

Electricity in Megacities



A Working Paper by Prayas Energy Group, Pune

प्रयास

आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न

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About Prayas Energy Group

Prayas is a non-governmental, non-profit organisation based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of the society, in particular. Prayas Energy Group (PEG) has been active since 1990 in the area of electricity sector. We believe that effective control and influence on governance by people and civil society organisations is the key to efficient governance that would protect and promote public interest. Public interest issues include consumer issues as well broad social issues. In consumer issues, PEG gives more attention to the issues affecting the poor and the disadvantaged. Social issues include environmental sustainability and equity. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. All our publications are available at our website.

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Abstract

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Increasing population and resource use in cities is a trend all over the world and India is no exception. It is therefore important to study the cities, especially the megacities, which have a population more than 5 million, from multiple perspectives to improve planning and governance. This paper looks at the electricity sector in six megacities of India, namely Bengaluru, Chennai, Hyderabad, Kolkata, Mumbai and New Delhi. Megacities have high consumer and load densities. Compared to the megacities of developed countries, Indian megacities have high growth rates. With a mix of sky scrapers and sprawling slums, they present a picture of contrasts. They house not only a large number of poor, with low consumption and limited service delivery expectations, but also many high end consumers, who expect world class quality of electricity supply and service.

This paper, prepared on request from Centre for Policy Research for their study for the Ministry of Urban Development, looks at the broad contours of the electricity landscape in megacities covering institutions, demand profile, generation and distribution infrastructure, consumer tariff and usage patterns, service quality indicators and planning.

Planning, construction and operation of the megacity electricity system is largely the responsibility of the distribution companies, though they have to manage this in coordination with many other institutions like generators, transmission companies, power traders, power exchanges, regulators, municipalities, State government, Central government and other service providers in the city. The paper notes that commercial and domestic consumers use nearly 60% of the electricity and are the fast growing segments. The demand profile of megacity is quite different from that of the State, with peak occurring in the day time and large variation of demand with weather changes. Considering the impending fuel crisis and climate challenge, megacities could play a pioneering role in promoting green power. Megacities have severe space shortage challenge which has to be met through technology and management innovations. A facilitating role of the municipalities in improving the urban planning process by catering to the requirements of electricity service providers and institutionalising the coordination between various service providers would improve electricity service delivery in megacities.

1. Introduction

Increasing population and resource use in cities is a trend all over the world and India is no exception. It is therefore important to study the cities, especially the megacities¹ (which have a population more than 5million) from multiple perspectives to improve planning and governance. This paper prepared by Prayas Energy Group looks at the electricity sector in six megacities of India. It is expected to contribute to the bigger study undertaken by the Centre for Policy Research (CPR), New Delhi for the Ministry of Urban Development, called “How to Govern India’s Mega Cities: Towards the Needed Transformation” enquire into the future of urban governance in India by studying, understanding and then articulating possibilities and directions required in urban governance systems.

There have been studies on energy in megacities, though very few on Indian cities. Examples are: World Energy Council (WEC 2010), International Energy Authority (IEA 2008), IEEE 2007 and Murayama 2006. WEC 2010 study includes a study on New Delhi and IEEE report covers Mumbai. These studies cover electricity, transport and cooking dimensions of energy, to face the challenges of growth and climate change. These studies are detailed in terms of data and analysis, but there is scope for making them comprehensive by including non-commercial energy use (bio-mass, human labour etc.), incorporating the consumption of goods and services (which in turn require energy to produce and transport), elaborating the scope of green energy (end-use efficiency and renewable energy) and exploring the inequity concerns in energy distribution.

