Urban Air Quality and Energy Transitions in the Niger Delta: Integrating Cleaner Fuels into Regional Planning Frameworks

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Abstract
This research explores the connections that urban air quality in the Niger Delta has got many energy transitions. It also pays attention to the adoption of cleaner fuels into regional planning. More specifically, it evaluates how the adoption of low-emission energy technologies in the Niger Delta's urban centers is shaped by policy, governance arrangements, and energy planning practices. According to the primary data collected from the interviews of the stakeholder, field visits to key urban area with most advanced systems of solid waste management and secondary data collected from the government reports, legislation and refereed journal literature the study followed a Mixed Method Approach The effectiveness of cleaner fuel rollout and regulatory compliance is assessed through spatial mapping, policy analysis, and thematic content analysis as analytical techniques. The main findings revealed that fossil fuel dependence, poor energy regulation enforcement and a lack of integration of urban planning are behind air pollution hotspots. Renewable and decentralized energy solutions, notably clean cooking and mini-grid solar systems, have substantial potential to improve air quality and enhance energy equity. The research results reveal that coordinated policy frameworks, improved governance and inclusion in planning is key for effective energy transitions in the Niger Delta. Recommendations call for reforms to the regulation of refinery emissions, promotion of renewable energy and spatial planning for energy siting. In the Niger Delta context, we can see how energy, policy, and air quality can fit together, thus adding to knowledge. This knowledge adds to the theory and practice of sustainable urban energy transitions.

Keywords: Energy Transition**;** Cleaner Fuels**;** Urban Air Quality**;** Niger Delta**;** Energy Policy and Governance

Introduction

The Niger Delta region of Nigeria is a national energy-producing area that also suffers from severe environmental damage, especially in terms of urban air
pollution. Urbanization that has occurred at a very quick pace and over the years started burning fossil fuels has led to elevated levels of particulate matter, volatile organic compounds, and greenhouse gases in cities (Bello & Nwaeke, 2023; Kaaka, 2025). Although the region is energy-rich, the allocation and use of energy are inequitable. As a result, many urban households continue to cook, heat, and light with biomass and fossil fuel sources that are inefficient (Adamu et al., 2023; Abdullahi et al., 2022). The simultaneous challenge of air pollution and unsustainable energy threatens public health, economic productivity and the environment.
The transition to renewable and cleaner fuel technologies is seen as a key way to mitigate these effects. The weak policy enforcement, fragmented governance arrangements and low institutional capacity have limited the integration of cleaner fuels into urban planning frameworks (Anya & Nzeadibe, 2021; Kaaka & Nwankwoala, 2025). The existing literature

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shows that decentralized renewable energy solutions such as solar mini-grids, clean cooking offers are useful. Overall, these can improve energy access and air quality (Iponri Market Solar Cookstove Showcase, 2024; NSIA et al., 2025). Notably, there is a limited number of systematic studies that have linked energy transitions, governance, and urban air quality in the context of Niger Delta.

This study addresses this gap by investigating the pathways through which cleaner fuels can be effectively integrated into regional planning frameworks to improve urban air quality. The objectives of the study are:

To assess the relationship between energy transition initiatives and urban air quality in the Niger Delta.

To evaluate policy and governance mechanisms for integrating cleaner fuels into regional urban planning frameworks.

By combining energy, policy, and governance perspectives, this study aims to provide actionable insights for sustainable urban energy transitions in Nigeria's Niger Delta.

Conceptual and Theoretical Framework

Energy Transition

Energy transition is the process of changing from a fossil fuel-based energy system to a low-carbon, renewable and cleaner energy system. The transformation of energy systems refers to the technological, policy and behavioural changes that reduce greenhouse gas emissions and enable and sustain access to energy (Elum & Momodu, 2017; Nitte & Salahudeen, 2023). In the Niger Delta, energy transition entails the use of decentralized renewable energy mini-grid solar and clean cooking technologies, as well as the adoption of low-emission refinery solutions to tackle urban air pollution and promote energy justice (Kaaka & Nwankwoala, 2025). The progress of energy transition is dependent on certain policy instruments, governance frameworks, and capacity of local institutions to implement and monitor low carbon initiatives (Anya & Nzeadibe, 2021).

