollution and ecological degradation burdens. Clean transportation addresses these inequities by reducing air and noise pollution prevalent in densely populated urban areas. The adoption of electric vehicles and the expansion of green public transit systems contribute to cleaner air and healthier living conditions, particularly for vulnerable populations most affected by pollution.

5. **Energy Independence Achieved with Locally Sourced Renewables:** Clean transportation contributes to energy independence by reducing reliance on imported fossil fuels and promoting locally sourced renewable energy. This shift enhances national energy security and ensures that energy resources are distributed more equitably. Countries can harness their renewable energy potential by investing in clean transportation infrastructure and creating a more resilient and self-sufficient energy system.

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Nextier

info@thenextier.com
www.thenextier.com
5 Kikuyu close, off Nairobi Street,
Wuse 2, Abuja, Nigeria