In the area of electricity in Indian megacities, the Central Electricity Authority (CEA) is preparing a report as a part of the 18th Electric Power Survey (EPS). The 18th EPS would give projections for the 12th five year plan and perspective plan for 13th and 14th five year plans. Up to the 17th Electric Power Survey, the Survey covered the forecast of energy requirement and peak demand of various states and Union Territories. Considering the massive growth in urban areas the electricity demand and consumption pattern of megacities, CEA has included power survey of megacities to facilitate proper planning of infrastructure in foreseeable future. As part of this, two separate Volumes, covering electricity demand forecast study for 13 megacities with population greater than 2 million is planned. Volume II covers 12 megacities of Greater Mumbai UA (as per CEA, Urban Agglomeration covering districts 21,22,23), Kolkata UA (districts 10,11,12,16,17,18), Chennai UA (districts 1,2,3), Hyderabad UA (districts 4,5,6), Bengaluru UA, Ahmedabad UA (districts 6,7), Pune UA, Surat UA, Kanpur UA, Jaipur Municipal Corporation, Lucknow UA and Nagpur UA. National Capital Territory (NCT) Delhi will be covered in Volume III of the EPS. This study is expected to have exhaustive quantitative data on electricity in megacities up to year 2022 (like energy, peak demand, consumer details, substation data, Transmission & Distribution loss trends, industrialisation plans etc) but is not expected to address issues related to operation and governance. Data on demand and distribution infrastructure has been collected from States and the reports are expected in 2012 (CEA 2010a, CEA 2011, CEA 2011a).

This paper has been prepared using available data sources to provide a quick overview of the electricity sector in megacities. Objective of this paper is to provide a thumbnail sketch of the status,

¹As per the definition of United Nations, urban agglomeration of more than 10 million inhabitants is a megacity (WEC 2009). CEA’s study on ‘electricity in megacities’ covers cities with more than 2 million inhabitants (CEA 2011). In this study, we have considered 5 million as the population limit, as per the discussions with CPR.

issues and challenges in the arena of electricity in megacities. It covers six of the seven Indian megacities, namely Bengaluru, Chennai, Hyderabad, Kolkata, Mumbai and New Delhi. Ahmedabad is not covered in this study. Secondary sources such as regulatory submissions, tariff orders, distribution company annual reports, city master plan documents, reports of the Central Electricity Authority (CEA), research papers and Census 2011 are the main sources of data. Some data has been collected using questionnaires and meetings with distribution utilities. This paper has been prepared in a short time of three months and the focus has been to capture the qualitative trends rather than being exact in quantitative aspects.

To capture the electricity scenario, megacities have been approximately mapped to distribution company(ies) or distribution circle(s). Exact mapping has been difficult since the boundaries of megacities and distribution companies or their administrative divisions do not match. In the available short time, it has not been easy to gather all the required electricity sector data like circle wise details for distribution companies. Hence reasonable approximations have been made, which help to consolidate data and arrive at the key features and trends. In cases of Kolkata, Mumbai and Delhi, Distribution Companies (DISCOMs) have been mapped to the respective megacity. For the megacities of Bengaluru, Chennai and Hyderabad, whenever possible, data on distribution circles of companies in the megacity has been used and if this was not possible, DISCOM data has been presented.

For Bengaluru, Bangalore Electricity Supply Company (BESCOM), the State owned DISCOM which covers 8 districts, has been used as a proxy for the city. Data for Bengaluru distribution circles (Bangalore – South, North & East) is used when available. Chennai is served by Tamil Nadu Generation and Distribution Corporation Ltd. (TANGEDCO), formed after the recent restructuring of Tamil Nadu Electricity Board (TNEB). Data from TANGEDCO for distribution circles in Chennai (Chennai – North, Central, South, West and Chengalpattu) is used when available. For Hyderabad, Andhra Pradesh Central Power Distribution Company Limited (APCPDCL), the State owned DISCOM which covers 7 districts, has been used as a proxy for the city. Data for Hyderabad city distribution circles (Hyderabad-North, Central, South, Rangareddy– North, South, East) has been used when available. Kolkata has been mapped to area served by CESC Limited, the private sector DISCOM, which serves 70% of Kolkata. State owned West Bengal State Electricity Distribution Company Limited (WBSEDCL) serves the rest of the city. Mumbai has been mapped to Reliance Infra – Distribution and Tata Power – Distribution (both private sector distribution companies) and BEST, which is owned by the Mumbai municipality. Some parts of Mumbai city are also served by Maharashtra State Electricity Distribution Company Limited (MAHADISCOM or MSEDCL). New Delhi has been mapped to BRPL and BYPL (BSES Rajdhani Power Limited and BSES Yamuna Power Limited, both jointly owned by Reliance Infra and NCT Government with Reliance having majority stake) and Tata Delhi Power Distribution Ltd (formerly NDPL, jointly owned by Tata Power and NCT Government with Tata having majority stake). Government owned New Delhi Municipal Council (NDMC) serves a small area housing the Central Government offices and Military Engineering Services (MES) serves the military cantonment.

