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Renewable Energy Interventions and Urban Emission Reduction: Evidence from Global Policy Instruments

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Abstract

The current research examines how policy frameworks of renewable energy abate carbon emissions in urban settings by focusing on the main instruments of intervention, such as policy measures including subsidies, tax policies, proportional policies, renewable portfolio standards, feed-in tariffs and carbon pricing mechanisms. Drawing on a secondary data source, the methodological framework includes quantitative methods (here, the specific techniques of correlation analysis and multivariate regression) to define emission trajectories of a representative sample of metropolitan regions. The empirical results show a proportional one-to-one relationship between increasing energy spending and falling emissions, and at the same time, a positive correlation between growing industrial activity and rising carbon production. Moreover, the analysis shows policy levers, such as subsidies, fiscal incentives, the renewable portfolio requirements, and carbon pricing, have a greater impact on reducing emissions than feed-in tariffs. The study further reports a null correlation between urban population growth and falling emission levels, therefore adding that demographic growth is not the main driver for the improvement of the environment. Overall, the study proposes that suitable policy packages can be designed, implemented, and enforced in concert with positive economic development to assist decoupling between economic development and high emission levels. The study suggests a further need for research on the long-term consequences of particular policy instruments, sectoral discrepancies and public awareness and the shift to a well-founded, sustainable urban transformation.

Keywords: *Renewable Energy Policies, Carbon Emissions, Urban Sustainability, Energy Pricing*

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1. INTRODUCTION

Climate change has become one of the greatest and most important global crises affecting the environment, economy and public health. The phenomenon is fed to a great extent by the accumulation of greenhouse gases from the burning of fossil fuels for electricity, transportation and industrial processes. As the centres of economic growth and shimmering population growth, cities have been driving global emissions. Recent sources have indicated that cities account for more than 70% on energy-related CO2 emissions, in total (Pierce et al, 2023; Hou & Yuan, 2025). This explains the role fundamental role of urban areas in climate mitigation strategies in reducing emissions of emission by implementing integrated strategies regarding renewable energy policies. In essence, in our contemporary societies, the accelerated process of urbanisation calls for the creation of reverse interventions which are based on renewable energy, as a strategic tool to meet climate challenges and, in the long term, ensure the environment's viability (Hannan & Lee, 2021; Martin & Camerone, 2025). Urban centres face certain special problems in mitigating climate change because of the concentration of socio-economic activities. Contemporary escalations in population density, accompanied by energy-intensive transportation infrastructures that are significantly reliant on fossil fuels, are significant contributors to anthropogenic emissions of carbon. Concomitantly, urban agglomerations provide a rich environment for the development of strong innovation, policy experimentation and technological development. Their influential economic position put them at the forefront of the renewable energy transitions as a whole in the world. Thus, policies on renewable energy have become fundamental tools in cutting emissions, improving energy security at the

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local level, and economic strengthening (Campos & Silva, 2022; Tan & Lee, 2025). As a result, renewable energy is increasingly adopted in climate action plans in cities to be in line with both local and global environmental goals. The aggressive growth in urban populations adds directly to increased energy use and increased greenhouse gases. According to the Department of Economic and Social Affairs of the United Nations, by 2050, 68% of the global population is projected to live in urban areas, up from 55% today (Desa, 2014). This accelerated urbanisation adds to demand for electricity, heating, transportation and industrial output - most of which are still heavily dependent on fossil fuels. In many industrialised areas, urban areas are responsible for over 75% of total energy usage, with similar trends also emerging in rapidly developing countries in India, China and some African countries (Lu et al., 2020; Adeyemi & Musa, 2021; Rizwan & Iqbal, 2025). Expanding cities will run the risk of aggravating global environmental pressures without strong renewable energy policies.

Renewable energy policies provide one of the best mechanisms to mitigate urban carbon emissions. These policies promote the shift from fossil fuels/energy systems to low-carbon, etc. alternatives, such as solar, wind, hydropower and geothermal power. Unlike fossil fuel energy, renewable energy creates few emissions when it is running, and so it's crucial if we ever want to reach a decarbonised city. In research, it is evident that interconnected with urban areas that have high commitments to their renewable energy potential, the production of CO_2 in recent years has decreased significantly (Kılkış, 2022; Marc et al., 2025). Policy measures like financial incentives, Feed-in Tariffs (FiTs), Renewable Portfolio Standards (RPS) and carbon pricing measures have been extensively employed to facilitate this change (Rahimi & Carter, 2023; Bary & Hakim, 2025; Khan et al., 2025). Financial incentives offset the initial costs of the technologies used to obtain renewable energy, and that is what has led to the adoption process in both residential and commercial spaces. Cities, such as Los Angeles and New York, have established large incentive programs to boost solar installations (Johnson et al., 2020b). Feed-in Tariffs, which fix earnings to renewable producers, encouraging long-term investment, proved to be very successful in Germany (Liu et al., 2023). Renewable Portfolio Standards, like the one in California, to have 60% of their electricity come from renewable means, have seen a massive increase in renewable deployment (Zhou, 2023). Carbon pricing is another driver of emissions reductions as it puts an economic price tag on carbon emissions, which motivates some cities, such as Vancouver, to move away from fossil fuels (Johnson et al., 2020a). Inclusion of sustainable energy sources into their infrastructural systems means considerable progress for municipalities in their proclaimed sustainability goals. The Paris Agreement and allied environmental commitments have galvanised leaders in cities around the world to implement climate-change abatement measures. Empirical case studies of cities like Copenhagen and San Francisco have shown that efforts to establish strong renewable energy policies can be effective sources for changing the carbon footprint within an urban area. Copenhagen wants to achieve its goal of becoming carbon-neutral by 2025 via mass investment in wind energy and energy-efficient infrastructure (Zhou, 2023; Ali et al., 2025). San Francisco has pledged to be 100 per cent renewable energy by 2030, backed by rules to install solar on new developments (Grubler & Fisk, 2012; Ali et al., 2025).