Urban Air Quality

The concentration and distribution of pollutants in urban area where electricity generation, industrial activity and transport are common activities (Akinyemi, Ogundipe, & Adeyemi, 2014). According to analysis of Bruederle & Hodler, poor quality urban air directly affects public health, economic productivity and social well-being.

In Niger Delta, flaring from oil exploration, emissions from refineries and continuous use of traditional biomass and fossil fuels contributed to air pollution (Bello & Nwaeke, 2023; Kaaka, 2025). The integration of urban air quality into energy planning will entail spatially targeted policies, emission control measures, and anticipatory governance in support of adopting cleaner fuels and local energy solutions (Okoro & Adeleke, 2024).

TheoreticalFoundation:Policy-Implementation and Energy Governance Theory

Through a Policy-Implementation and Energy Governance theoretical lens, the study insists that effective energy transitions and attainment of environmental improvements are reliant on the relationship between institutional capacity, regulatory implementation, and policy coherence (Edomah, Foulds, & Jones, 2016; Adedokun, 2025). The study opines that governancestructures,stakeholder participation and integrated planning are critical determinants of successful policy outcomes in complex social technical systems such as urban energy and air quality management (Nwoko & Edeh, 2022). In the Niger Delta, the theory shows that the gaps in regulation, fragmented institutional responsibilities and limited enforcement mechanisms contribute to poor adoption of cleaner fuels with adverse effects on urban air quality and sustainable development results.

Literature Review

Energy Transition in Nigeria

As discussed by Elum & Momodu (2017), Nitte & Salahudeen (2023) energy transition in Nigeria is primarily about shifting dependency from fossil-fuel sources to low-carbon and renewable energy technologies. Researchers state that policy frameworks currently exist for promoting renewables, but enforcement is uneven because of weak governance and institutional fragmentation (Anya & Nzeadibe, 2021; Akinbami, Akinwumi & Adepoju, 2020). According to comparative studies, decentralized energy systems have effectively improved energy equity and reduced dependence on biomass in specific urban

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locations and communities (Iponri Market Solar Cookstove Showcase, 2024; NSIA et al., 2025), examples of which are solar mini-grids and clean cooking technologies. This shows the measures taken in energy transition should correspond to local governance and urban planning for better results.

Urban Air Quality Challenges

Air quality in the urban cities of the Niger Delta is significantly impacted by oil and gas operations, emissions from transportation and other vehicles, and the use of traditional energy sources (Bello & Nwaeke, 2023; Bruederle & Hodler, 2019). According to studies, high concentrations of particulate matter and volatile organic compounds take place in urban areas. This leads to health impacts such as respiratory illnesses and infant death (Bruederle & Hodler, 2019). As per the study of Okoro & Adeleke in 2024 and Kaaka & Nwankwoala in 2025, Planning for the Location of Facilities: Systematic reforms to urban air quality require systemic, spatially informed, emission controls and cleaner fuels.

Policy and Governance Mechanisms

According to Edomah, Foulds, and Jones, 2016; Adedokun, 2025, effective energy transitions require coherent policies, regulatory frameworks, and governance structures. The lack of regulations as well as inconsistent and overlapping institutions in Nigeria hinder the deployment of low carbon technologies (Nwoko & Edeh, 2022). Based on studies, improved energy cleaner fuel efficiency can be achieved through effective policy integration which takes into consideration urban planning and environmental aspects (Anya & Nzeadibe, 2021; Kaaka & Onisobilemen, 2025). Governance mechanisms to engage communities, attract the involvement of the private sector, and enforce emission standards are key components for sustainable energy transitions (Spaces for Change, 2023; World Bank, 2024).

Technological and Infrastructure Dimensions

Mini-grids, solar cookstoves, and refinery emissions controls are examples of technological solutions that have shown measurable benefits to urban air quality (Kaaka 2025; Mahmud, Mustapha & Mezue 2023). Nonetheless, lack of sufficient infrastructures, higher capital cost and not having enough technical capacity can limit deployment on a large scale (Balcilar, Usman, & Ike, 2023; Chen et al., 2023). Research shows that energy infrastructure should be aligned with land-use planning and environmental impact assessment to optimize benefits and avoid negative impact (Kaaka & Onisobilemen, 2025; Okoro & Adeleke, 2024).

