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Economic disparity and CO_2 emissions: The domestic energy sector in Greater Bangalore, India

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ABSTRACT

Energy consumption constitutes one of the important sources of carbon dioxide emission which cause global warming. This paper analyses greenhouse gas (GHG) emissions due to energy consumption in the domestic sector considering household activities and socioeconomic parameters. A stratified random survey of 1967 households in Bangalore pertaining to the energy consumption reveals that annual per capita electricity consumption ranges from 9.64 to 2337 kW h/year with an average of 336 ± 267 kW h/year. Emission from most of the wards (66 wards) is about 10–15 Gg/year, while wards in peri-urban areas emit less than 10 Gg/year. Extrapolation of these, show that total carbon dioxide from all wards of Greater Bangalore accounts to 3350 Gg/Year. The energy consumption analyses reveal a proportional increase in the per capita energy consumption with the family income suggesting that economic levels in respective wards is an important parameter in the domestic energy consumption and also GHG emissions. Suggested interventions through large scale penetration of renewable sources of energy and energy conservation would help in reducing greenhouse gases and consequent warming of the Earth.

Contents

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1. Introduction

Energy constitutes a fundamental and strategic tool to attain the minimum quality of life and energy consumption patterns are closely linked to the agro-climatic conditions and socio-economic factors [1,2]. Recent estimates indicate of sharp escalation in the energy demand, increasing by one-third over the period to 2035 [3]. The study also highlights of an increase of approximately 56% during next two decades of energy demand, which are mainly from the domestic sector (raise from 524 quadrillion Btu in 2010 to 820 quadrillion Btu in 2040 [3]. Exploitation and conversion of natural resources through various energy conversion devices for heating, lighting, etc. have made significant improvement in life-styles. The dependency of human on energy has increased from 2,500 kJ/day to more than 2 lakh kJ/day. India is the seventh largest geography and ranks fourth among high energy consuming countries in the world with over 1.27 billion population. During past three decades, energy consumption has increased from 18 MTOE (in 1980) to 104 MTOE (2011) in India [4]. The per capita energy consumption is higher in the developed nations (USA-7.3 TOE, Canada- 7.6 TOE, Japan 3.7 TOE) compared to the developing (India-0.6 TOE, China- 1.8 TOE, Brazil-1.4 TOE) and less developed nations (<0.4 TOE). Energy consumption per capita versus GDP per capita among the countries (Fig. 1) reveals Norway is high in GDP per capita (99,933 million USD) followed by Switzerland (79,024 million USD), Australia (65,430 million USD) and Sweden (55,341 million USD) which shows the effective utilization of energy. The per capita GDP value of India is 1555.50 million USD, which is lowest among these countries. Energy intensity of India is about 0.42 kgoe/million USD which is more than 12 times that of Switzerland (0.033 kgoe/million USD), more than 4 times that of Germany (0.092 kgoe/million USD), more than 3 times that of USA (0.137 kgoe/million USD) and about 1.3 times that of China (0.325 kgoe/million USD) in illustrated in Fig. 2. Most of the Asian countries have high energy intensity (energy/GDP) and lower per capita consumption, which illustrates the inefficient use of energy [5,6]...

However, over exploitation of natural resources especially fossil fuels for meeting the ever increasing energy demands and unplanned developmental activities has affected the environment and health [7–9]. Conventional fossil fuels in the form of coal, diesel, petroleum (gasoline) and electricity used by road, rail and air are responsible for emission of 80%, 13% and 6% respectively [10]. Consumption of fossil fuels is the prime reasons for enhanced greenhouse gases (GHG) in the atmosphere trapping heat and light in the earth's atmosphere, resulting in the global warming. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulfur hexafluoride (SF6) are the major greenhouse gases. Among the GHG's, carbon dioxide is the most predominant gas causing global warming [11].

