RESEARCH ARTICLE

Benefits and challenges of urbanization and low carbon energy needs in India

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Abstract: Urbanization has occurred rapidly in India principally due to social, economic and political drivers and has offered improved quality of life, access to amenities and economic opportunities for many. However, this has been accompanied by challenges that include insufficient energy, lack of urban infrastructure, and poor delivery of basic services, resulting in undesirable environmental impacts, congestion, and urban sprawl. India's urbanization has placed tremendous demand on the country's resources. Providing energy to all while maintaining a low carbon footprint is a global priority. Although economic development is anchored by both urbanization and industrialization, urbanization itself is a major determinant of energy use, including energy use related to transportation. Deficiencies in urban planning and management have to be overcome if India's urban environment is to meet the rising expectations of an expanding urban population and provide an environment consistent with rapid, inclusive and sustainable growth. India's energy demand in 2030 is likely to be double that of current demand. Achieving a greener future in a sustainable way with low energy costs can be addressed by measures such as preferential policies towards renewables, investment in technology and empowerment of local government to meet the low carbon energy needs in India.

Keywords: urbanization, low carbon energy, transportation, technology, renewable energy, sustainable

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1. Urbanization in India

1.1 The Story so Far

The phenomenon of 'urbanization' or population shift from rural to urban areas is occurring at an unprecedented rate in India. According to the 1901 Census, the population residing in urban areas in India was 11.4%. This count steadily increased post-independence and crossed the projections in the 2011 Census to reach a staggering 31.2%[1,2]. With 12.5 million people, Mumbai (Figure 1) was the largest metropolis by population in India, followed by Delhi

Figure 1. Urbanization's physical manifestation in Mumbai, India (http://www.iaacblog.com).

with 11 million inhabitants. With the fastest rate of urbanization in the world, as per the 2011 Census, Delhi's population increased by 4.1%, Mumbai's by 3.1% and Kolkata's by 2% when compared to the 2001 Census. At these growth rates, by 2015, the population of Mumbai will stand at 25 million, that of Delhi and Kolkata at 16 million each, while that of Chennai, Bangalore and Hyderabad at 10 million[3]. According to a 2007 State of the World Population survey report by the United Nations, 40.8% of India's population is expected to reside in urban areas by the year 2030. In absolute terms, this means that the country's urban population will increase from 340 million to nearly 600 million in the next 15 years. As per McKinsey Global Institute's report[4], India will have 68 cities with a population of more than 1 million, 13 cities with more than 4 million and 6 megacities with 10 million or more people. Also, at least 5 states will be more than 50% urbanized with Mumbai and Delhi figuring among the top 5 largest cities in the world. Moreover, cities development will account for 75% of the national Gross Domestic Product.

However, to put this into perspective, this proportion of urban population is much lower than the current level of other emerging market countries, for instance, China (48% urban population), Mexico (78% urban population), South Korea (83% population) and Brazil (87% urban population)[5]. Census 2011 lists 7,935 towns (urban areas) in India, a count that has increased by 2,774 since the 2001 Census. Many of these towns are part of urban agglomerations, in which, it is a part of two or more physically contiguous towns or a town with a minimum population of 20,000 along with its outgrowths, while the rest are independent urban areas.

Urbanization in India has kept pace with India's economic growth which accelerated close to 8% per annum in the 2001–2011 decade, compared with 5.5% in the previous two decades[5]. Recently, India's Finance Ministry said that the country's economic growth could accelerate to as much as 8.5% in the coming fiscal year, which could make it the world's fastest-growing large economy. Nonetheless, this growth over a relatively short period has not only led to an improvement in overall wealth but also caused deficiencies in energy, urban infrastructure and service delivery leading to environmental degradation, congestion and urban sprawl.

1.2 Causes of Urbanization — How did we Arrive Here?

So, what has caused such a drastic change in the demographic scenario of the country over the last decades? Research and analysis shows that the principal underlying causes of urbanization in India are social, economic and politically driven.

