VOLUME 34 NUMBER 8 AUGUST 2009

ISSN 0360-5442

ELSEVIER

TECHNOLOGIES RESOURCES RESERVES DEMAND

ENERGY

IMPACT CONSERVATION MANAGEMENT POLICY

The International Journal

SPECIAL ISSUE

Energy and its sustainable development for India

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SPECIAL ISSUE

Energy and its sustainable development for India

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Energy 34 (2009) 923–927

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Editorial

Energy and its sustainable development for India, Editorial Introduction and commentary to the Special Issue of Energy – The International Journal

1. Introduction

It gives us great pleasure to present this SI (Special Issue) "Energy and sustainable development for India" of ENERGY – The International Journal. The recent concern for energy and climate change has brought countries together in a globalised world. India as well as the world are watching the need for India's energy and associated greenhouse gas (GHG) emissions.

This **Editorial Introduction** provides a very brief summary of the most recently available energy and emissions data,[1] outlines the structure of the SI, fills some information gaps, and offers brief comments for some sustainable paths to the future.

2. Current developments in India

It is necessary to have a broad picture of current energy developments in India to appreciate the articles of the SI in qualitative and quantitative terms as well as in comparative terms with other countries and the world as whole.

2.1. *Population and overall energy data [1–6]*

India, at 1.17 billion people, is the second most populated country in the world and is home to 17% of the world population. Its primary energy consumption (in 2007) was 18.65 EJ, 3.75% of the entire world. It amounts to 15.9 BJ/person-year. With a world average consumption of 72.4 BJ/person-year, China's of 56.2 BJ/person-year, Europe's of 146.2 BJ/person-year, and U.S. of 355.5 BJ/person-year, and with India's strong GDP (Gross Domestic Product) growth of about 9% (2007, expected to drop somewhat due to the current worldwide economic turndown) and a relatively high population growth of 1.55% (compared with 0.65% for China, 0.97% for the U.S., 0.11% for the European Union, and 1.17% for the world, all 2009 estimates), it is obvious that significant growth is expected as the people of India increase in number and strive to improve their standard of living.

The fractions of the energy resources supplying the primary energy demand are shown in Fig. 1. More than half is met by coal, 10% of which is imported. It is also noteworthy that much animal power is used (according to some: estimates 12,000 MW, or about 8% of the installed electric capacity [7]) but the share of animal power and non-commercial biomass is dropping every year due to economic progress.

Nuclear power generation in India is not addressed in the SI in detail, and a few very brief comments about this important subject follow. India generates only 2.5% of its electricity from nuclear power, but 6 new reactors are under construction (second only to the Russian Federation, at 7) and there are plans to increase this fraction, especially encouraged by the signing in 2008 of the India–U.S. nuclear agreement, in which the ban on nuclear technology and fuel trading with India was lifted. It was initially proposed to allow India to add 25,000 MWe of nuclear power capacity (about 16% of India's current electricity production) through foreign fuels and technology. While nuclear power use reduces CO_2 (carbon dioxide) emissions, the problems of waste storage, proliferation risk, and to some extent safety, that have arrested nuclear power growth in many countries, remain largely unresolved so far.

In 2008 India's per capita GDP (PPP (purchasing power parity) $ of the year 2000) was $2800, with annual growth rate of 3.7%. To avoid confusion it is noted that the overall real GDP (not PPP nor per capita) growth was 9% in 2007.

The energy intensity, in 2007, in MJ per PPP $ of the year 2000, of India was 7.9, as compared for example with that of 13.8 of China, 6.9 of Europe, and 9.3 of the U.S. There is always room for improvement, but it also depends on the choice of economic products: financial activities such as banking, or computing and software development, have a very low energy intensity, while manufacturing products such as aluminum, steel, glass, plastics and paper have a very large one.

India continuously faces severe electricity shortages, which are estimated by the government to be eliminated by adding about 63% generation capacity by the year 2012. It is noteworthy that transmission losses are very high, approaching 40% in part due to grid problems and in part due to illegal unpaid use.

Despite a recent drop in economic growth rate, India's energy demand continues to increase. Energy demand in the transport sector is expected to be particularly high, as vehicle ownership is increasing rapidly.