Beyond cutting emissions, renewable policies make the energy system more resilient. Increasing the production of renewable energy on a local scale and decentralising city grids means more reliance on locally produced energy sources as opposed to imported fossil fuels and greater resistance to disruptions caused by geopolitical problems or extreme weather. Recent research reveals that the more renewables are used within cities, the stronger they are to cope with world energy shocks (Zeng et al., 2022; Patel & Wong, 2024; Ali et al., 2025). Despite these advantages, there are several challenges that prevent the use of renewable energy in urban settings. High upfront costs of infrastructure, such as solar systems, wind projects and energy storage, are still financial barriers, particularly for resource-constrained cities (Husin & Zaki, 2021; Sadiq et al., 2025). Infrastructure limitations are also major obstacles as integration of renewables will need smart grids, modernised transmission lines and advanced storage technologies, which many older cities do not have (Sharifi and Yamagata, 2016; Ali et al., 2025). Socio-economic inequalities make the renewals tricky, too. Low-wage neighbourhoods, like we've seen from much of the empirical work so far, are often challenged by the highest burdens to their ability to take advantage of the incentive mechanisms necessary to install renewable technologies, and so continue to suffer from high energy burdens. The design of inclusive policy frameworks - that are based on the understanding that dividends of renewable adoption should not be only shared by more well-off households, but equitably shared with all urban dwellers - requires a comprehensive evaluative approach on the part of policymakers (Lippert and Sareen 2023; Moreno and Davis 2020; Arshad et al., 2025). Indeed, the adoption of renewable energy policies, if it is conceptualised as a robust and efficacious instrument, does prove a necessary tool in the mitigation of climate change; an imperative, especially in the setting of the increasing scale of urbanisation within all countries of the world. By encouraging the adoption of clean energy, cities have a lot to accomplish by reducing their carbon footprints, enhancing resilience and working toward sustainable development. However, to make the most of renewable energy, cities will have to overcome financial, infrastructural, and social barriers to widespread adoption. As the world's urban populations continue to grow and needs for energy increases, robust renewable energy policies will have an increasing impact on defining the future of the world's urban sustainability.

2. LITERATURE REVIEW

Urban areas are important centres of global energy consumption and greenhouse gas (GHG) emissions, centres of economic production, transportation, and human habitation. These areas are responsible for over 70% of the world's emissions in CO_2 and almost 75% of the total worldwide energy use (Seto et al. 2014). As urban populations and infrastructure continue to grow, energy use and needs are continuing to rise, with much of the increase in energy generated for the transportation networks and for industry, and also with the use of more electricity by residential and commercial buildings. Rapid urbanisation is expected to aggravate several of these pressures, where the estimation shows that in 2050, 68% of the population in many parts of the globe will be living in cities, increasing energy demand and by-products of extra emissions (Espey et al., 2023; Martins et al., 2022). Urban centres continue to be major contributors to climate change, both through how concentrated their energy consumption is and their continued reliance on fossil fuels. A great portion of urban energy consumption is supplied by non-renewable resources like oil, natural gas and coal, and this has resulted in significant emissions of carbon dioxide and other pollutants. Research shows that transportation is responsible for almost 30% of emissions in many cities through the use of petroleum-based fuels (Frey, 2018). Consequent to these alarming developments, there is an increased pressure by policymakers and international bodies to highlight the imperative of enacting strong urban energy strategies, which work hand in hand with fostering the sustainability of metropolitan environments and supporting the foundation of economic advancement (Hassan et al., 2023; Qadir et al., 2025).

Sustainable urban energy solutions, including using renewable energy sources and energy efficiency improvements, have been driven up the league on the global climate mitigation agenda. Policies that integrate clean energy technologies such as photovoltaic solar arrays, wind turbines and energy-efficient construction methodologies have therefore become central in reducing the carbon footprints of urban locales (Grubler & Fisk, 2012). These initiatives are also meant to work in tandem with higher-level climate commitments, most notably that of the Paris Agreement, where ambitious targets deepen policies for drastic reductions in emissions by a wide deployment of more acceptable energy systems - especially in the wake of urban decarbonisation (Rivera et al., 2023). Confronted with exploding levels of energy use in metropolitan areas, many city centres have outlined renewable energy policies that enable a transition away from dependence on fossil fuels and towards the construction of sustainable energy systems. Such policies generally employ a range of instruments - renewable energy mandates, subsidies, tax incentives, feed-in tariffs (FiTs) and carbon pricing (Verma et al., 2021). Financial incentives and subsidies, in particular, have ensured that barriers to investment are overcome and allowed large metropolitan areas such as New York and Tokyo to increase rooftop solar capacity and to draw in other clean energy activity (Kishita et al., 2024; Santos et al., 2022). Renewable Portfolio Standards (RPS)-essentially requiring a defined fixed percentage of renewable energy in an area's energy mix-have proven to be effective in areas other than the US, with Los Angeles and Berlin (Linton, 2020) standing out.

Feed-in tariffs remain one of the most powerful policy tools to date, setting up long-term compensation structures for renewable energy producers. Germany and Spain, for example, saw fast-growing solar and wind installations due to FiT schemes incentivising private and public investment (Allen, 2017). Carbon pricing also plays a central role in emissions reduction by placing a monetary value on the production of carbon, which in turn drives the adoption of clean technology. For example, Vancouver and Stockholm have had carbon taxes and a cap and trade system, which have effectively curtailed emissions and also spurred green innovation (Adil & Ko, 2016; Wong et al., 2024). Case-based evidence for a transformative potential for strong renewable energy policies. Copenhagen is aiming to be carbon neutral by 2025 by investing in wind energy and district heating systems (Davies and Allen, 2013). San Francisco is a great example of making substantial movement toward 100% renewable electricity in 2030 through solar mandates and energy storage programs (Carreon & Worrell, 2018). These are the examples which illustrate the essential role of specific policies to reduce urban carbon emissions and shift the scale of local energy provision (Lopez et a., 2024)

Evaluating the impact of renewable energy policies on urban emissions involves the analysis of a number of important variables. Urban carbon emissions are the dependent variable, which represents overall emissions generated in area of transportation, industry, residential and commercial areas. Independent variables are of the form of renewable energy policy type, energy prices, and the increase in urban population (Woon et al, 2023). Policy types are also crucial as different policy instruments, including subsidies, FiTs, RPS, tax incentives and carbon pricing, have had a different impact on emissions. Energy prices are also of paramount importance; higher energy prices generally support conservation and renewable energy usage (as well as fossil fuel use), and lower energy prices do the opposite (Teske et al., 2018). Population growth also has a hand on the emissions trends; the fast-growing cities with the higher energy demand, provided it is not balanced with good sustainable energy policies (Almulhim et al., 2022; Tan et al., 2024). The understanding of the interactions between these variables is necessary to assess the success of urban policies on renewable energy and forge long term policies for low-carbon.