Economic:

- Industrialization and the resultant expansion in employment opportunities.
- Economic and educational opportunities along with better standard of living.
- Access to technology and better infrastructure facilities in the urban areas.
- Growth of the private sector after the year of 1990.
- Development of transit and transport infrastructure aiding movement and migration.

Social:

- The continuing influx and migration of people post-partition of India.
- The attraction for cities and its perceived status and comfort.
- Increase in birth rates in urban areas.

Political:

- Important urban centers are de facto political capitals/seat of government.
- Expansion in government services and infrastructure.
- Eleventh five-year plan that promoted urbanization for the economic development of India.

1.3 Consequences of Urbanization — What are we Faced with?

The rapid rise in urban population in India has resulted in several unforeseen or unplanned consequences such as the increase in slums, poor standard of living, increase in air pollution, urban sprawl and traffic demand, and environmental degradation along with demand for rising income and comfortable living. There are also the classical problems arising from an unmanaged and sudden unintended population increase such as unemployment, change in family and social structures and increase in crime rates. Under such scenarios, it is inevitable that cities unprepared for this kind of onslaught are facing a crisis, all of which has a detrimental effect on the quality of life of the citizens, thus, perpetuating a vicious cycle.

2. Impediments of Urbanization — the Challenges

As India attempts to achieve faster and more efficient

growth, it is indisputable that cities have and will continue to play an important role as the engines of its economic growth. India's urbanization, which is similar to other developing countries, has indeed placed tremendous demand on the country's resources and is not without its share of challenges (Figure 2).

The main challenges are as follows:

- Deficit in urban infrastructure and poor service delivery — including drinking water, waste water treatment, solid waste management, affordable housing, food security and public transport; all of which have the greatest impact on the lower-income urban population.
- Pollution from industries and vehicles that have an impact on the health of all urban dwellers and the resultant investment required to combat illnesses.
- Investment climate is adversely affected by the absence of planned urbanization.
- High cost of living and increase in the number of urban poor as the cities are not inclusive — this in turn leads to a rise in slums or overcrowded neighborhoods with poor sanitary conditions and lack of basic infrastructural facilities.
- No growth boundaries or master plans — lack of detailed, enforceable planning. Land use planning is irrational and the existing plans do not have proper implementation.
- Outdated governance structures that do not encourage capacity building and self-governance
- Social isolation along with the physical form of urban areas leading to high crime rates.
- Negative impacts on environment — water bodies, public spaces, air quality, green spaces and increased energy consumption.
- Difficulty in meeting the mobility needs of the urban population through mass public transport leading to shift towards private modes (Figure 3).

3. Advantages of Urbanization — the Opportunities

Despite challenges, urbanization has several benefits especially if it is occurring in a planned environment with foreseeable outcomes. The opportunities it presents are as follows:

- It brings in competencies as people migrate from rural to urban areas — it creates employment opportunities in urban centers and offers conveniences that are unavailable in rural areas.
- Brings in efficiency in land utilization and service delivery functions — it involves lesser per capita cost and effort in providing basic services like water supply and electricity.
- Provides access to amenities, resources and facilities that are not easily available in rural areas —access to education, research, health, social services and cultural activities is much more readily available.
- Increases the standard of living compared to that in the rural areas.

Figure 2. The challenges presented by urbanization.

Figure 3. Impact of urbanization on transportation.

- Fosters economic growth and growth in trade and tourism — urban areas act as hubs of investments, high-tech industries and sharing of natural resources
- Provides an environment for social integration — whereby people of various backgrounds, groups, religions and income categories live and work together
- Act as knowledge hubs — providing the resources needed to train and develop human resources, so that people may exchange ideas and pursue careers of their choice, thereby improving their economic conditions
- Provide access to transit and transport networks at reduced costs including overhauling the efficiency of railways to move people and goods.

Therefore, planning for urbanization and better management of the cities is not only important for the quality of life for those living in our cities and towns, but also because it contributes to a better economic and environmental climate for the country as a whole.