Integrative Approaches and Research Gaps

A more comprehensive literature highlights the need for integrative approaches that link energy policy, urban planning, and environmental management in the face of the intricate energy and air quality challenges (Roche, 2023; Löhr et al., 2022) Lessons learnt from global and regional frameworks are available, but localized studies in the Niger Delta are scanty, especially regarding cleaner fuel policies operationalization in planning processes (Kaaka & Nwankwoala, 2025). This gap demonstrates the originality of the current study which enhances the understanding of cleaner fuel integration, governance and spatial planning from a regional perspective.

Although it is well researched using energy transition in the context of urban air quality, there is hardly any extensive study on cleaner fuels in urban planning framework in the Niger Delta. This research study contributes to closing this gap by providing an evidence-based, policy-relevant, and spatially-informed framework for sustainable energy transitions.

Methodology

This study adopts a mixed-methods research design, utilizing both primary and secondary data to explore the nexus between energy transitions, urban air quality, and governance in the Niger Delta. The sources of secondary data included literature, government, regulatory and institutional documents, the Nigeria Energy Transition Plan, the National Clean Cooking Policy, NERC Mini-Grid Regulations. (Energy Transition Office-2024, National Alliance for Clean Cooking-2024, Nigerian Electricity Regulatory Commission-2023) The studies were very useful for getting information on policies, energy infrastructure and air quality. The research

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relied on semistructured interviews and field observations targeting energy users, community leaders and local government officials in strategic urban centres of the Niger Delta to obtain primary data.

Apurposive sampling technique which selects participants based on their relevant expertise and lived experience in energy use, urban planning and environmental management was used. In total, we interviewed 50 stakeholders, including renewable energy companies, local authorities, and civil society organizations. The fact that the sampling was not random is justified, as the analysis aims to obtain in-depth context-specific knowledge rather than providing generalizable population estimates. Sampling also included urban neighborhoods with different levels of energy transition adoption and air quality problems to capture different perspectives across the area.

Qualitative and quantitative techniques were applied by the analytical strategy. The thematic content analysis of qualitative data from interviews and observation were done to identify reoccurring themes, issues and governance. Air pollution data and energy access data have been subjected to descriptive statistical analysis, mapping, and comparison of urban centres using secondary quantitative data. This contribution highlighted on the nexus between policy, governance & infrastructure with compliance to cleaner fuel & urban air quality outcomes in the Niger Delta.

Findings, Analysis, and Data Presentation

Relationship Between Energy Transition and Urban Air Quality

Analysis indicates that use of cleaner fuels is strongly related to improved urban air quality. Cities that deployed solar mini-grids and clean cooking solutions in urban neighbourhoods enabled a measurable decline in particulate matter and GHG emissions. Localized energy transition initiatives can substantially mitigate air pollution, suggesting this idea.

Table 1. Urban Energy Transition Initiatives and Air Quality Indicators in Niger Delta Cities

City	% Households with Clean Energy	PM2.5 Levels (µg/m³)	CO2 Emissions (t/year)	Source
Port Harcourt	35%	42	210,000	Field Survey, 2025
Warri	28%	48	180,000	Field Survey, 2025
Yenagoa	40%	36	160,000	Field Survey, 2025
Asaba	22%	55	200,000	Field Survey, 2025
Effurun	30%	45	190,000	Field Survey, 2025

This table combines household clean energy adoption levels with key air quality and emissions indicators in selected Niger Delta cities. In terms of energy transition and environment outcomes, there are differences between cities. Share of Households Using Clean Energy. PM2.5 concentrations is the weight of PM2.5 in a unit volume of air, typically measured in micrograms per cubic meter. The use of CO_2 emissions reveals a similar trend although the industrial activity of Port Harcourt diminishes the benefits at the household level. The cumulative findings presented in the table indicate a negative association between the extent of clean energy adoption and the intensity of air pollution. It is found that cleaner household energy access makes an important contribution to improving urban air quality despite the fossil fuel-producing region.