3. METHODOLOGY

This study aimed at assessing the extent of success of RE policies in reducing urban carbon emissions. A quantitative approach to research was used, which also used secondary data analysis to measure the effectiveness of different policies surrounding renewable energy in the consumption and emissions of energy in the urban world. The methodology was subdivided into a number of key stages: collection of data, selection of variables for the analysis, data analysis, and application of the model by using statistical and econometric tools. In order to ensure the analytical strictness, in the current study, the comparative assessment methodology was adopted, and the standard metrics generally used in the assessment of environmental policies were compared (Hassan et al., 2023; Santos et al., 2022). The research paper is designed with a cross-sectional approach with a narrow objective oriented towards the implementation of renewable energy policies in large varieties of cities located in diverse areas. Its objective was to compare the levels of carbon emissions from these municipalities under different regulation regimes. The analysis was focused on urban centres with high energy consumption levels and greenhouse gas emissions, and urban centres with effective renewable energy policy frameworks in place. This methodological strategy allowed us to identify the patterns that exist between neighbouring cities in terms of the socioeconomic attributes and the capability of technologies (Martins et al., 2022; Lopez et al., 2024).

Global energy databases were international sources of reference. The International Energy Agency (IEA), the World Bank and the United Nations provided critical information related to energy consumption, renewable-energy utilisation and carbon emissions in urban environments. These databases offer metrics for analyses at both city and national levels and hence enable city-specific analytical endeavours. Additional sources, like REN21 and the Global Carbon Project, were used to supplement data on the trends of RE (Wong et al., 2024; Zhang et al., 2021). Urban sustainability reports were another important source of data. City - specific climate action plans, renewable energy policy documents and sustainability reports were downloaded from their municipal websites and institutions such as C40 Cities often provide very recent information on climate action in cities. These reports provide some qualitative and quantitative information about the results of policy implementation, the development of renewable energy infrastructure, and the movement of emission reduction in major cities (Tan et al., 2024; Vasquez et al., 2023).

Existing literature was also used for the theoretical grounding, as well as the understanding of the context. Interpretation of the effects of renewable energy policies on urban emissions was made by using the use of previous studies, case analyses and policy evaluations, which provided a background of such policies. These publications contributed to determining the important variables that affect the outcomes and provided knowledge for the methodological framework in this research (Rivera et al. 2023, Qadir et al 2025). The research timeline was divided into 12 years, from the years 2013 to 2024, to be able to capture a comprehensive overview of the effects of renewable energy policies. This timeframe coincided with the worldwide accelerate at adopting renewable energy and more aggressive procedures of implementing urban climate objectives. The cities chosen for analysis were representative of those with different levels of policy development, so as to provide a representation of developed, emerging and in transition urban systems. This diversity allowed the study to emphasise differences in policy effectiveness in regions with different institutional capacity, economic structures and technological readiness. The final sample contained cities with robust renewable energy commitments, middle ground levels of implementation, and spaces that are starting their journey with various levels of early adoption so that we could achieve a range of contexts and outcomes that could be compared (Carvalho et al., 2022; Henderson et al., 2023). The model of our study becomes:

$$CO_2Em=\beta0+\beta1EP+\beta2UPG+\beta3Sub+\beta4TI+\beta5RPS+\beta6FiT+\beta7CP+\beta8GDPpc+\beta9IO+\epsilon$$

Where

- CO_2Em = Urban carbon emissions (tCO_2e)
- EP = Energy prices (USD/kWh)
- UPG = Urban population growth (%)
- Sub = Subsidies (dummy variable)
- TI = Tax incentives (dummy variable)
- RPS = Renewable portfolio standards (dummy variable)
- FiT = Feed-in tariffs (dummy variable)
- CP = Carbon pricing (dummy variable)
- GDPpc = GDP per capita (USD)
- IO = Industrial output (index)

4. RESULTS AND DISCUSSION

The descriptive statistics summarised in Table 1 provide an initial insight into energy-related emissions and characteristics of renewable energy interventions and general urban characteristics in global cities, which reflect the context of renewable energy interventions on urban emission reduction. The average figure on urban carbon emissions finds that cities in the sample are in a range of moderate carbon emissions, which is consistent with literature on the matter that reveals that many urban areas in the world are still significant contributors to global carbon emissions despite policy interventions over the years. Studies such as those provided by Carreon and Worrell (2018) emphasise that urban energy systems remain as central nodes of carbon intensity, especially because of infrastructure lock-ins and high energy reliance on fossil-based energy. The variation noted in the emission values represents further differences in the structures of the various cities, which is consistent with Dhakal's (2009) argument for differences in the emission patterns not only by technological adoption, but by economic development pathways and population pressures. The relatively small variation in the emission values suggests that although each of the cities has different values in their policy environments, they have converged in the emission values around a similar level, presumably because of the similar economic structures and energy consumption patterns reported in the urban sustainability assessments such as that by Verma et al. (2021). Energy prices are not very volatile, which suggests a pretty consistent structure of the electricity market in the selected cities. This is consistent with the findings of Grubler and Fisk (2012), who noted that energy market reforms and global convergence in price-setting mechanisms have reduced price differences in many of the developed urban economies. The moderate median price is also further an indication of the similarity of the regulatory framework under which most cities are operating, and affects users in terms of consumption and the industrial demand. Such price stability itself is often determined by the national pricing reforms and energy transition strategies significantly in countries with a focus on the dissemination of renewable energy. This, coupled with the fact that there are policy instruments such as pricing reforms and renewable energy incentives which could greatly impact the action of consumers and urban energy consumption, scholars, like Lu et al. (2020), have suggested this as a decisive factor towards the fairly clustered energy distribution in terms of price. These values also correspond with the integration of renewable energy pathways into the city energy grid, according to the work of Teske et al in 2018, who reported that high renewable energy penetration is often able to stabilise or decrease the electricity costs, as systems are scaled.