4. From the Energy Standpoint

According to United Nations, cities account for nearly 75% of global energy consumption and 80% of greenhouse gas (GHG) emissions. In 2030, GHG emissions in Indian cities could increase to 1.6 billion tons (CO_2 equivalent) from 230 million tons in 2005. This amounts to 1.1 tons per capita and represents GHG emissions from transport, buildings, public areas and city design.

Heating, ventilation and air conditioning are gradually making way into India in a big way to ensure comfort and create a pleasant environment for people, besides improving the air quality of the spaces. However, it consumes large quantities of energy produced in the country. To put it into perspective, the energy consumption in India is the fourth largest after China, USA and Russia[6]. As of 2013, in India, the total primary energy consumption from various sources was as follows: crude oil 29.45%, natural gas 7.7%, coal 54.5%, nuclear energy 1.26%, hydroelectricity 2.0%, while wind power, biomass electricity and solar power is 595 metric ton of oil equivalent (Mtoe).

That year, India's net imports were nearly 144.3 million tons of crude oil, 16 Mtoe of liquefied natural gas (LNG) and 95 Mtoe coal, totaling to 255.3 Mtoe of primary energy which was equal to 42.9% of total

primary energy consumption. About 70% of India's electricity generation capacity is from fossil fuels, with coal accounting for 40%[7,8]. This means that despite having huge coal reserves, India is largely dependent on fossil fuel imports to meet its energy demands. By 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption.

5. Transportation as a Key Stakeholder in the Energy Sector

Urban areas typically have high concentrations of people and economic activity which in turn causes high levels of movement of people and goods, thereby having an impact on the energy use of transport and its GHG emissions. With an estimated 40% contribution to emissions, vehicle ownership, vehicle use (number of trips and trip distances), modal split and fuel economy are the major determinants of road energy use[9]. Thus, urbanization increases not only the quantity of passengers and goods but also the distances over which these passengers and goods are carried. Urbanization increases transport energy use in three ways: firstly, it facilitates economic specialization and labor division which in turn increases the movement of goods, secondly, food needs to be transported from outside the urban areas in order to feed the urban population, further increasing the use of fuel-powered modes, and thirdly, residences and workplaces are often segregated and separated in urban settings leading to longer commutes, thus encouraging the use of fuel-powered faster transportation modes. Although economic development is anchored by both urbanization and industrialization, urbanization by itself is a major determinant of energy use. Although production efficiencies may be achieved, it is often at the cost of energy use for external factors such as transportation. Thus, in urban areas, activities which traditionally used manual labor move to the use of energy-intensive modern technologies. Amongst these, personal transportation remains the largest source of change in energy use. As wealth increases, people migrate to personal modes of transport, thus tilting the scales in favor of fuel-powered modes in cities. However, to tilt this balance back, rail-based mass transportation systems like metros, suburban commuter rails and bus rapid transport systems need to be promoted in order to increase the efficiency of the fuel usage. A major source of carbon emissions are direct emissions from vehicles, thereby making transportation a key player in energy consumption.

6. The Need for Clean Energy/Transportation Fuels

"The low-carbon economy envisions a better quality of life enabled by economic and technological innovation along with reduced natural resource consumption and pollution." — UK Energy White Paper[10]

Given the above facts, the recent global environmental focus is evidently on minimizing the human-inflicted carbon footprint by reducing or even eliminating the use of nonrenewable energy resources. In 2003, the UK government issued the 'UK Energy White Paper: Our Energy Future — Creating a Low Carbon Economy', which first proposed the low carbon economy concept[10]. In the white paper, low carbon economy is defined as one in which 'society creates higher standards of living and a better quality of life through improved economic output underpinned by advanced technological innovation and new business and job opportunities, while at the same time reducing natural resource consumption and environmental pollution'. Achieving a greener future in a sustainable way with low power costs is expected to be addressed by measures like the replacement of fossil fuels with clean energy, energy conservation and use of energy efficient systems, processes and equipment.