2.2. *Greenhouse gas emissions [1,4,5,8]*

To consider one environmental impact criterion into account, energy-related CO_2 emissions (2006) for India were 1300 million

[1] The data is mostly for the years 2006/2008. Some differences exist between the data in the Editorial Commentary and those in the SI papers, as well as between those among some of the individual papers, mostly because the data used were not always for the same year as sources. Furthermore, a sad fact is that there is a large uncertainty in the accuracy and completeness of the energy data from and about India, as also noted in the SI paper by *Gielen and Taylor*.

0360-5442/$ – see front matter
doi:10.1016/j.energy.2009.07.001

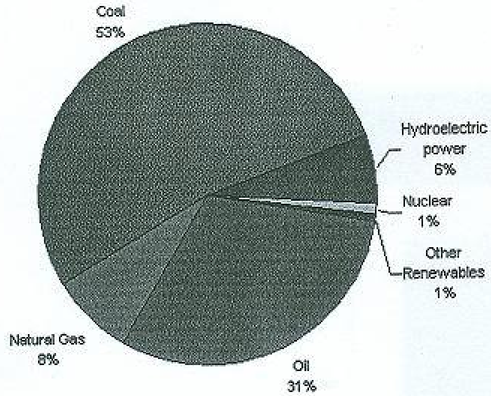

Fig. 1. Total energy consumption in India, by type (2006) [5].

metric tons (4.4% of the world total), i.e. 1.16 metric tons per capita. In comparison, those for China were 6012 million metric tons (4.58 metric tons per capita), OECD (Organization for Economic Co-operation and Development) Europe 4429 million metric tons (8.2 metric tons per capita), and the U.S. 5900 million metric tons (19.57 metric tons per capita). Based on PPP GDP, the CO_2 emissions are 0.34 metric tons per thousand PPP $ of the year 2005, as compared with 0.65 for China, ~0.33 for OECD Europe, and 0.51 for the U.S. [5]. This is relatively not bad for India as a country that primarily uses coal.

2.3. Fuel switching and new technologies

Substitution of other oil and natural gas for coal would significantly reduce CO_2 emissions but is not likely to increase much because of the scarcity of these fuels and the abundance of coal. Most of the natural gas is imported, with increasing priority for fertilizer production and other chemical processes, and not power generation. At the same time, development of advanced technologies for the conversion of coal to oil, and especially to synthetic gas, as well as new power generation systems such as the IGCC (integrated gasification combined power cycles) could help in this direction.

2.4. Renewable energy

Opportunities for lowering the CO_2 emissions to PPP GDP $ ratio obviously reside in reducing emissions and/or increasing the PPP GDP. Increased use of renewable energies will enable the former, traditionally by use of hydropower and biomass that together already supply about 7% of the total energy demand, and more recently by the rapid increase in use of wind power (mostly motivated by tax benefits) that brought its installed peak capacity to about 6000 MWe.

While about 1.65 million m^2 of water heating solar collectors are installed in India, it is a minute fraction of both the potential and the overall energy consumption. A growing but miniscule amount of electric power is generated by photovoltaic devices. Both wind and solar power generation are at least two orders of magnitude below potential, thus allowing large expansion if the economics permit. A critical need for the increased use of inherently intermittent renewable sources of energy such as wind and solar, for electricity generation, is the availability of an extensive and smart electricity distribution grid.

Large expansion of the use of biomass and hydropower, by perhaps more than an order of magnitude for the former and three-fold for the latter [9], is feasible based on resource availability, but sustainability has to be proven. Typical of agrarian societies, biomass has played an important role in India's energy supply, and continues to do so. A major drive is underway for its expansion, including efficient biomass stoves, biogas, biomass combustion and gasification and process heat and liquid fuels (mostly biodiesel), but it hasn't had much effect yet, for both economic and policy reasons.

Biomass energy has the very important benefits of contribution to the security of fuel supply, somewhat lower greenhouse gas emissions, and support for agriculture, but there are also some important concerns and obstacles. These include the fact that bioenergy production and policies have mostly not been based on a broad cost/benefit analysis at multiple scales and for the entire production chain, which is particularly true for bioenergy's impact on agriculture (for brief summary cf. [10]). Due to increasing concerns about the effects of biomass use on water, land, and the environment in general, and on food prices, a thorough sustainability analysis of biomass use in India is warranted.