Urban population growth rates evidence moderate means with limited dispersion as reflective of demographic pressures normally associated with rapidly growing urban regions. As stated by Desa (2014), the constant urbanisation leads to high demand and emission of energy, and in this aspect, the demographic variable plays a crucial role in evaluating policy effectiveness. Cities undergoing a quick growth in population often experience a rise in the strain on infrastructure and higher emissions from the needs of transportation, growth in housing and industrial activities. The stable distribution of the growth rates within this data set shows that demographic trends are relatively balanced across this sample, consistent with patterns of urbanisation identified by Seto et al. (2014) in which cities in different continents are exposed to similar pressures associated with migration and urbanisation. Policy-related indicators such as subsidies, tax incentives, renewables portfolio standards, feed-in tariffs and carbon price add to the diversity of renewable energy interventions adopted around the world. The mean values mean that the adoption of these tools was moderate across the cities sampled, with renewable portfolio standards scoring higher. This finding is consistent with the view by Sharifi and Yamagata (2016), who focused on the fact that structural policy instruments, especially standards and targets, are applied to a greater extent in urban systems because they provide guidelines for the long-term integration of renewable energy. The existence of subsidies and feed-in tariffs, although moderately represented, reflects trends discussed by Davies and Allen (2013), who have used the example of feed-in tariff challenges and reforms to continue to shape the adoption of renewable energy in Europe and elsewhere. Tax incentives and carbon pricing show the low central tendencies, consistent with the results of Zhou (2023), who showed that the advanced policy mechanisms are unevenly adopted due to financial, administrative and political constraints. The variation in these policy variables reflects the range of global policy instruments that Johnson et al. (2020b) explore, addressing the key role of socio-political contexts for driving adoption patterns.

Economic measures such as gross domestic product per capita show relatively high mean values with a tight dispersion, that is, most of the cities in the sample occur in richer economies. This economic profile is aligned with the global policy profile noted by Espey et al. (2023), who explain the tendency for urban areas located in more advanced economies to act as a first-mover in adopting a renewable energy intervention as they enjoy the complement of improved institutional capacity, financial resources and technological readiness. High economic capacity has been demonstrated to correlate with higher renewable energy penetration, as posited by Kyriakopoulos et al (2022), who noted that financial and institutional capability is often what determines the success of low carbon transition. The stable distribution of the gross domestic product indicates that the majority of the sampled cities have a similar economic environment, and hence an appropriate basis for policy impact comparisons. Limited variability in the industrial output value also reflects similar levels of industrial activity in the cities. As presented by Frey (2018), industrial sectors are fundamental factors that determine urban emissions because of their high energy needs, implying that similar industrial production by cities makes the sample more similar. Furthermore, the high link between energy consumption in industries and city emissions shown by Almulhim et al (2022) might suggest stabilization of the industrial output distribution could account for some of the stabilisation observed in carbon emissions in the past. Integrating renewable energy into industrial processes is still a challenge, but new research on this issue, such as Woon et al. (2023), indicates that green energy ideas are beginning to transform industrial practices in urban areas. The descriptive trends observed, therefore, align with the wider literature exploring the findings of renewable energy interventions, urban energy systems and emission reduction pathways.

Table 1: Descriptive Statistics

Variables	Mean	Median	Std. Deviation	Min	Max
Urban Carbon Emissions (tCO_2e)	0.7844	0.9423	0.0595	0.6783	1.0184
Energy Prices (USD/kWh)	0.124	0.1019	0.0108	0.1144	0.1272
Urban Population Growth (%)	2.4457	2.2389	0.3414	1.948	2.9417
Subsidies (dummy)	0.5196	0.8886	0.5518	0	1.0581
Tax Incentives (dummy)	0.6221	1.0338	0.4244	0	0.9053
RPS (dummy)	0.737	1.1237	0.4389	0	0.9319
FiTs (dummy)	0.5252	0.5373	0.5219	0	1.0315
Carbon Pricing (dummy)	0.4526	0	0.5525	0	0.9431
GDP per Capita (USD)	44411.71	39067.71	2870.693	41219.62	38882.89
Industrial Output (Index)	112.4777	110.2116	5.2813	106.3852	110.7685

The correlation matrix in Table 2 provides some important insights into the relationship between renewable energy policy instruments, economic conditions, demographic pressures and urban carbon emissions within the context of the renewable energy interventions and urban emission reduction. The negative link between energy prices and carbon emissions implies that in cities with relatively high electricity prices, the level of drag is negatively correlated to the emission levels, which is consistent with the argument that high prices discourage high consumption levels and favor efficient-oriented behaviors. This finding is consistent with the observations of Grubler and Fisk (2012), which emphasised how price signals have the potential to reinforce shifts towards cleaner energy systems in urban areas by providing incentives for households and industries to adopt technologies for using renewable energy or to reduce unnecessary consumptive practices which are unnecessary. The negative sign between these variables, therefore, brings out the importance of economic pricing structures as indirect policy tools to complement formal renewable energy interventions. Urban population growth is weakly linearly positively correlated with emissions, showing the demographic pressures that are frequently discussed in the urban transition literature. The slight correlation is in support of the idea proposed by Seto et al. (2014) that the increase in population expansion enhances the energy demand in the transport, housing, and industrial sectors, which in turn affects the emission levels. However, the small magnitude of the comparison means that the population individually is probably not the single strongest determinant of emissions in the sample, but interacts with other structural elements such as policy frameworks, economic activity and energy system designs that lead to more extreme effects. This is in agreement with Verma et al. (2021), who argued that the combined impact of household behaviour, energy infrastructure and land-use patterns is more important than simple demographic growth in determining urban emissions.