It can be seen that Mumbai and Delhi have many distribution companies serving the megacity. With Ahmedabad city distribution managed by Ahmedabad Electricity Company Limited (a Torrent group

private company), electricity distribution in four of the seven megacities are largely managed by private companies².

2. Electricity in Megacities: An Overview

Megacities have high consumer and load densities. Compared to the megacities of developed countries, Indian megacities have high growth rates. The current megacities are slowly changing from being industrial centres to commercial capitals and the emerging megacities are expected to be largely commercial centres. With a mix of sky scrapers and sprawling slums, Indian megacities present a picture of contrasts. These house not only a large number of poor, with low consumption and limited service delivery expectations, but also many high end consumers, who expect world class quality of electricity supply and service.

This study looks at the broad contours of the electricity landscape in megacities covering institutions, infrastructure, electricity use, tariff, quality indicators and planning. Most of the data presented is for the year 2011 except for few parameters like tariff, for which the latest available figures are used. The next sub-section gives an overview of institutions in the electricity sector. The subsequent sections address the demand profile, generation & distribution infrastructure, consumer tariff, electricity use pattern, quality indicators and planning in megacities.

2.1 Overview of institutions

The main institution in a megacity responsible for electricity sector is the Distribution Company (DISCOM), as is the case for rest of the country. DISCOM could be state or private owned. DISCOM constructs and operates the distribution infrastructure and supplies electricity to consumers. They purchase power from generating stations located within the city or outside. DISCOM is connected to the transmission grid through which it receives this power. On issues related to consumer services, DISCOM has to operate under the policy directions of the State government. The State Electricity Regulatory Commissions issue license to DISCOMs and have an oversight role on their functioning. Megacities of Kolkata, New Delhi and Mumbai are served by multiple DISCOMs, some of them private owned, as described in Section 1. DISCOMs are organised into Distribution Circles, typically covering a district, or part of a city (like Hyderabad having 6 circles), which are further divided into Divisions, sub-Divisions, Sections and sub-Sections. Power from outside the city is carried to the city by the Transmission Companies (TRANSCOs), which are currently government owned. The State Electricity Regulatory Commission (SERC) issues license to the DISCOM, fixes the consumer tariff periodically, reviews the investment plans, approves the power purchase contracts and sets the standards of performance on quality of supply and service, which includes load shedding. The State government owns DISCOMs of Bengaluru, Chennai and Hyderabad. It has the roles of policy making and providing budgetary support to DISCOMs. Electricity is in the concurrent list, with specified roles for State and Central governments. The Central Electricity Act (2003) lays down the broad legal framework and the Central Electricity Authority (CEA) prepares the national electricity plans. The Central government prepares national policies. It also owns and operates generation and transmission companies which support the States. There are also many Central government

²Information in this paragraph is from the respective DISCOM and SERC websites

programs relevant to the megacities like the Restructured Accelerated Power Development and Reform Program (R-APDRP) for improvement of urban distribution systems and Jawaharlal Nehru National Solar Mission (JNNSM), which promotes solar power. Market operations have commenced in electricity sector after the Electricity Act 2003. Market players consist of merchant power plants (which have not contracted all their capacity), power traders (who buy and sell power), power exchanges (where sellers and buyers can submit bids) and Unscheduled Interchange (power transaction based on frequency variation, currently included in market monitoring reports, but strictly not a market mechanism). DISCOMs have the option of purchasing power through long term Power Purchase Agreements (PPAs) with generating stations or from the market.