The ever increasing numbers of vehicles and fuel requirement has compelled the research on alternative sources of transportation fuels in recent decades. This has led to the emergence of many potential alternatives such as biodiesel, methanol, ethanol, butanol, dimethylether, diethylether, bioethanol, synthetic natural gas (SNG), Fischer–Tropsch diesels hydrogen, straight vegetable oils (SVO), hydro-treated vegetable oil (HVO), F-T diesel and hydrogen[11]. Over time, many techniques and methods have been developed and still continue to be developed for betterment in terms of yield, economic cost and sustainability. It is becoming more important to study the feasibility of substitution of crude oil/petroleum with alternative fuels, which are available or can be produced locally on a substantial scale for commercial utilization. While several alternative derived fuels present potential, the relative high cost in comparison to petroleum presents a major obstacle in their widespread use. Thus, these alternative fuels need to be further explored and production technologies have to be upgr-

aded in order to meet the fuel quality requirement as well as economic feasibility.

On other viable renewable energy sources, India has a tremendous locational advantage to consider solar energy as a powerful alternative to conventional sources. Recent investment pushes in large solar projects, solar parks, microgrids and solar rooftops are being backed by heavy investments and policy frameworks. Net metering, whereby solar photovoltaic system owners can sell excess solar energy to the utility company or buy deficit energy from the utility company using a meter to track this energy exchange, has been implemented in several states in India such as Karnataka, West Bengal, Andhra Pradesh and Maharashtra. Similarly wind power has been making huge strides towards becoming a significant contributor to the distributed energy systems. With the 5th largest installed wind power capacity in the world, it presents in several states and is already contributing to nearly 2% of the national power needs[12]. High capital costs and land intensive installation are some of the barriers to this technology. Although endowed with economic viability in India, hydro power is yet another energy source that has not been fully exploited to its potential of about 1.5 Lac MW (150,000 MW)[13]. This is primarily because of ecological concerns apart from the non-reliability of this source in case of droughts and other environmental externalities.

Re-thinking on the energy sources and fuels is as important as equitable and smart mobility systems as part of smart cities to combat the negative impacts of urbanization. The demand for petroleum-based fuels has seen a sharp rise due to the ever increasing automation and motorization worldwide. The future availability of the various energy sources and its environmental impact will determine the sustainability and advancement of our global future. As per research, fossil fuels contribute to nearly 80% of the global energy consumption, of which around 58% is expended by the transport sector alone[11]. Therefore, meeting the energy needs of our population in a sustainable manner and reduction in emissions is the mainstay of the research on energy and urbanization.

7. The Role of Coal in Addressing Energy Needs

In terms of resources, India has the world's 4th largest coal reserves and it is the bulk of primary energy contributor with over 50% share. However, as per data from 2013, India ranks 5th in global coal production at 228 Mtoe (5.9%) when its inferior quality coal tonnage is converted into tons of oil equivalent[6]. Accounting for 59% of India's installed electricity capacity, coal-fired power plants are also used for cement and steel production in substantial quantity[14].

The retail prices of petrol and diesel are relatively high in India to make electricity (derived primarily from coal) driven vehicles more economical. Gasification of coal or lignite produces syngas or coal gas which is a mixture of hydrogen, carbon monoxide and carbon dioxide gases. Coal gas can be converted into SNG by using Fischer–Tropsch process at low pressure and high temperature. Coal gas can also be produced by underground coal gasification where the coal deposits are located deep in the ground making it uneconomical to mine. However, compressed natural gas (CNG) and LNG are economical alternatives to diesel oil only when there is an escalation in international crude oil prices. Under such a scenario, synthetic natural gas production technologies have tremendous scope to meet the transport sector requirements by fully utilizing the locally available coal in India. For example, Dankuni Coal Complex is producing syngas which is piped to the industrial users in Calcutta. Many coal-based fertilizer plants which are non-functional can also be retrofitted economically to produce SNG as LNG and CNG fetched good price by substituting imports. Another hugely potential alternative is the clean coal technology development which refines coal and unloads the carbon so as to reduce emissions greatly which addresses the air-quality issues related to coal-burning. However, the environmental mitigation of risks associated with carbon capture and storage intrinsic to this process has still not developed to the extent to make it viable for mass utilization.