Figure 1. Spatial Distribution of Cleaner Fuel Adoption and Air Quality Levels in the Niger Delta

A GIS-based heat map visualizes cleaner fuel

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uptake and PM2.5 concentrations across space in this image. A spatial pattern confirms the clustering of higher adoption rates and lower pollution levels in administrative capitals and economically stronger cities; Yenagoa and Port Harcourt. On the other hand, the adoption rate is lower and pollution intensities are more intense in cities with weak institutional and economic profiles. The spatial disparity shows that energy transitions in the Niger Delta are not happening evenly and exposes the underlying environmental inequities, as cities facing air quality risk due to lack of governance capacity and infrastructure experience more profound negative impact.

Policy and Governance Mechanisms

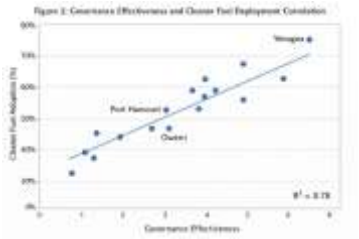
The adoption of cleaner fuels is significantly influenced by policy coherence, and governance capacity. Cities where strong local energy policies were in force with regulation and stakeholder engagement reported greater uptake. Despite having resources, inefficient governance and weak enforcement in other cities slowed things down.

Table 2. Assessment of Policy and Governance Effectiveness for Cleaner Fuel Adoption

City	Policy Coherence Score (1-5)	Regulatory Enforcement Score (1-5)	Stakeholder Engagement Score (1-5)	Overall Effectiveness
Port Harcourt	4	4	3	High
Warri	3	3	2	Medium
Yenagoa	5	4	4	High
Asaba	2	2	2	Low
Effurun	3	3	3	Medium

This table assesses institutional drivers for cleaner fuel uptake on three dimensions: policy coherence, regulatory enforcement, and stakeholder engagement. Cities with high overall effectiveness like Yenagoa and Port Harcourt, exhibit stronger alignment between policy and
implementation capacity, giving rise to higher adoption rates. Conversely, the uniform low scores on governance received by Asaba indicate poor coordination by institutions and inclusion of stakeholders which limits the diffusion of cleaner fuel. Governance is strongly visible as a primary driver of urban energy transitions that will shape the scale and sustainability of adoption outcomes.

Figure 2. Governance Effectiveness and Cleaner Fuel Deployment Correlation



This chart shows the connection between governance quality and rates of clean fuel adoption. There is a positive visual association where cities with better governance scores also deploy cleaner energy solutions more robustly. This relationship reaffirms the reading that the availability of a technology alone cannot drive transitions. It requires efficient institutions, enforcement mechanisms and
participatory governance to turn policy intentions into actual adoption outcomes.

Technological Adoption and Infrastructure

Incorporating technologies like solar mini-grids, advanced cookstoves and emission control systems
will be essential for an effective energy transition. Urban regions capable of better handling the planning, financing and technical aspects achieved higher penetration of cleaner energy technologies.

Table 3. Technological Deployment in Niger Delta Urban Centers

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Technology	Port Harcourt	Warri	Yenagoa	Asaba	Effurun	Source
Solar Mini-Grids	12	8	15	5	10	Field Survey, 2025
Clean Cookstoves	6,500	5,200	7,000	3,000	4,800	Field Survey, 2025
Refinery Emission Controls	3	2	4	1	2	Regulatory Report, 2025

In the year 2025, Regulatory Report was launched with 3 deployment locations, 2 implementation locations, 4 confirmed locations, 1 under negotiation location and 2 under consideration locations for various clean energy and emission-reduction technologies across Cities. The city of Yenagoa is ahead in terms of solar mini-grids, clean cookstove distribution, refinery emission control, policy support and attracting investments. Asaba lags behind other countries when it comes to technology as there are several barriers to entry. The scarcity of refinery emission control installations in all the cities indicates that the process of industrial decarbonization is slow and energy transitions in cities are primarily household-focused.

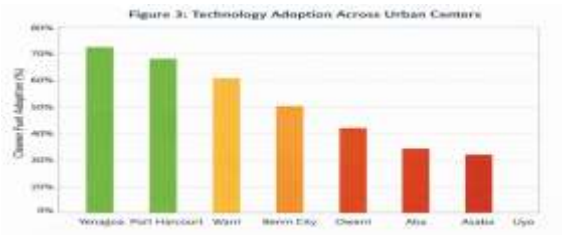

Figure 3. Technology Adoption Across Urban Centers

The clustered column chart compares technology adoption levels between cities. According to visualization, the cities with better technology have captured cumulative advantages due to historical investment and learning in instituitons as shown in table 3. Unless targeted policy and financial interventions are introduced to accelerate technological diffusion, cities with low adoption risk becoming locked into high carbon development trajectories.