The Municipal Administration has a limited role in planning and operation of electricity distribution in a megacity. BEST –Mumbai and NDMC- Delhi (both agencies of the local municipality, managing distribution in a relatively small part of the city), are exceptions. Municipality has an impact on electricity planning in megacities through its decisions on land use, building rules, housing schemes and facilitating other services like transport or water supply. In the area of operation, the role of municipality is limited to managing street lighting and coordinating with service providers (electricity, water supply, roads, railways, telephone, internet, television cable etc.) for maintenance. Considering the complex and specialised nature of electricity, this status is unlikely to change.

2.2 Key electricity parameters

Table 1 gives the key electricity parameters of the six megacities with population, peak load, electricity sales and per-capita consumption. Household electricity access is near universal in all megacities. As per Census 2011 data, household electricity access in these cities is 98% or higher, except Kolkata where it is 96%. This compares well with the national urban household electricity access of 93% and contrasts with the rural electricity access of 55%.

Table 1: Key Electricity Parameters of Megacities

City	Bengaluru	Chennai	Hyderabad	Kolkata	Mumbai	New Delhi	India
Population (<i>in millions</i>)	6	7	6	13	16	16	1,210
Peak Demand(<i>MW</i>)	2000	2,000	2,170	1,856	3,192	5,014	118,676
Demand Growth Rate Compounded Annually (%)	13	4	13	3	4	7	7
Sales (<i>MU/year</i>)	18,736	10,800	28,741	8,135	17,963	20,684	876,856
Per Capita Power Purchase (<i>Units/Person/Year</i>)	1,074	1,366	1,279	1,110	1,121	2,036	779
1. Megacity population from CEA letter dated 22/07/11 regarding data collection on megacities for 18th EPS							
2. Peak demand data from approximated from reports on respective cities. Kolkata figure is of CESC							
3. Load growth rate for Bengaluru and Hyderabad are of the respective DISCOMs. Kolkata figure is of CESC							
4. Sales and power purchase data from reports on respective cities. Bengaluru data is BESCO's and Hyderabad is CPDCL's							
5. Per-capita for megacities are approx calculations done by authors. Bengaluru data is BESCO's and Hyderabad is CPDCL's							

Population figures for the megacities are from the CEA, which is consolidating electricity data for megacities, as mentioned in Section 1. Peak demand for Bengaluru, Chennai and Hyderabad are approximate values from utility reports. Peak demand given in the table for Kolkata is that of CESC, and the figure of Kolkata is higher at 2392 MW. It can be seen that the peak demand is relatively high for Mumbai and New Delhi. Peak demand of the megacity is about one-fifth to one-third of the respective State's peak demand. The per-capita peak load for mega cities is in the range of 150-300 W/person, quite high compared to the national figure of 100 W/person. High electricity use by

megacities is also reflected in the per-capita consumption (calculated as total power purchase divided by the population). It can be seen that the per-capita consumption in megacities is much higher than the national average of 779 Units/person/year and is the highest for New Delhi. This will naturally result in higher per-capita carbon emissions in the megacities, compared to the all India average. Per-capita consumption values for Bengaluru and Hyderabad are for the respective DISCOMs. International studies report that cities of the world, housing half the population, consume two-third of the energy (WEC 2010, IEA 2008). It can be seen that the growth rate is of the order of 3-4%, except for New Delhi, which has a high growth rate of 7%, comparable to the all India growth of 7%. In the core of the megacity, load growth rate seem to be low, but it seems to be high at the newly developed townships like Electronic city (Bengaluru), Hitec city (Hyderabad), Salt Lake City (Kolkata) etc. Load growth rate is high for DISCOMs in case of Bengaluru and Hyderabad and cannot be compared to that of megacities.

