Cities and Global Sustainability: Insights from Emission and Ecological Efficiency

In the wake of 21st century, humanity witnessed a phenomenal raise of urban agglomerations as powerhouses for innovation and socioeconomic growth. Driving much of national (and in few instances even global) economy, such a gargantuan raise of cities is also accompanied by subsequent increase in energy, resource consumption and waste generation. Much of anthropogenic transformation of Earth's environment in terms of environmental pollution at local level to planetary scale in the form of climate change is currently taking place in cities. Projected to be crucibles for entire humanity by the end of this century, the ultimate fate of humanity predominantly lies in the hands of technological innovation, urbanites' attitudes towards energy/resource consumption and development pathways undertaken by current and future cities. Considering the unparalleled energy, resource consumption and emissions currently attributed to global cities, this thesis addresses these issues from an efficiency point of view. More specifically, this thesis addresses the influence of population size, density, economic geography and technology in improving urban greenhouse gas (GHG) emission efficiency and identifies the factors leading to improved eco-efficiency in cities. In order to investigate the influence of these factors in improving emission and resource efficiency in cities, a multitude of freely available datasets were coupled with some novel methodologies and analytical approaches in this thesis.

Merging the well-established Kaya Identity to the recently developed urban scaling laws, an Urban Kaya Relation is developed to identify whether large cities are more emission efficient and the intrinsic factors leading to such (in)efficiency. Applying Urban Kaya Relation to a global dataset of 61 cities in 12 countries, this thesis identified that large cities in developed regions of the world will bring emission efficiency gains because of the better technologies implemented in these cities to produce and utilize energy consumption while the opposite is the case for cities in developing regions. Large cities in developing countries are less efficient mainly because of their affluence and lack of efficient technologies. Apart from the influence of population size on emission efficiency, this thesis identified the crucial role played by population density in improving building and on-road transport sector related emission efficiency in cities. This is achieved by applying the City Clustering Algorithm (CCA) on two different gridded land use

datasets and a standard emission inventory to attribute these sectoral emissions to all inhabited settlements in the USA. Results show that doubling the population density would entail a reduction in the total CO_2 emissions in buildings and on-road sectors typically by at least 42 %. Irrespective of their population size and density, cities are often blamed for their intensive resource consumption that threatens not only local but also global sustainability. This thesis merged the concept of urban metabolism with benchmarking and identified cities which are eco-efficient. These cities enable better socioeconomic conditions while being less burden to the environment. Three environmental burden indicators (annual average NO_2 concentration, per capita waste generation and water consumption) and two socioeconomic indicators (GDP per capita and employment ratio) for 88 most populous European cities are considered in this study. Using two different non-parametric ranking methods namely regression residual ranking and Data Envelopment Analysis (DEA), eco-efficient cities and their determining factors are identified. This in-depth analysis revealed that mature cities with well-established economic structures such as Munich, Stockholm and Oslo are eco-efficient. Further, correlations between objective eco-efficiency ranking with each of the indicator rankings and the ranking of urbanites' subjective perception about quality of life are analyzed. This analysis revealed that urbanites' perception about quality of life is not merely confined to the socioeconomic well-being but rather to their combination with lower environmental burden.

In summary, the findings of this dissertation has three general conclusions for improving emission and ecological efficiency in cities. Firstly, large cities in emerging nations face a huge challenge with respect to improving their emission efficiency. The task in front of these cities is threefold: (1) deploying efficient technologies for the generation of electricity and improvement of public transportation to unlock their leap frogging potential, (2) addressing the issue of energy poverty and (3) ensuring that these cities do not develop similar energy consumption patterns with infrastructure lock-in behavior similar to those of cities in developed regions. Secondly, the on-going urban sprawl as a global phenomenon will decrease the emission efficiency within the building and transportation sector. Therefore, local policy makers should identify adequate fiscal and land use policies to curb urban sprawl. Lastly, since mature cities with well-established economic structures are more eco-efficient and urbanites' perception reflects its combination with decreasing environmental burden; there is a need to adopt and implement strategies which enable socioeconomic growth in cities whilst decreasing their environment burden.