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Urbanization, energy consumption and emissions in the Indian context A review

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ABSTRACT

As the world's fastest growing major economy and home to nearly one-fifth of the worlds population, India a vibrant democracy is in the midst of a profound transformation and rapid urbanization. Urbanization improves the quality of life of people while promoting economic growth; however it also increases energy consumption and is capable of generating an energy crisis. Urbanization has a significant impact on Carbon Dioxide (CO_2) emissions as well. This paper empirically investigates the temporal, dynamic and causal relationships between urbanization, energy consumption and emissions. The study also aims to understand the urbanization process in India, in terms of the level and tempo of urbanization and the urban growth morphology, by utilizing the census data of 1901–2011. The rise in energy consumption and resulting emissions in the context of rapid urbanization is also reviewed. To address these problems the study recommends a series of measures and a set of strategies that include energy intensity and emission intensity reduction measures through continuous monitoring, information feedback systems, introduction of industrial energy quota management, incentives for energy efficient facilities, shutting down of inefficient facilities, and setting up of smart residential buildings. Reduction of distribution and transmission losses by investing in smart grids is also highly recommended.

1. Introduction

Urbanization may be defined as a social process significant to human society in the 21st century. Cities grow due to the continuous flow of people into cities. When this flow stops, urbanization comes to a standstill [1]. Hiroshi Morikawa [2] defines urbanization as a transformation of life style of the rural population combined with expansion of urban built-up area. Pacione [3] states that urbanization is accompanied by an increase in urban population followed by urban growth and urbanism a term referring to the urban life style and social behavioural features. A comparative study of the process of urbanization in different countries reveals the fact that the path of urbanization adopted by different countries is based on their cultural background and stages of development [4,5]. It is very difficult to quantify urbanization, which is basically a process of progressive concentration [6], as the nation evolves from an agrarian to industrial society [7]. This modern process of urbanization is a relatively new phenomenon and is closely associated to the industrial revolution. Historical evidence proves that it is a universal process that is inevitable [8]. Most developed countries, in their final stages of urbanization are experiencing a slowdown [9].

Urbanization in India is occurring at unprecedented rates. The 1901 census states that the population residing in urban areas was 11.4% which has increased to 31.2% by 2011, a figure much lower than most of the developed countries [10]. The projected population at the end of 2015 in the city of Mumbai is 25 million, Delhi 16 million, Kolkata 16 million, while Chennai, Bengaluru and Hyderabad will have 10 million each [11,12]. 40.8% of India's population will be urbanized by 2030, according to the UN "State of World Population Report" of 2007 [13]. This would mean an increase in urban population from 390 million to almost 600 million in the next 15 years. Urbanization has a significant impact on the consumption of energy and CO_2 emissions, however the influence varies based on the stage of economic development of the region [14].

The concern regarding the impact of urbanization on the environment and in causing the energy crisis has risen and hence several researchers have investigated from various perspectives the connection between urbanization, consumption of energy and CO_2 emissions [15]. Some of these studies are listed in Table 1. The literature survey and review reaffirms the concern of researchers regarding urbanization,

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Table 1
Summary of recent analyses on urbanization, energy consumption, and CO_2 emissions.