3. Demand Profile and Generation & Distribution Infrastructure

This section covers the electricity demand profile as well as the generation and distribution infrastructure required to meet this demand in the megacities.

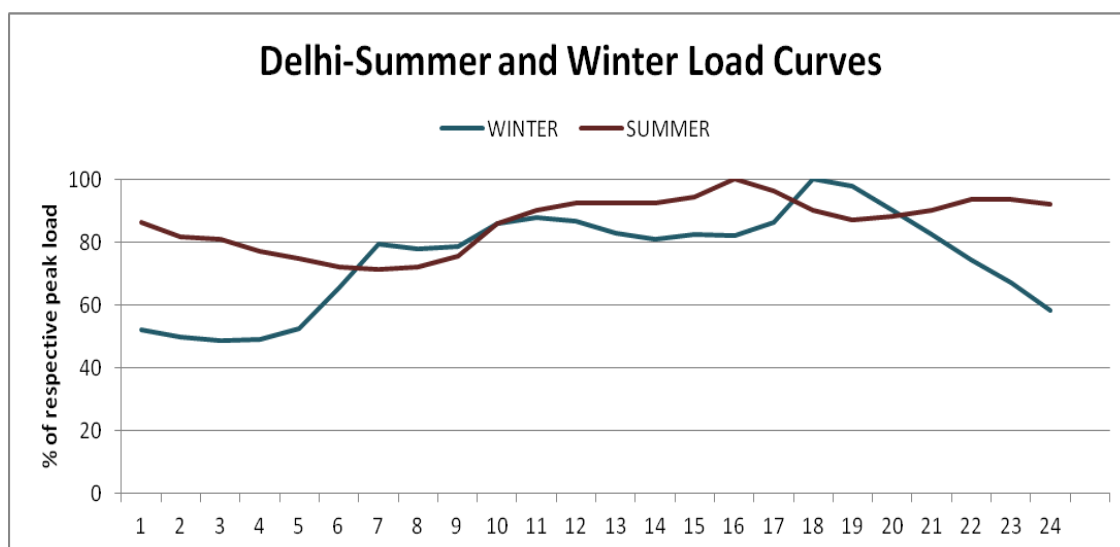
3.1 Demand Profile

The daily load profile of a megacity is quite different from that of the State, region or the country. The State load profiles are more or less flat due to load shedding in villages and regulated agriculture supply. Load shedding is relatively less (or absent) in megacities and the prominent demand is from commercial and domestic consumers. Due to all these, the daily peak demand in megacities occurs during the day time, unlike that for the State and there is large variation between peak demand to minimum demand. Ratio between peak and minimum demands can be 2:1 in a single day or as high as 4:1 if one considers ratio of annual peak to annual minimum occurring in different days of the year.

Load curves for typical summer and winter days for Delhi are given in Figure 1. Figures A1, A2 and A3 in Annexure -1 are the load curves for Hyderabad, Kolkata and Mumbai along with that of the respective States. These are plotted on an hourly basis showing demand as a percentage of the respective peak demand (normalised demand). These give a general idea of the city demand trend and compare it with that of the State for the same season. Table 2 gives the summary of load curve data. It gives the summer and winter peak and minimum demands for the megacities and the States.

From the load curves for Delhi in Figure 1 and Table 2, it can be seen that the summer load is higher than winter load and that the peak demand occurs during the day at 4 PM in summer and 6 PM in winter. The ratio between peak and the minimum demand during summer is 1.4, and 2.1 in winter. Ratio between summer peak and winter minimum is as high as 3.1.