In developing countries like India, the urban population is growing at rate of 2.3% per annum and global urban population is increasing from 220 million in 1900 to 3.2 billion in 2005 and is

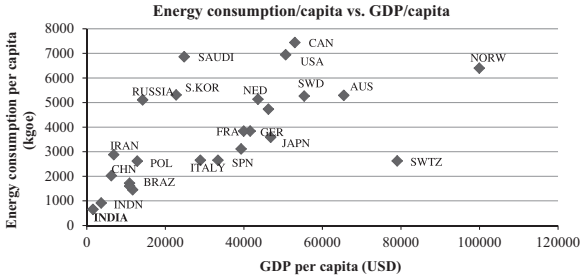

Fig. 1. Country wise energy consumption per capita versus GDP per capita.

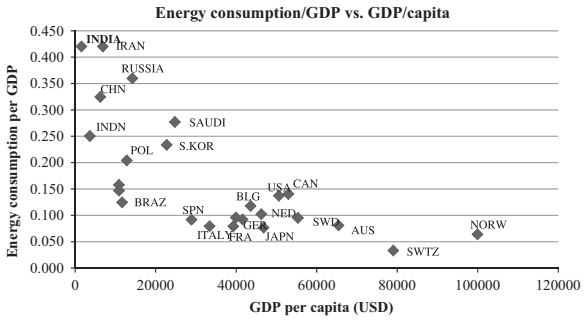

Fig. 2. Country wise energy consumption per GDP versus GDP per capita.

projected to step up to 4.9 billion by 2030 [11]. In terms of the global total anthropogenic GHG emission, cities contribute roughly 75–80% and the domestic sector is one of the major energy consumer in cities [10]. Assessment of GHG footprint (Aggregation of Carbon dioxide equivalent emissions of GHG's) across major cities in India reveals of emissions to the tune of 38633.2 Gg, 22783.08 Gg, 14812.10 Gg, 22090.55 Gg, 19796.5 Gg, 13734.59 Gg and 9124.45 Gg CO_2 eq respectively in Delhi, Greater Mumbai, Kolkata, Chennai, Greater Bangalore, Hyderabad and Ahmedabad. Sector-wise synthesis indicate that transportation sector (contributing 32%, 17.4%, 13.3%, 19.5%, 43.5%, 56.86% and 25%), domestic sector (contributing 30.26%, 37.2%, 42.78%, 39%, 21.6%, 17.05% and 27.9%) and industrial sector (contributing 7.9%, 7.9%, 17.66%, 20.25%, 12.31%, 11.38% and 22.41%) of the total emissions in Delhi, Greater Mumbai, Kolkata, Chennai, Greater Bangalore, Hyderabad and Ahmedabad respectively [11]. Macro-level analyses emphasized the need for detailed investigations to major sectors such as transportation [10] and domestic sectors.

This communication focusses on the GHG emissions due to energy consumption in the domestic sector considering household activities and socioeconomic parameters. Domestic energy consumption has various interrelated characteristics (ex. regional climate, building architecture, etc.). During the last decade, empirical studies have been receiving good attention in terms of domestic consumption and have included factors that are economical important such as fuel prices and economic stability [12] and variants of analytical techniques [13]. Most of these studies use aggregated time series data, and only a few research involves household-level data [14]. In India, these studies are limited [15] focusing on household socio-economic, demographic, geographic factors role in energy consumption. Estimation of residential energy demand in Seoul [16] based on 380 household samples revealed that the energy consumption pattern depends on the variables such as size of a house [17,18], family size, level of affluence, etc. [13,19,20].

Urban areas support 50% of the world population and are responsible for 67% of the world's energy demand and these region are under acute problem of energy consumption and GHG emissions [21]. It is estimated that by 2030, 73% of the world energy use will be in cities [22]. Urban households in India, for example, are responsible for about 45% of total primary energy use nationwide [23]. The sector wise temporal electric energy consumption in India (Fig. 3) shows that the industries sector is the highest consumption with 44.8%, followed by agriculture (17.3%), domestic (22%) and commercial sector (9%) [24]. Socio-economic growth coupled with urbanization, industrialization and burgeoning population lead to increase in the residential energy consumption for heating, lighting, electric appliances in many towns and cities in India [10] and the increase in energy demand is proportional with the urban growth [25]. Energy is required for heating, lighting, and motive power (to pump water, compressors, etc.) in the urban domestic sector and the increase in energy