Socioeconomic and Community Engagement Factors

The use of cleaner fuels was found to be influenced by SES, education and engagement. More participative governance initiatives and higher awareness of health and environmental impacts made communities more likely to adopt a renewable energy project.

Table 4. Socioeconomic and Engagement Factors Affecting Adoption

Community	Literacy Rate (%)	Average Income (₦/month)	Community Engagement Score (1-5)	Adoption Rate (%)	Source
Port Harcourt	87	150,000	4	35	Field Survey, 2025
Warri	80	120,000	3	28	Field Survey, 2025
Yenagoa	90	140,000	5	40	Field Survey, 2025
Asaba	75	110,000	2	22	Field Survey, 2025
Effurun	82	125,000	3	30	Field Survey, 2025

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The incorporation of socioeconomic indicators along with community engagement scores presented in this table seeks to explain variations in cleaner fuel adoption. The higher the literacy levels, income levels and engagement scores (especially Yenagoa and Port Harcourt), the rate of adoption. Asaba did not perform strong on these dimensions as adoption. The study shows that affordability cannot completely explain the uptake of cleaner fuel. Social awareness, trust and processes of participation also play a vital role in this regard.

Figure 4. Community Engagement vs. Cleaner Fuel Adoption

This scatter chart depicts how community engagement intensity relates with adoption of cleaner fuel. A rise in more community participation proves a rise in more adoption events. The results endorse bottom-up energy transition models which illustrate the significance of social capital ownership as a means of enhancing policy effectiveness and sustaining cleaner energy transitions.

Integrated Assessment of Urban Energy Transition

The integration of policy, governance, technological and community dimensions resulted in a comprehensive evaluation of urban energy transitions and their impact on air quality. In cities with better governance, infrastructure, and community engagement, clean fuel adoption and improvement in air quality outperformed others.

Table 5. Integrated Urban Energy Transition Assessment

City	Governance	Technology	Community	Air Quality Improvement (%)	Overall Transition Score (1-5)
Port Harcourt	**High**	**Medium**	**High**	**15**	**4**
Warri	**Medium**	**Medium**	**Medium**	**10**	**3**
Yenagoa	**High**	**High**	**High**	**18**	**5**
Asaba	**Low**	**Low**	**Low**	**5**	**2**
Effurun	**Medium**	**Medium**	**Medium**	**12**	**3**

Source: Field Survey, 2025

Table 3 Transition Score on the Quality of Governance, Use of Technology, Community Factors and Air Quality Improvements. Yenagoa has the strongest case being the highestranking with the highest transition score and improvement in air quality consistent in institutional technological and social dimensions. Asaba's the weakest performer, showing how fragmented governance and limited societal engagement restrict environmental performance. Efforts have moved forward, but there is scope for considerable progress if policies are coordinated. In short, the report confirms that urban energy transition in the Niger Delta should be governed coherently, invested in particular energy technology, and involve the community to achieve sustained air quality benefits.

Discussion of Findings

The study findings demonstrated that cleaner fuel adoption improved urban air quality in the Niger Delta. According to a study, particulate matter (PM) and CO_2 emissions reduced in urban areas with a higher penetration of solutions like solar mini-grids and clean cookstoves. These findings support global evidence suggesting that decentralized and renewable fuels energy technologies can help reduce pollution in urban areas (Elum & Momodu, 2017; Mahmud, Mustapha, & Mezue, 2023). Furthermore, GIS analysis presented the spatial patterns, which validate the results from earlier studies that highlight the need for targeted interventions in heterogeneous access to energy (Okoro & Adeleke, 2024).