Figure -1: Summer and Winter load curves for Delhi



Source: Summer Load Curve for 24.06.2011 as reported in Delhi SLDC Monthly Report (June), Winter Load Curve for 04.11.2011 as reported in Delhi SLDC Monthly Report (November)

Table 2: Summary of Load Curve data

City/State	Summer Peak Day				Winter Peak Day				Annual
	Peak (MW)	Time (Hrs)	Min (MW)	Peak / Min	Peak (MW)	Time (Hrs)	Min (MW)	Peak / Min	Summer Pk / Winter Min
Bengaluru	2,000	NA	1,000	2.0	NA	NA	NA	NA	NA
Karnataka	8,264	20	6,268	1.3	NA	NA	NA	NA	NA
Hyderabad	2,370	11	1,925	1.2	NA	NA	NA	NA	NA
Andhra Pradesh	11,400	5	9,700	1.2	NA	NA	NA	NA	NA
CESC - Kolkata	1,856	16	965	1.9	1,289	18	510	2.5	3.6
West Bengal	6,000	20	4,200	1.4	5,200	18	3,300	1.6	1.8
Mumbai	3,192	16	1,945	1.6	2,773	12	1,581	1.8	2.0
Maharashtra	17,779	14	15,068	1.2	20,890	13	15,507	1.3	1.1
New Delhi	5,014	16	3,567	1.4	3,294	18	1,600	2.1	3.1
1. Data compiled by the authors from Load Dispatch Centre Reports, Regulatory Submissions, DISCOM site etc									
2. Data for Chennai, Winter data for Hyderabad and Bengaluru not available									

From Table 2 and Figure A1 in Annexure-1 giving the load curve for Hyderabad and Andhra Pradesh on summer day, it can be seen that the peak demand occurs during the day at 11 AM for Hyderabad and in the morning at 5 AM or night at 10 PM for Andhra Pradesh State. The ratio of summer peak demand to minimum demand is nearly 1.2 for Hyderabad and for AP – quite the same in this case. We could not obtain winter data for Hyderabad.

From Table 2 and Figure A2 in Annexure-1 for Kolkata, it can be seen that the State load curve is relatively flatter compared to the city curve. For Kolkata, peak demand is at 4 PM in summer and 6 PM in winter. For West Bengal, it is at 8 PM and 6 PM respectively. The ratio of summer peak demand to minimum demand is 1.6 and in winter it is 1.8. Ratio of summer peak to winter minimum is as high as 3.5. For West Bengal, these ratios are lower at 1.4, 1.6 and 1.8, indicating less variation.

From Table 2 Figure A3 in Annexure-1 for Mumbai, it can be seen that the Mumbai peak demand occurs during the day at 4 PM in summer and 12 O'clock in winter. For Maharashtra, it is also in the day time, at 2 PM and 1 PM respectively³. The ratio of summer peak demand to minimum demand is nearly 1.6 and in winter it is 1.8. Ratio of summer peak to winter minimum is as high as 2. The load curves for Maharashtra is relatively flatter and these ratios are lower at 1.2, 1.3 and 1.1, indicating less variation.

Hourly load data was not available for Bengaluru. But BESCO sources and press reports indicate that the peak demand for Bengaluru is 1800-2000 MW occurring in the morning hours whereas the minimum demand is 1000 W at early morning hours. The ratio of peak to minimum demand is nearly 2 (see footnote 10). For the Karnataka State, this ratio of peak to minimum is 1.3, indicating a flatter load demand. Summer peak demand for Karnataka is at 8 PM.

3.2 Generation

Generation planning to meet the demand without much load shedding and addressing the peak demand variation is a challenge for megacities. DISCOMs use in-city power generation and power purchase from other generators to meet the demand. Table 3 gives data of in-city generation and compares it with the peak demand. Except Hyderabad, other megacities have significant in-city generation facility, a big facilitator for reliable supply⁴. Most of these have been set up years ago when cities were the main load centres. Shortage of land and strict environmental guidelines make it impossible to plan big coal based generating stations in the megacities.

As seen from Table 3, cities do have large coal based power plants. It can be seen that in-city generation is not sufficient to meet the peak demand in any city. Presence of in-city power plants increases the reliability of supply, since the city need not depend only on long transmission system to bring power into the city. The bigger, geographically spread State or regional transmission grids are more prone to failure, which would affect electricity supply to the city. Thus Mumbai, which has significant in-city generation, has an islanding scheme, which isolates the city in case of a Maharashtra grid failure.