In general, it is felt that rational government policies, focusing on the economic aspects, and aided by employment of the CO_2 mitigation CDM (Clean Development Mechanism) to infuse foreign investment and technology, would be very helpful in advancing the use of bioenergy in India.

2.5. Energy, economics, and efficiency [1,3,11]

The prevailing opinion among researchers is that a relationship exists between economic growth and energy consumption, but the direction of the causation of these relationships, i.e. whether increase in energy consumption drives GDP growth or the other way around, or both, is not always clear and varies for different countries (cf. [12]). Denmark for example has demonstrated that wise energy and economy management resulted in the doubling of the GDP over the 35-year period between 1972 and 2006, without change in energy consumption and with a 10% population growth during the same period. While the circumstances for Denmark and India are very different, it would be unwise to presume in planning that growth of GDP automatically requires a commensurate growth of energy consumption. Planning should, on the contrary, be based on GDP growth with minimal energy consumption growth. We also note that while GDP is an important economic index, it is not the only criterion for standard of living and happiness, and is overused and often misused.

3. The structure of the SI and introduction to articles

Kirit Parikh, Vivek Karandikar, Ashish Rana and Prasanna Dani: We begin with this overview of India's energy scene today that introduces a model that projects demand and supply scenarios up to 2030. This was behind the document of Integrated Energy Policy (2007) for India that was approved by the cabinet of ministers in India subsequently in 2008. This model is brought into public domain for the first time as a journal article here. It provides modeling framework, based on an activity analysis model. The paper looks at how India needs to deviate from a business-as-usual scenario based on coal, by gaining from higher energy efficiency, renewable energy, and gets also to reduce CO_2 emissions. They explained that to formulate energy policy, one needs to know the contours of energy requirements and options. Results show that energy efficiency emerges as a major option with a potential to reduce energy requirement by as much as 17%. Eleven alternate scenarios were built to map out feasible options. Scenario results indicate a pressing need for development of alternative sources of energy and energy efficiency.

This paper then also provides the framework for the SI. Various detailed articles on the above topics viz: coal, gas and renewable energy were therefore invited. Even today non-commercial energy (fuelwood, crop residue and animal dung) form 28% of the energy share, Unsatisfied needs of the developing countries like India are a matter of concern, where 600 million people do not have access to LPG (liquefied petroleum gas) and Kerosene as shown by one of the papers. Therefore, the papers on household energy and biomass were also included.

3.1. Fossil fuels, renewables and energy efficiency

Then we move on to two papers on fossil fuels, two on renewable energy and one on energy efficiency.

Ananth P. Chikkatur, Ambuj D. Sagar and T. L. Sankar present India's coal scene and identify sustainability concerns from resource extraction, costs' regulation and environment's point of view. Key challenges for the sustainable development of coal, and proposed policy approaches and suggestions are presented, showing that 30% of India's total energy needs are met through imports.

Jyoti Parikh, C. R. Dutta Biswas, Chandrashekhar Singh and Vivek Singh explain that natural gas is one of the important and cleanest form of energy derived from the fossil fuel basket and fuel choice for many section of India industry particularly coal and power sector where allocation is based on the priority basis. Demand projection of natural gas for next two decades is analyzed and reviewed in the context of changing government policies. They analyze various scenarios especially for fertilizer – which is considered a priority sector for natural gas given the importance of agriculture for the large population. However, this non-energy use of natural gas diverts from its availability for power.

Dolf Gielen and Peter Taylor from IEA (International Energy Agency) in Paris present energy efficiency picture of India's industry sector and compare with the global scene. Certain sectors such as cement are relatively efficient while others such as pulp and paper are relatively inefficient.

Indu R. Pillai and Rangan Banerjee observe that despite significant progress in renewable energy, the share of modern renewables in the energy mix is marginal in India. A diffusion model is used as a basis for setting targets and is fitted to the past trends for wind, small hydro and solar water heating. The economic viability and greenhouse gas saving potential is estimated for each option.