Under the current scenario, there are a few limitations to making coal the centralized mainstay in addressing the energy demand in India.

- It is a non-renewable energy source.
- Burning coal emits harmful products and GHG's which may lead to acid rains and other environmental threats.
- Clean coal and coal conversion to liquid or gas is an expensive technology which needs further improvements to make it viable.
- Current coal mining techniques can damage the landscape and have an impact on local ecology.
- Transporting coal is cost-intensive and can also cause additional pollution in the form of emissions from transportation vehicles (e.g., trucks, rail).

- The mining industry presents health and safety issues for miners.
- Current power plants do not have the capacity to handle loads needed to meet demand.

8. What Next? The Way Forward

So, how can we optimize energy consumption and emissions from the country's urban centers? Well-managed urbanization can reduce the demand for energy and thereby reduce emissions. Careful planning of city transport needs is particularly important as urbanization gathers momentum and cities have to cope with rising internal transport needs. These have to be met in a manner that economizes on energy and also avoids congestion and pollution, all of which depends upon an effective public transport system. Thus, in the transport sector, energy consumption can be checked to a great extent by promoting safe, low cost mass transportation systems both rail- and road-based in urban areas. It requires close cooperation among different government departments and to make use of carefully designed systems of taxes and cross subsidies to encourage the right kind of transport development.

Higher pollution tax on coal and a big push towards renewable energy sources are the present government's formula for powering cleaner economic growth. To this end, the Government of India plans to set up five new ultra-mega power projects, each consisting of 4000 MW in the 'plug-and-play' mode and the same information was announced on February 28, 2015 while presenting the General Budget for 2015–2016. In the domain of energy, a target of 175,000 MW renewable energy capacity by 2022 would help India's roadmap to cut its carbon footprint. India attempts to reduce its greenhouse gas emissions by doubling of green cess on coal, funding investment in renewable sources and clean coal technology for power plants. Solar power will take the lion's share of the renewable energy target at 100000 MW, followed by 60000 MW of wind energy, 10000 MW of biomass and 5000 MW of small hydro projects up to 25 MW each. India also envisages increasing the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years[15]. Natural gas is yet another fuel that can contribute to the energy needs complementing and supplementing the other energy sources mentioned here. Although natural gas is a non-renewable source of energy, it is cleaner than petroleum and is present in large reserves in India; making it an attractive alternative. Therefore, research and development of these energy sources need to be pursued and the efforts need to be supported and promoted at the state and municipal levels.

In the domestic sector, energy use can be reduced and optimized by adopting technologies and processes to promote green architecture and city design. Design of buildings should be aimed at reducing the impact of the built environment on human health and natural environment. National and international rating systems such as GRIHA and LEED have been developed to promote sustainable design through system efficiencies leading to minimal or zero off-site discharge. Integration of land use and transportation is an essential component of urban planning which leads to efficiencies of place-making and energy consumption and should be a priority in all planning-related policies and decisions. The Indian government has made ambitious public commitments to both sustainable energy and urban development. It has already announced its plans to build 100 smart cities across the country by 2024 in a collaborative public-private partnership.

Given that 35.5% of the population still lives without access to electricity supply, the approach towards addressing the energy demand needs to be multi-pronged[16]. Coal, which is the mainstay of the local product, needs to be explored as a clean 'Made in India' technology. Investments into clean coal should be encouraged and leveraged to understand and address the ease of use, its adoptability by user and viability for mass production, subsequently optimizing the current set-up and investing into new ones as well. Further, going forward, India's policy should be to incentivize research and development of clean and renewable energy sources such as solar, wind, hydro and nuclear power.

9. From a Policy Standpoint

Rather than an insurmountable challenge, India should view urbanization as an opportunity to save energy and reduce emissions. Additionally the following policies should be adopted and implemented to reduce energy consumption:

- Frame preferential policies and provide more financial subsidies to develop new and renewable energy. For example, in order to ensure environmental security, the government should promote the innovation, research and development of decentralized wind power and rooftop solar.