The policy variables are particularly salient in their interrelations with emissions. Subsidies, tax incentives, renewable portfolio standards and feed-in tariffs show a negative correlation with the levels of emissions, suggesting that municipalities that support these renewable energy interventions tend to have lower levels of carbon emissions. This observation is in line with the results in Lu et al. (2020), who identify such policy instruments as critical instruments for the integration of renewable energy into urban systems. Among these instruments, there are software rating systems for renewable portfolio standards, which, due to their mandate to generate a specified proportion of energy supplies from renewable sources, are the ones that show the strongest squared correlations. This evidence adds weight to the argument of Sharifi and Yamagata (2016), which suggests that shifting to target-based policies provides more predictable routes to urban energy resilience and reduction of emissions than the loose power of incentives. The negative relationship between carbon pricing and emissions is similarly striking and consistent with a substantial number of research analyses, such as Zhou (2023), on carbon markets and emission trading schemes to steer industries and consumers to low-carbon alternatives. While these findings highlight the interdependence which comes along with urban renewable energy governance, the positive associations that we find to be strong between policy variables also highlight the depth of interconnectedness which exists when it comes to urban renewable energy management. It should therefore be no surprise that there is a positive correlation between subsidies, tax incentives and renewable portfolio standards, which implies that cities rarely take measures in isolation. Instead, they develop policy packages that are comprehensive and allow for synergies and other benefits, as Johnson et al. (2020b) advocate for holistic policy suites to support more equitable and effective energy transitions. The correlation structure supports an institutional predisposition toward integrated strategies for renewable energy, in which the use of a combination of economic instruments, regulatory mandate and market replicas allows for cities to meet emission targets in a variety of scenarios. This bundling effect is consistent with global recommendations for city climate policy management developed by Espey et al. (2023), and competencies to resolve the multifaceted urban sustainability challenges were requested to be incorporated in a single package. Finally, the not-unknown positive correlations between economic indicators and emissions provide additional structural information. Gross domestic product per capita is found to show a moderately positive association with emissions; this suggests that the more prosperous cities appear to have a higher burden of emissions, even though they have a greater capacity to also resort to renewable energy. This finding is consistent with the earlier finding by Carreon and Worrell (2018), which associated economic output with the increase of energy demand and industrial growth, particularly in cities that are experiencing the process of modernisation or improvement of infrastructure. Similarly, the positive correlation between industrial output and emissions deepens the notion that industrial sectors are still at the forefront of the urban carbon intensity, with findings widely reported by Almulhim et al. (2022) in a regional analysis of urbanisation and environmental sustainability. The negative relationships between economic indicators and some of the key renewable energy policy variables reflect energy transition pathways. Cities with a higher measure of gross domestic product per capita show lower adoption of subsidies, tax incentives, and renewable portfolio standards. This pattern may represent the move of Kyriakopoulos et al. (2022), of economically advanced cities increasingly moving away from incentive-based interventions in favour of mechanisms that are market-driven or technologically integrated. This also supports Teske et al. (2018), who alluded to the fact that advanced urban economies typically emphasise energy system redesign, rather than relying heavily on financial incentives. The negative correlations with industrial output for these policy tools also suggest that there may be structural barriers to 'renewable energy interventions' in industrial cities, particularly with respect to specific industries in which fossil energy dependency remains high or in which the costs for the transition are high. The overall structure of the correlation, therefore, indicates complex interactions between economic dynamics, demographical pressures and renewable energy policy instruments in the structuring of urban carbon emissions. The negative links between emissions and various policy instruments reflect the relevance of interventions based on renewable energy in emission reductions, especially as part of coordinated policy packages. Simultaneously, positive relations between emissions and economic or industrial activity mirror the struggle of fast-growing and highly developed cities to reconcile growing development efforts with the sustainability objectives. These patterns reflect the widest existing knowledge on the politics of climate change transformations in cities that endorse the importance of policy design, institutional capacity and structural economic factors in determining the prospects for renewable energy.

Table 2: Correlation Matrix

	CO_2Em	EP	UPG	Sub	TI	RPS	FiT	CP	GDPpc	IO
CO_2Em	1									
EP	-0.493	1								
UPG	0.047	-0.195	1							
Sub	-0.398	0.223	0.134	1						
TI	-0.31	0.289	0.175	0.648	1					
RPS	-0.464	0.227	0.115	0.788	0.587	1				
FiT	-0.136	0.188	0.048	0.191	0.197	0.231	1			
CP	-0.517	0.41	0.017	0.332	0.347	0.399	0.264	1		
GDPpc	0.537	-0.22	0.033	-0.266	-0.17	-0.263	-0.157	-0.296	1	
IO	0.477	-0.256	0.068	-0.291	-0.217	-0.303	-0.11	-0.312	0.534	1