Study	Dependent variable	Method	Country/ies (period)
Ullash [48]	Energy and emissions	Long range energy analysis using TIMES Modelling Framework	India / 1990–2100
Ramchandra [38]	Energy Security and lowering energy dependency	NA	India / 2006–2031
Shahbaz and Lean [44]	Financial Development and Energy Consumption	Autoregressive Distributed Lag (ARDL) bounds testing approach	Tunisia / 1971–2008
Poumanyvong and Kaneko [22]	Urbanization, energy use and emissions	Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model	99 countries / 1975–2005
Wang et al. [89]	Energy related CO_2 emissions	STIRPAT model	Guangdong province, China /2005–2009
Mukesh et al. [90]	CO_2 emissions from India's power sector	Clean Coal Technology	India / 2014–2050
Yabo and Shaojian [39]	Urbanization, Economic growth and Energy consumption	Econometric models and Vector-error correction model (VECM)	China / 1980 –2012
Salim and Shafiei [91]	Renewable and non-renewable energy consumption	STIRPAT model	OECD countries / 1980 – 2011
Kakali and Debesh [92]	Energy consumption	Structural Decomposition Analysis (SDA) method	India / 1973–1992
Ghosh and Kanjilal [43]	Urbanization, Economic growth and Energy consumption	Autoregressive Distributed Lag (ARDL) bounds testing approach	India / 1971 – 2008
Jyoti and Kirit [93]	Energy needs and CO_2 emissions	Energy efficiency (EE) / Demand side management (DSM) scheme	India /1980 –2031
Chaolin et al. [1]	Urbanization	NA	China / 1970–2012
Ke and Boqiang [14]	Urbanization, industrialization, energy consumption and emissions	STIRPAT model	73 countries / 1971–2010
O'Neill et al.[94]	Energy consumption	Integrated Population-Economy-Technology-Science (iPETS) model, computable general equilibrium (CGE) model	India and China / 2000 – 2100
Yaobin [57]	Urbanization and energy consumption	Autoregressive Distributed Lag (ARDL) and Factor Decomposition Model FDM	China /1978–2008
Richard et al. [20]	Environmental impacts	STIRPAT, IPAT and imPACT	Cross national
Ying et al. [28]	CO_2 emissions	STIRPAT	Different countries / 1975–2000
Shoufu et al. [29]	Environmental impact	STIRPAT	China / 1978–2006
Richard et al. [27]	Climate change	STIRPAT	Global
Brant and Sidney [30]	Age-structure, urbanization and Climate change	STIRPAT	Developed countries
Inmaculada and Antonello [26]	Urbanization and CO_2 emissions	Semi-parametric mixture model	Developing countries / 1975–2003
Zhang and Lin [23]	Energy consumption and CO2 emissions due to urbanization	STIRPAT	China

energy consumption and CO_2 emissions at the national level. There is no widely accepted consensus at the national level which all scholars can follow. In order to affirm a positive correlation between urbanization or industrialization and the use of energy, earlier studies have relied on datasets from a cross-section of countries [16–20]. A study by Azam et al. [21] found that urbanization had profound statistical impacts on energy consumption in Thailand and Indonesia. Poumanyvong and kaneko [22] used the STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model to investigate the effects of urbanization on energy consumption in a balanced dataset of 99 countries over the period of 30 years from 1975–2005. Using the same model Zhang and Lin [23] found an increase in consumption of energy and CO_2 emissions due to urbanization in China. Identical conclusions were drawn from the province of Guangdong [24] and Beijing in China [25]. Inmaculada and Antonello in their study on a sample of developing countries, found an inverted U-shaped relationship between urbanization and emissions of CO_2 [26]. An interesting relationship was established by Richard et al. [20]. They found that population had a unitary elastic effect on CO_2 as well as on the energy footprint. Another study by the same team of researchers [27] concludes that affluence drives emissions and that non-tropical nations show higher emissions as compared to non-tropical nations. Ying et al. [28] in their study indicated that the impact of population, technology and affluence on CO2 emissions is dependent on the level of development of that particular country. Research done by Yaobin Liu [52] using Auto Regressive Distributed Lags (ARDL) and the Factor Decomposition Models (FDM) suggests that enhancement of energy efficiency coupled with the acceleration of the process of urbanization could help in sustainable development. Shoufu et al. [29] were able to prove that the effect of GDP per capita on the environment was much higher than the effect of increasing population. Brant and Sidney [30] on the other hand established a positive relationship between urbanization and energy consumption especially in the residential sector.

2. Urbanization trend in India

India follows the characteristic features of urbanization of developing countries. The number of urban agglomeration (UA) / town has increased from 1827 in 1901 to 7935 in 2011. The total population grew from 238.4 million in 1901 to 1210.2 million in 2011, a five-fold growth, whereas the urban population has risen from 25.85 million in 1901 to 377.1 million in 2011, a growth of almost fifteen times (Table 2). The process of urbanization in India is depicted in Fig. 1. The graph reflects a gradual increasing trend of urbanization. India is passing through an accelerated stage of urbanization.

3. Changes in degree of urbanization

The degree of urbanization may be measured using the percentages of urban and rural population and also the urban to rural population ratios. Urban to rural population ratio is an index to estimate the number of urbanites for every rural person within a geographical areal unit. Table 3 gives the index of urbanization from 1901 to 2011, in