S. C. Bhattacharya and Chinmoy Jana: Promoting renewable energy in India has assumed great importance in recent years. Wind energy has achieved the most dramatic growth rate and success in India. However, with a capacity factor of 0.14 they would produce about 840 MWe, still only 0.6% of the overall electric generation capacity. After many years of slow growth, demand for solar water heaters appears to be gaining momentum. Small hydro has been growing in India at a slow but steady pace.

3.2. Household energy and biomass

B. Sudhakara Reddy and T. Srinivas: They have analyzed the pattern of the energy consumption in the household sector and the causalities underlying the present usage patterns. "Actor-oriented" analysis was also referred to in which we understand how various actors of the energy system are making the system work, and what incentives and constraints each of these actors is experiencing.

N. H. Ravindranath and P. Balachandra: As explained, biomass and household energy are very important from the point of view of access to energy. Alternate energy sources may be critical for the sustainable development of the energy starved Indian economy. Authors discuss the potential role of bioenergy to meet the rural energy needs.

Pallav Purohit: A variety of policy measures including fiscal and financial incentives have been adopted by the government of India for promotion of solar energy systems in the country. Nearly 0.4 million solar home systems have been installed so far, that is far below their respective potential. Solar home systems could be of interest under the clean development mechanism (CDM) because they directly displace greenhouse gas emissions while contributing to sustainable rural development, if developed correctly.

Having discussed energy system, we now look at CO_2 emissions' implications.

3.3. Energy and CO_2 emissions

Jyoti Parikh, Manoj Panda, A. Ganesh-Kumar and Vinay Singh from Integrated Research and Action for Development (IRADe) present the CO_2 structure of the Indian economy in the input–output framework using a 2003–04 social accounting matrix. Detailed estimates of CO_2 emissions for the Indian economy in the year 2003–04 by fuel type, sector, final demand and expenditure classes are shown. Here one can see contribution of CO_2 by two sectors of the economy in terms of consumption, production and trade. Emissions emitted for intermediate government and private consumption – the latter is split in five rural and urban classes with low medium and high monthly person-expenditures. The results show that electricity sector is the highest direct emitter followed by manufacturing steel and road transportation. The urban top 10% accounts for emissions of 3416 kg per person-year while rural bottom 10% accounts for only 141 kg per year.

Amit Garg and P.R. Shukla: coal is the abundant domestic energy resource in India however its use exacerbates global climate change. CO_2 and CCS (carbon dioxide capture and storage) can mitigate CO_2 emissions from coal-based LPS (large point source) clusters and therefore would play a key role in mitigating both energy security risks for India and global climate change risks.

4. Possible paths for sustainable energy development

Paths for sustainable energy development in India are described and analyzed in the excellent paper by *Kirit Parikh* et al. in this SI. It also should be recognized that forecasting is fraught with uncertainties, which have especially plagued the energy field, with many examples shown by Smil [13], and presently punctuated by the unforeseen rapid and large fluctuations in energy prices that are unjustified simply by supply and demand economics, by the precipitous worldwide economic downturn, by unforeseen international conflicts, by environmental effects (especially those that are energy related) such as global warming that wasn't even considered a couple of decades ago, by new unaccounted energy demands, such as those associated with the worsening situation of water and food supply, and by rapid improvements in technology. A few examples of the latter are the rapid improvements in energy conversion efficiency, which has nearly doubled over the past three decades, to reach about 60% with gas-fueled combined power cycles, and about 55% by advanced diesel engines, and perhaps even higher by future fuel cells, by the maturation/improvement of wind power generation through improved efficiency and reliability and lower cost, by the current trend to replace much of the fuel-powered vehicle fleet by electric or hybrid ones, and by the more distant (at least 50 years in the future) possibility of commercial use of fusion power and of power generated in space [14], and of superconductive electricity transmission.

The first step in any path to the future is wiser use of the energy resources, also referred to as conservation. This would include elimination of obvious waste, higher energy conversion efficiency, substitution for lower energy intensity products and processes, recycling, and more energy-modest lifestyles. Benjamin Franklin's famous adage "a penny saved is a penny earned" takes in the energy area the form "a Joule saved is worth significantly more than a Joule earned": it takes significantly more than 1 J of energy to generate 1 J of power. This is amplified several fold when one considers the resources and environmental impact associated with the construction and operation of a power plant or even a vehicular engine. At the same time, conservation should not be implemented in a way that would deprive large fractions of humanity of basic comforts of life.