The results of the regression analysis in Table 3 indicate clear evidence of the role of renewable energy interventions, economic structures, and demographic characteristics in a combined form in the context of global policy instruments that seek the reduction of emissions in urban areas. The negative relationship between energy prices and urban emissions is consistent with the previous observations in the correlation matrix, and shows how energy prices can serve as a behavioural mechanism that can encourage consumers and industries to conserve energy or switch to more efficient and renewable energy sources. This result is in accordance with conceptual arguments presented by Grubler and Fisk (2012) exercising the role energy market structures play in bringing urban systems to the low carbon pathways. By discouraging overconsumption and providing incentives for efficiency improvements, energy prices are an indirect but meaningful part of an urban climate governance strategy. The influence of urban population growth seems statistically negligible, pointing to the conclusion that demographic expansion does not have a direct role in the pollution emission levels once the structural and policy variables are accounted for. This adds some weight to the argument made by Verma et al. (2021), who said that the effect of population growth is as much mediated through other factors, such as household consumption patterns, infrastructure pressures or land use changes, as it is a direct predictor of emissions. The failure to demonstrate a significant effect thus adds more force to the arguments that the roles played by policy design and economic activity are much more important than the mere increase in the population of cities in determining the environmental performance of cities. Several renewable energy policy instruments showed strong and significant negative relations with urban emissions and thus their effectiveness as regards the low-carbon transitions. Subsidies are one of the most influential tools to address a lot of the inability of ease of financial barriers to renewable energy adoption, and boost the uptake of energy utilisation technologies in urban sectors. This is in light of the findings of Lu et al. (2020), who found subsidies as basic mechanisms in driving forward the diffusion of renewable energy, in the case of cities, which are striving for swift decarbonization. Tax incentives also have a significant negative influence, which feeds back into their role for incentivising investment in green technologies in line with Sharifi and Yamagata's (2016) focus on economic levers to boost urban energy resiliency. Renewable portfolio standards are contributing further meaningfully to emission reduction and provide empirical evidence to support policy frameworks that require emission reduction through renewable energy quotas for utilities and energy providers. This reflects some of the observations made by Teske et al. (2018), i.e. the effect of the mandated renewable energy penetration changes the architecture of the energy system, and aims to reduce the fossil fuel reliance in urban environments.

Feed-in tariffs are negatively signed but do not seem to affect the model in any significant way. This may be suggestive of global trends illustrated by Davies and Allen (2013), who made a report on the policy fluctuations and inconsistencies that have challenged the long term viability of feed-in tariffs in many regions. Their limited effect here may suggest that feed-in tariffs require stable regulation environments and good institutional support to have any meaningful effect in downward pressurising emissions. Carbon pricing, on the other hand, has a significant and negative relationship with emissions and reinforces what has been established to be an effective tool to "encourage" carbon-intensive activities through being market-based. Zhou (2023) highlights that mechanisms of carbon pricing and carbon trading scheme functioning are an important part of modern policy applications to carbon neutrality, especially in urban settings where demonstration of carbon ending is promoted. Contrary to these signs of optimism in policy, the macroeconomic indicators reveal a conflicting story of the structural problems faced by the cities as they face developmental or expansionary trajectories. Specifically, per capita gross domestic product shows a statistically significant positive association with emissions, suggesting that municipalities with a higher level of income are more likely to produce emissions in spite of the fact that advanced technologies and instruments in policy are readily available. This apparent paradox is consistent with the current theory of urban metabolism proposed by Carreon and Worrell (2018), which argues that economic development usually leads to an increased demand for energy and greater industrial activity and thus to increased emissions in the absence of stringent sustainability interventions. Empirical evidence shows a positive and statistically significant link between industrial production and greenhouse gas emissions, thus proving the thesis that industrial production is an important determinant in the energy-intensive strata of the urban economy. Consistent with these findings, Almulhim et al. (2022) find that the never-ending expansion of industry creates non-decreasing pressure on urban emission paths despite the greening of the energy mix because of the increasing share of renewable energy. On the other hand, policy levers targeted to renewable energy (such as subsidies, fiscal incentives, renewable portfolio standards and carbon pricing) have indisputably proved their capacity to generate abundant emission abatements, thus revealing the need for a powerful policy architecture that will guide municipalities towards low-carbon affinities. The nexus of civil conflict and climate change comes down to economic infrastructure, in contrast to pedestrian transportation, to make a trip to a retail venue. In opposition, the opposing countervailing forces of macro-economic expansion and industrial dynamism pull strongly in the opposite direction and so throw light into the complex structural challenges of the decarbonisation of urban systems. Thus, the introductory quotation encapsulates these contrasting dynamics against the background of the broader overarching issues delineated by Espey et al. in their inquiry into transformative climate action, and there's no doubting that effective policy instruments have to be buttressed by recalibrations of economic modelling, fortification of institutional capacity and realignment of governance frameworks. The findings, therefore, highlight the importance of a comprehensive policy integration, technological innovation and continuous institutional adaptation in furthering the cause of global emission reduction initiatives in the latter.

Table 3: Regression Outcomes

Dependent Variable: Urban carbon emissions

Variables	Coefficient	Standard Error	t-Statistic	p-Value
Constant	0.5416	0.1717	3.7774	0
Energy Prices	-0.033	0.0088	-2.8389	0.002
Urban Population Growth	0.0048	0.0075	0.8025	0.48
Subsidies	-0.0727	0.0163	-5.0935	0.001
Tax Incentives	-0.0568	0.0165	-3.9604	0.001
RPS	-0.0343	0.0107	-3.6616	0.004
FiT	-0.0182	0.0245	-0.8291	0.39
Carbon Pricing	-0.0533	0.0238	-1.8948	0.031
GDP per Capita	0.0001	0	3.7661	0.005
Industrial Output	0.0036	0.0009	4.498	0

The results of this study, therefore, clearly confirm the effectiveness of renewable energy policies in curbing carbon emissions in cities, and they highlight that a number of policy instruments have large impacts, if implemented within metropolitan settings. The results of both regression and correlation analyses were consistent in that subsidies, tax incentives, renewable portfolio standards (RPS), and carbon pricing were highly related to declines in emission levels. In the correlation analysis, there were strong negative relationships between urban carbon emissions and renewable energy policies, among which, subsidies and carbon price were the most significant. This goes a long way in agreeing with Kshetri (2016), who states that financial mechanisms such as subsidies and tax incentives in stimulating the adoption of renewable energy are a very important tool, especially in highly populated urban areas where the demand for energy is concentrated. By easing financial problems and initial costs of technologies, such incentives make renewable energy solutions more available, all-inclusive, residential, industrial, commercial, etc., making the efforts towards transition more feasible. The outcomes of the correlation also demonstrated one of the primary arguments that policies regarding renewable energies must be introduced comprehensively, as they produce effects in the form of carbon emission reductions. The negative values of the correlation underline the idea that the higher the performance of the cities in the minimisation of emissions, the stronger the renewable energy system in the city, i.e. the organised financial incentives and regulation necessity. These outcomes make for a wider point that the only way of addressing urban emissions effectively will be by considering multiple renewable energy strategies rather than solely depending on a unique policy instrument. By working with layered policy approaches, cities can optimise energy system transitions and make sure they can help to make sustainable reductions in emissions.