Table 3: In-city Generation

City	Major Fuel Source	Installed Capacity (MW)	Peak Demand (MW)
Bengaluru /BESCOM	Diesel	108	2,000
Chennai	Coal, Gas, Diesel	1,400	2,000
Hyderabad	N/A	0	2,170
Kolkata	Coal	1,225	1,856
Mumbai	Coal, Gas	1,580	3,192
New Delhi	Coal, Gas	1,103	5,014

Source: Various Tariff Orders and Regulatory Submissions by DISCOMs

The draft National Electricity Plan prepared by CEA, covering the generation and transmission systems for the 12th plan recommends setting up of 400 MW gas based peaking power plant with

³In the previous years, both Mumbai and Maharashtra demand peaks were in the evening at around 7 PM

⁴Hyderabad had the Hussain Sagar thermal power station with 4 units adding up to 22.5 MW. This was set up in 1920 and demolished in mid 1990s (Reminiscence of a tech marvel , Times of India, Hyderabad 06/04/2012)

black start capability located near five major metros. CEA plan says that these plants could be constructed near the metro cities in the vicinity of existing or proposed gas grid and operated for about 6-8 hours a day. Besides meeting the peaking demand these plants could also be operated during the system contingencies such as low voltage, transmission constraints, etc., thus adding to reliability of power supply. This would also provide black start facility (starting up the system after a total failure) in the event of a grid collapse. It suggests a Task Force under Central Electricity Regulatory Commission (CERC) to deliberate upon the various aspects associated with setting up of these. Plan also says that the experience gained from operation of these peaking plants would pave the way for creation of additional peaking plants in other major cities and higher capacity in future (CEA 2012).

Figure 2 gives the fuel mix of annual power purchase in Million Units (MUs) by megacities. This includes purchase from plants within and outside the cities and from the market, for which the fuel used is not known. Data for Bengaluru, Chennai and Hyderabad is for BESCO, TANGEDCO and CPDCL.