Conservation may also lead to forecasting errors: for example, following the oil embargo of the 1970s, and the resulting rise in energy prices, the world energy consumption during the period between 1979 and 1983 has reversed trends from continuous increase to a small decrease, due to major decreases in OECD consumption and despite the growing energy demand in the developing countries. Among other consequences of this unforeseen trend change, it has frustrated the power generation utilities in the U.S. (for example) that have based their generation expansion to the relatively constant >5% growth rates that preceded 1979, and caused significantly negative economic impacts.

The pursuit of more efficient and less polluting transportation must include not only vehicular improvements (with preference for the plug-in electric or hybrid car) but also traffic management, significant development of efficient public transit, and redesign of cities.

Buildings and household energy use amount to ~30% of India's energy consumption (*Sudhakara Reddy and Srinivas* in the SI) and greenhouse gas emissions. An excellent and practically attainable way to reduce this problem is the design and retrofit of buildings and appliances to such that consume less energy (including embodied energy) over their life time, with and without incorporation of renewable energy sources, and further with an extension to "Eco-efficient" buildings that not only reduce their negative environmental impact but also help heal and improve the environment. A broader method is to design residential communities in a way that reduces both indirect use of energy and emissions by reducing the need for transportation and resources by the residents.

While increasing energy conversion and use efficiency are vitally important steps in the path to sustainability (industrial process efficiencies are described in the SI paper by *Gielen and Taylor*), measures must also be taken to prevent energy efficiency "rebound", the frequent outcome in which higher efficiency and lower costs lead to increased consumption (cf. [15,16]) and thus at least partially negate the positive outcomes Such measures may include demand-side management. An innovative approach to analyze and influence customer energy demand is presented in the SI paper by *Reddy and Srinivas*, and could be developed and adapted for examination and control of the rebound effect.

As to sustainable paths related to energy resources, coal will remain a major component for at least the next half of a century, and thus major efforts and priorities should be made to make this process more efficient and less costly and polluting. Advanced and new technologies should be adapted (progress has been made worldwide), developed and implemented in coal mining, transportation and power generation (see also the SI paper by *Chikkatur* et al.). Renewable energies, led in significance by hydro, biomass, wind and solar are currently employed to only a small extent of their potential, could, and should, when they are proven to be economical and sustainable, developed to their potential (see also SI papers by *Ravindranath and Balachandra, Pillai and Banerjee, Bhattacharya and Jana*).

The absence of an efficient, extensive, and smart electricity distribution grid stymies energy and economic development and contributes significantly to greenhouse gas emission, and must be viewed as a critical priority target for development.

All the above-discussed measures for reducing energy consumption use of fossil fuels, and renewable energy employment, will also reduce GHG emissions. Reasonable cost technology is also available for carbon capture when fossil fuels are used in power generation, yet practicality of technologies for sequestration of the captured carbon is still very uncertain (cf. [17]). If and when sequestration become practical it may be economically wise to attempt to cluster large coal power generation plants at a relatively short distance from sequestration sites as *Garg and Shukla* propose and discuss in this SI.

We also note that countries with a large agriculture (India ranks second in the world in agricultural production) also have large associated emissions of GHG, such as methane and N_2O. These amount to about 37% of India's total GHG emissions ([18] albeit for 1994), and we remark that some fraction of that is energy related due to the large use of animal power. Important measures must be taken to reduce these emissions too, and reasonable methods are available.

Energy conversion and use are associated with major environmental, economical and social impacts, and all large energy projects should therefore be designed and implemented sustainably. Sustainability is only emerging as a science, and thus must be developed and applied urgently to provide analysis and evaluation tools.

Sustainable development is founded on the three pillars of economic, environmental and social impacts. While the first two pillars are discussed in the SI more extensively, it is very important to address the social pillar, without which sustainable development cannot succeed. Quoting from the SI paper by *Chikkatur* et al.: "Thus, there is a great need for moving towards a philosophy of "planning with people" that empowers project-affected people and allows them to influence decision-making, rather than "planning of people" or "planning for people".