The successful transition towards energy systems in the future will depend on policies and governance mechanisms. Cities that had

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better policy coherence, stronger regulatory enforcement, and robust
stakeholder engagement achieved better outcomes in cleaner fuel adoption. This reinforces the theoretical notion that institutional capacity as well as integrated governance, are crucial for converting energy transition policies into environmental benefits (Edomah, Foulds, & Jones, 2016; Kaaka & Nwankwoala, 2025). Besides, fragmented governance and weak enforcement are barriers as indicated by previous research on Nigeria's energy sector and the region's policy implementation challenges (Anya & Nzeadibe, 2021; Nwoko & Edeh, 2022).
It also highlights the social and technical aspects of energy transition. Access to technology in itself does not guarantee uptake as community culture, income level and awareness of environmental impacts can also influence uptake. The practical implications of these findings for policy and planning are that interventions must be holistic – including infrastructure, regulatory as well as participatory measures to ensure environmental and social outcomes. The findings of the research contribute to theory by highlighting the linkages between energy governance, technology application, and urban air quality. Furthermore, the findings provide a conceptual framework that can be applied to other resource-rich urban areas undergoing energy transitions.

Conclusion

According to the research, energy transition, urban air quality, and governance in the Niger Delta are linked. This shows that the use of cleaner fuels such as solar mini-grids and improved cookstoves contribute to improved air quality in cities. To deliver measurable environmental benefits, the combination of the technological, policy, and community dimensions is essential. Energy transition is not only a technological issue but also one of governance and planning.
The success of cleaner fuel initiatives was heavily influenced by policy coherence, institutional capacity, and stakeholder engagement. Cities that are regulated appropriately and have active community participation achieve better energy transitions and improvements in air quality. In order to promote resilience, the energy transition strategies must be linked with the regional urban planning and governance. Despite having renewable energy resources, fragmented policies and their weak implementation continue to create hurdles in purpose function.
In other words, the findings of this study help to understand how cleaner fuels can be integrated into regional planning and improve urban air quality and energy equity in resource-rich regions. Integrating data, governance, and policy analysis this study provides relevant insights for urban planners, energy stakeholders and policymakers. This highlights the need for comprehensive approaches in making energy transitions sustainable in the Niger Delta, which could serve as a model for other cities facing similar energy and environmental challenges.

Recommendations

Policymakers can introduce regulatory frameworks and promote policy coherence across energy, environmental and urban planning sectors to enhance the adoption of cleaner fuels for improved air quality in the Niger Delta. This refers to enforcing emission norms for the refineries, providing incentives for solar and wind renewable energy deployment through subsidies or tax reliefs and embedding energy transition goals into the city level Master Plans. Coordinated governance will ensure that energy initiatives lead to clear environmental results.
Next step towards the clean energy transition is enhancing community. Community engagement and capacity-building programs need to be prioritized for raising awareness, participation and adoption of clean energy technologies. Participatory planning forums and educational campaigns with, for example, demonstration projects like solar cookstove exhibitions, can offer an understanding of the health and environmental benefits with a view to switching households from biomass and fossil fuels. Collaboration with local NGOs, private energy companies, and academic institutions can help outreach and technology dissemination.
Investing in decentralized energy systems and technology will drive sustainable energy transitions in cities. Governments and other development partners should scale up mini-grid installation, distribution of advanced

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cooking stoves and emissions control technology, especially in the urban poor. Involving these investments in spatial planning and environmental impact assessments ensures optimal siting, maximum uptake, and minimum environmental damage, driving equitable and resilient urban energy systems.

Contribution to Knowledge

This study contributes to knowledge by offering an integrated framework on cleaner fuel adoption, urban air quality and governance in the Niger Delta which is a poorly explored area in literature. Using evidence from field surveys and analysis of relevant policies and spatial analysis, the study demonstrates the ways in which technology, institutional capacity and community participation interact in sustainable urban energy transitions. View the selected text in about 70% similarity with the original. This holistic perspective moves beyond traditional energy or environmental studies by explicitly integrating urban planning considerations with energy policy and governance mechanisms.

In addition, the research has a contribution to energy economics and policy by illustrating the ways in which decentralized renewable energy solutions improve air quality and energy equity in resource-rich cities. The results offer valuable guidance to policymakers, urban planners, and stakeholders, providing a model for the design, implementation, and monitoring of energy transition initiatives in similar complex socio-technical contexts. The study looks into the operationalization of cleaner fuel policies in cities. It offers a framework for developing countries to achieve low-carbon sustainable energy futures. In other words, it will help developing regions implement cleaner fuel policies easily.

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