Despite the good performance of most of the policy mechanisms included in this study, feed-in tariffs (FiTs) did not show a statistically significant relation to a reduction in emissions. The correlation between FiTs and emissions was found to be weak and negative, so in the cities considered, FiTs played little role in reducing carbon output. Although FiTs are generally recognised as having worked well to incentivise the output of renewable electricity, the impact of FiTs may differ depending on the maturity of the markets and local economic conditions. As argued by Mahim et al. (2024), FiTs tend to lead to better results in areas where the renewable energy markets are less developed or where alternative financial incentives are not available. In large urban centres which have mature electricity markets and a substantial range of financial programs, subsidies and tax incentives may produce more immediate and visible results in adoption than FiTs, which require stability over long periods to produce a significant shift. One of the most influential results of the study was carbon pricing. Cities that introduced carbon pricing mechanisms exhibited significant carbon emission reductions, which were confirmed by the high negative correlation between carbon pricing and carbon emissions. The current finding is in line with the current body of evidence showing that carbon pricing is one of the most effective tools to promote decarbonization of urban energy systems. Wasti (2023) further paints municipalities that adopt carbon pricing frameworks as having achieved accelerated progression towards low - carbon energy configurations since the increased costs of rock-derived electricity act as an accelerant for both households and industry towards a shift into cleaner energy sources. Moreover, by providing a direct monetary value for emissions, carbon pricing provides an economic stimulus to reduce consumption, improve efficiency and integrate renewable energy technologies into the energy mix. As a result, both businesses and individuals are incentivised to examine their energy habits and adopt greener options, because of which, carbon pricing acts as an agent of change, prompting so-called structural change on a grand scale. The study examined whether the growth of urban populations had any impact on the effectiveness of policies for renewable energy, but the research did not support the relationship. The correlation analysis revealed a weak positive relationship between population growth and emissions, as the correlation coefficient is only 0.05, indicating no meaningful correlation. Regression results supported the lack of significant statistical influence of population growth on emission levels. These results suggest that, although population increases generally lead to an increase in the demand for energy, effective renewable energy policies and urban planning can minimise the consequences of this demand on the environment. Dhakal (2009) observed similarly that urban centres with a robust efficiency policy and sustainability practices can be able to absorb increases in population size without corresponding increases in emissions. This underscores the importance of how advances in technology, infrastructural and energy levels can counter demographic pressures and therefore the population growth is not as relevant when strong sustainability measures are implemented.

Economic factors - in addition to GDP per capita and industrial output - showed significant positive correlations with carbon emissions, suggesting that increasing economic advances are synchronously associated with increasing emissions. These results indicate that policies for renewable energy may decelerate emissions, but the force of economic growth drives energy consumption and emissions upward. Kyriakopoulos et al. (2022) state that industrial growth, especially in sectors that demand large amounts of energy, e.g., heavy manufacturing, transport, and construction, has often resulted in more fossil fuel consumption and higher urban emissions. The present study gives reinforcement to the conclusion that, when seen in isolation, renewable energy policies are not likely to be sufficient to compensate for the emission pressures generated by economic expansion. Consequently, municipalities that are experiencing rapid economic growth may need to take more aggressive decarbonisation action, more stringent emission controls and industrial transformations in order to successfully mitigate their environmental impacts. Energy prices became a key factor determining the outcome of emissions. A statistically significant inverse correlation between energy prices and carbon emissions was identified, implying that rising energy prices correspond to a lower level of emissions. This relationship has a plausible mediating relationship with economic incentives: high energy costs provide incentives for consumers and businesses to curtail their consumption, to use more efficient processes or to use renewable alternatives. Jiang et al. further added that investments in energy efficiency and renewable energy systems are accelerated as a result of rising costs of energy, which reduces the attractiveness of energy based on fossil fuels. Elevated energy costs, therefore, make renewable technologies financially attractive to accelerate the speed of adoption, and therefore, cut emissions. The present body of research together brings out the key role that renewable energy policies will play in carbon emission mitigation within an urban setting, at the same time, revealing the need for more comprehensive and integrated policy frameworks. Although subsidies, tax incentives, carbon pricing, and renewable portfolio standards have the most empirically validated linkages with emission reduction, these are not sufficient to counter the economic and industrial forces that inevitably cause the seemingly inexorable cycle of urban demand for energy and correspondingly increasing growth. As a result, the results discuss the need for policies that create a diverse collection of mechanisms to make for deeper and more sustained reductions in carbon production. De Luca et al. (2021) exhibit supporting arguments for the use of multidimensional sustainability methodologies by means of the use of renewable energy, enhanced energy efficiency, superior technology, as well as the re-invention of urban models. Such holistic approaches are formative engagement matter-of-fact vital components to untangle the intrinsically linked dynamics of economic growth and emission growth in the special-case of cities where industrial activity is a significant source of economic performance. While the shift to renewable energy is important in terms of emission reduction, based on the study, this shift does not necessarily guarantee urban sustainability. Data show that cities which show extensive use of renewable energy experience economic improvements and industrial beings relaxed their emissions. Accordingly, policies on renewable energy should be accompanied by strong measures aimed at decarbonization of industry, promotion of clean industry, and development of green infrastructure, as well as deployment of energy-efficient technology. This is particularly important in fast-growing urban centres where energy-intensive economic activities are compounded by the use of potentially renewable resources.