- Existing major resources such as coal should be developed in capacity in parallel so as to reduce emissions. More than lip-service funding must be provided for the same situations.
- In order to accelerate the extensive application of highly resource-efficient and environmentally sound technologies in urban areas, the government should promote technological innovation and capital flow through policy incentives and financial support such as intelligent transportation systems, promoting energy-efficient vehicles for mass transport, improvement in road conditions and proper road management systems. In addition, the government should encourage implementing financial subsidies and preferential tax policies, such as a consumer savings based model in mass transit.
- Rail transport needs to be overhauled with new technologies to optimally utilize the existing resources in developing advanced and efficient rail systems to move people and goods in the urban areas, whereas the surrounding suburban areas need to be developed.
- Recognizing that industrial production will continue to play a big role in urbanization, the government should fund and support the application of technologies that save the energy consumption in production. In addition, the government should introduce energy-efficiency indicators and regulations to enforce and monitor business' energy consumption behavior.
- Focus on sustainable urbanization through devolution of power to local government so as to enable better environmental legislation which is enforceable. For example, any policy aiming to curb the impact of urbanization on energy demand must address its associated externalities of urban sprawl and automobile dependency.
- Energy research results in a lot of public good such as economic competitiveness, national security, and environmental protection that private markets do not care much about. Thus, Government of India should focus and embrace energy research in a big way to look for alternative new sources of pollution free, inexhaustible energy including solar, wind and low energy nuclear reactions (LENR) with a view towards distributed energy generation plans.

Higher quality of life is realized in tandem with policies that reduce the demand on resources. Deficiencies in urban planning and management have to be overcome if India's urban environment is to meet the rising expectations of an expanding urban population and provide an urban environment consistent with rapid, inclusive and sustainable growth. If cities are to grow and provide an impetus for growth, they need to attract investment — and to do so; the cities must compete with each other in terms of the quality of the urban environment it provides. India's energy demand in 2030 is likely to be doubled that of current demand. The role of advanced engineering and innovative technologies will increase significantly in coming years for harnessing renewable energy and to make transformation of low carbon energy to a more sustainable economy. The likely growth trends in major non-renewable energy sources like coal and renewable feed stocks are highlighted in Figure 4. The population of vehicles on Indian roads will be more than 300 million by 2030. Priority should therefore be given to the making of road and rail transport systems in India with more energy efficient and less dependent on fossil fuels. Hence, urban energy planning and urbanization management will become future challenges of paramount importance in order to create the right framework conditions for a sustainable energy in future.

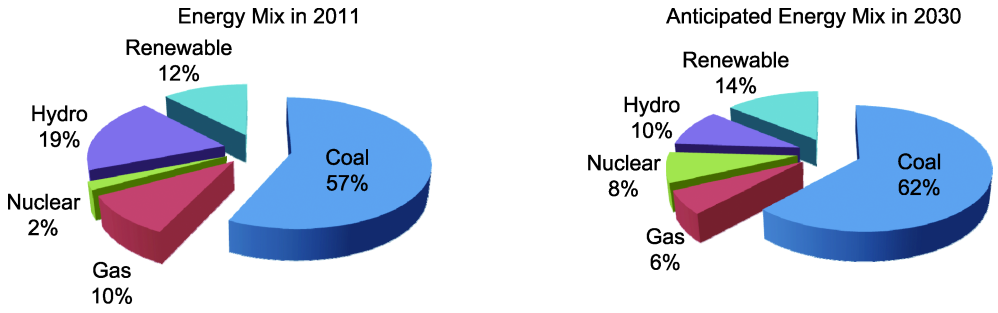

Figure 4. Anticipated energy mix for power generation in India (2011–2030).
Source: Indian National Academy of Engineering report 2015

"Deficiencies in urban planning and management have to be overcome if India's urban environment is to meet the rising expectations of an expanding urban population and provide an urban environment consistent with rapid, inclusive, and sustainable growth." — Isher Judge Ahluwalia (Chair, Indian Council for Research on International Economic Relations)

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