Acknowledgments

We thank all the authors, for submitting the articles and patiently following the review process, the reviewers (listed below), Nirbhay Srivastava for helping with the editorial work and Laura Barker who has been a constant source of help. We also are grateful to the current Editor-in-Chief of ENERGY, Professor Henrik Lund, for helping in the completion of this SI.

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Available online 24 July 2009

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Projecting India's energy requirements for policy formulation

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ARTICLE INFO

Article history:
Received 11 December 2007
Received in revised form
21 November 2008
Accepted 21 November 2008
Available online 20 May 2009

Keywords:
Energy modeling
Bottom-up model
India
Energy policy

ABSTRACT

Energy policy has to have a long-term perspective. To formulate it one needs to know the contours of energy requirements and options. Different approaches have been followed in literature, each with their own problems. A top down econometric approach provides little guidance on policies, while a bottom up approval requires too much knowledge and too many assumptions. Using top-down econometric approach for aggregate overall benchmarking and a detailed activity analysis model, Integrated Energy System Model, for a few large sectors, provides a unique combination for easing the difficulties of policy formulation. The model is described in this paper. Eleven alternate scenarios are built, designed to map out extreme points of feasible options. Results show that even after employing all domestic energy resource to their full potential, there will be a continued rise of fossil fuel use, continued importance of coal, and continued rise of import dependence. Energy efficiency emerges as a major option with a potential to reduce energy requirement by as much as 17%. Scenario results point towards pushing for development of alternative sources.

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Natural Gas requirement by fertilizer sector in India

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ARTICLE INFO

Article history:
Received 26 September 2008
Received in revised form
8 January 2009
Accepted 19 February 2009
Available online 28 May 2009

Keywords:
Natural gas
Urea demand projection
Agriculture
Government fertilizer policy

ABSTRACT

Natural Gas is one of the important fossil fuel energy resources in India. Anchor customers of natural gas are the power sector and nitrogenous fertilizer. It is the cleanest form of energy derived from the fossil fuel basket. Because of clean combustion characteristics, natural gas is the fuel choice for many sections of Indian industry. The demand for natural gas will grow with time. Currently natural gas accounts for 7% of the primary energy consumption of India. The Government of India has its commitment to food security and energy security. The policies are directed toward greater allocation of natural gas on a priority basis to fertilizer and the power sector. Natural gas is the main and preferred feedstock for urea manufacture. This paper analyzes and estimates projected demand of natural gas in the next two decades. The demand projections have been reviewed in the context of changing government policies regarding the fertilizer industry, such as farm gate price regulation and self-sufficiency level of indigenous urea production. The current growth plan of natural gas supply and evolving supply scenario in the future are also considered in the study.

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Energy

journal homepage: www.elsevier.com/locate/energy

CO_2 emissions structure of Indian economy

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ARTICLE INFO

Article history:
Received 23 April 2008
Received in revised form
30 January 2009
Accepted 19 February 2009
Available online 6 May 2009

Keywords:
SAM (Social Accounting Matrix)
Direct emissions
Indirect emissions

ABSTRACT

This paper analyses carbon dioxide (CO_2) emissions of the Indian economy by producing sectors and due to household final consumption. The analysis is based on an Input–Output (IO) table and Social Accounting Matrix (SAM) for the year 2003–04 that distinguishes 25 sectors and 10 household classes. Total emissions of the Indian economy in 2003–04 are estimated to be 1217 million tons (MT) of CO_2, of which 57% is due to the use of coal and lignite. The per capita emissions turn out to be about 1.14 tons. The highest direct emissions are due to electricity sector followed by manufacturing, steel and road transportation. Final demands for construction and manufacturing sectors account for the highest emissions considering both direct and indirect emissions as the outputs from almost all the energy-intensive sectors go into the production process of these two sectors. In terms of life style differences across income classes, the urban top 10% accounts for emissions of 3416 kg per year while rural bottom 10% class accounts for only 141 kg per year. The CO_2 emission embodied in the consumption basket of top 10% of the population in urban India is one-sixth of the per capita emission generated in the US.