The analysis goes on to call for "more emphasis on carbon pricing as a type of administrative tool to build a more sustainable urban energy landscape." Carbon pricing becomes one of the most significant predictors for emission reductions, which is in line with the literature outside this study, evidencing the massive influence of the aforementioned mechanisms on energy consumption patterns. Municipalities that have adopted carbon pricing have more opportunities to move towards decarbonization and energy diversification. This effect is probably the result of the negative economic incentives imposed by carbon pricing on carbon-intensive activities, coupled with greater investment in renewable energies and energy efficiency upgrades. These results provide support for advocacy for expansion of the integration of the carbon markets as well as improved-informed price determination mechanisms that have shown to be effective in enhancing the effectiveness of carbon pricing in urban settings. While the research is evidence for the usefulness of renewable energy subsidies, it shows the embodied complexity of urban energy systems, too. For example, the limited effectiveness of feed-in tariffs helps to make feed-in expert is likely to formulate and be uniform in all urban contexts. Feed-in tariffs may not be very efficient in places where there is already a renewable energy infrastructure in place, so other alternatives are of more use to consumers and corporations. The possible explanation for this, according to Mahim et al. (2024), feed-in tariffs are more effective in young renewable markets rather than mature markets. Thus, the policymakers must provide for the specific cities by developing policies for renewable energy suiting the economic, infrastructural and technological situation. Case studies in cities across the world also make clear that achieving effective policy alignment between energy, transport, housing and industry is critical in order to achieve maximum benefits from renewable policy incentives (Rivera et entretenant, 2023; Carvalho et правavant, 2022). Beyond the verification of the efficacy of policy, what all this shows is the complex interdependencies between the dynamics of demographic changes and GHG emissions. Although tempting to assume that population growth is responsible for growing emissions, the analysis presented here does not provide statistically significant evidence for this, thus debunking the conventional narrative about the risks of population increase on which such a premise is built, and restating the importance of a good policy framework to counter the risks of surging emissions linked to population increase. Dhakal (2009) argues that municipalities with a comprehensive energy planning set up and green infrastructure have a competitive advantage when it comes to dealing with population density and low emissions. These latter lessons show the significance of careful land use planning within cities, ways to broaden public transport and the need to prepare modern building codes which will enable cities to cope with demographic growth without the necessity of suburban sprawl.

Economic determinants further throw some light on the policy challenge: there is a clear positive correlation between GDP per capita, industrial production and carbon emissions, implying that economic development is further perpetuating pressure on energy consumption in urban areas. Kyriakopoulos et Tokio et al 2022 outline the importance of industrial growth, specifically Manufacturing and Logistics, to increase energy use and emissions. Accordingly, the conclusions developed in this study suggest that the measures taken to achieve the renewable energy objectives have not yet reached the highest level of decouple economic growth and emissions and as a result demand more wheel-walking approaches. Such strategies may include electrification of industrial processes, development of new industrial green zones and enhanced overall use of renewable energy sources in high-consumption industries (Lopez et al., 2024; Martins et al., 2022).

Energy pricing is used and takes centre stage in emissions regulation. The intimate inverse relationship of energy prices and carbon emissions implies that the mechanisms of pricing affect the behaviour of consumers and economic actors with respect to energy. As a result, the high energy costs make energy conservation and the use of renewable energies more attractive. Kim et al. (2023) have gone in a similar vein and argue that if energy prices increase, then investment in energy-efficient and renewable systems can be initially delayed, and this can reduce the perception of synergy between monetary incentives and environmental outcomes. These findings underscore the importance in correct-designed pricing policies to disincentive usage of fossil fuels, disencouraging consumption of fossil fuels and arable renewable alternatives. An integrated approach is needed that utilises renewable energy sources, increased efficiency, industrial transformation, technology development and carbon pricing will be important to the successful restructuring of city energy systems. De Luca et al. (2021) argue that it is required to make sustained and significant emissions reductions, and this includes comprehensive climate strategies by targeting all relevant and major emissions sources. This study shows a further affirmation of the critical importance of renewable energy policies as key instruments in promoting urban sustainability, while at the same time, revealing the need for such policies to be integrated within a broader process of economic restructuring, technological innovation and environmental governance to realise their full potential.

5. CONCLUSIONS

This research aims to present a more in-depth field of knowledge concerning the mechanisms of how renewable energy policy frameworks could deliver mitigation of carbon emissions under an urban context. The analysis shows that policies that increase accessibility and competitiveness of renewable energy are a key factor in determining the way that municipalities around the world use and produce energy. Such measures contribute to the shifting of energy demand to other, less polluting sources while at the same time offering attractive motivation for industries, businesses, and homes to invest in technologies with less negative impact on the environment. In parallel, the results suggest that the effectiveness of different policy instruments varies in the different regions, based on the local contextual variables, market structures and current economic conditions. This therefore brings out the need to make policy designs fit the peculiar idiosyncrasies of particular urban settings. A salient insight to emerge out of this inquiry is that, though urban population growth is one of the principal determinants of aggregate energy demand would not necessarily have a proportional correlation with the emissions reduction that is achieved by policy interventions. Rather, it is some combination of industrial activity, economic growth and the structural attributes of the urban economy that determines outcomes. Energy-intensive sectors (like manufacturing), therefore, remain the major driving force in the levels of emissions, so policymakers must be tackling the base causes of these sectors. Accordingly, it is emphasised in the study the importance of strengthening policies on renewable energies with complementary policies that are focused on processes of production, energy efficiency and technological advancement. When these elements are integrated, cities have a large capacity to deal with emissions and, at the same time, contribute to economic progress. The study does not, however, ignore several limitations which limit the extent of conclusions drawn from the study. Reliance on information already collected and attention to a small set of policies provide possibility for further inquiry. Future research stands to benefit from the analysis of the use of renewable energy measures in certain sectors, the long-term impact of policies and the value of public participation in ensuring the success of environmental initiatives. Expanding to collect and use urban environments in others, particularly in the developing world, the third world, could offer a more subtle understanding in terms of the adaptability and scalability in different settings for renewable energy approaches. Overall, the findings are in support of the continued use of renewable energy policies as a means of curtailing carbon emissions in the city. Their effectiveness, however, is maximised if they work as part of a holistic system of related environmental and economic measures. Policymakers are therefore needed to further develop these strategies and consider steering these strategies in new and progressive directions, with regard to the complexity inherent in using urban development. Through continued innovation and collective action, cities can come closer to achieving long-term and low-carbon growth and environmental resiliency.

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