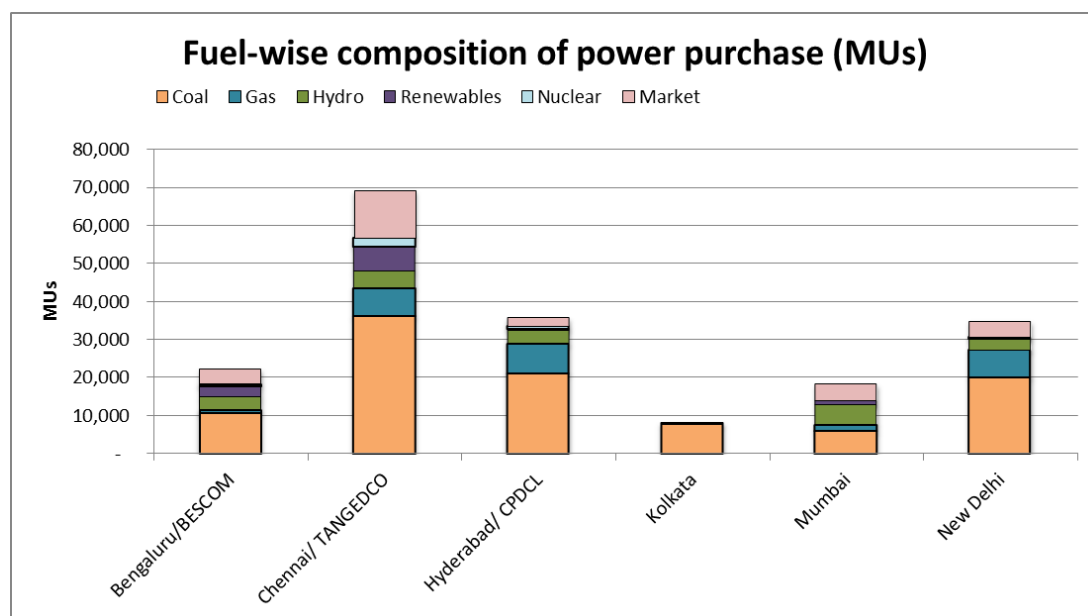


Figure 2: Fuel wise composition of power purchase

Source: Tariff orders of DISCOMs

Total values for Bengaluru, Chennai and Hyderabad are high because they are for respective DISCOMs. New Delhi is the megacity with the highest amount of power purchase and coal continues to be the main fuel for providing electricity to megacities. The proportion of renewable sources has been slowly increasing over the years and is expected to increase further.

Figure 3 gives the percentage break-up of megacity power purchase by ownership. This includes State, Centre, Private and Market. Market purchase is through short term contracts (few hours to few months) from traders, power exchanges or through Unscheduled Interchange (power transactions based on frequency).

Data for Bengaluru, Chennai and Hyderabad are for the respective DISCOMs. It can be seen that Kolkata and Mumbai, which have been managed by private DISCOMs for many years, purchase most

of the power from private sources. New Delhi, being the capital city gets most of its electricity from Central sources as was the case before privatisation of distribution in 2002. The proportion of power purchase by from market sources is high in Mumbai (24%), considering that at the national level about 10% of electricity is transacted through the market. High percentage of market purchase significantly increases the power purchase cost, as short term market power is costlier than long term contracted power.

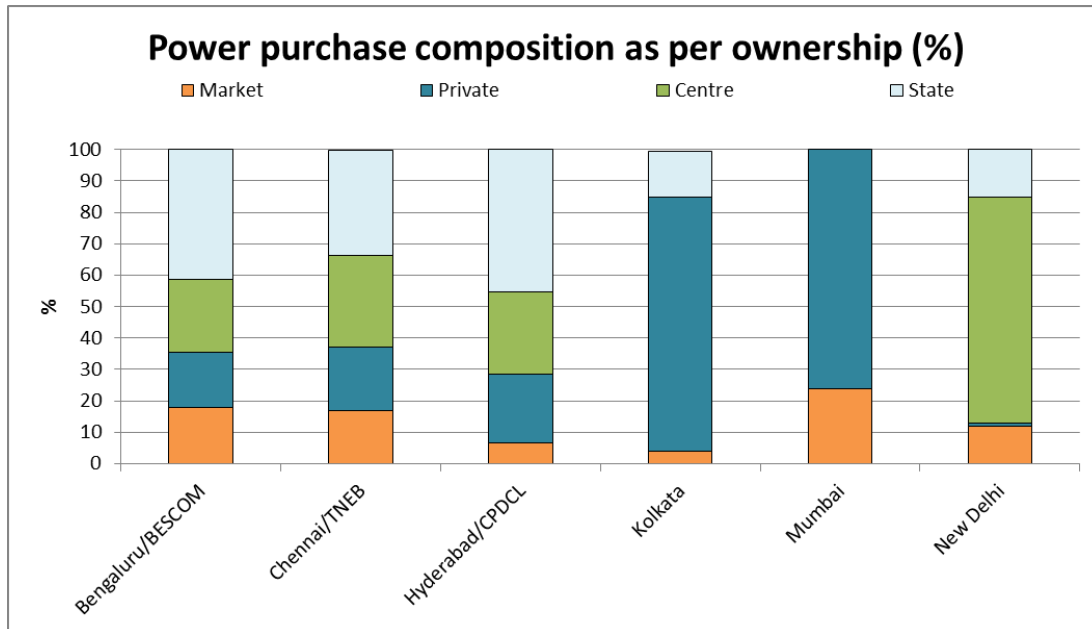


Figure 3: Power purchase by ownership

Source: Tariff orders of DISCOMs

3.3 Distribution

The transmission & distribution infrastructure in megacities is robust compared to the rural distribution system with redundancy to cater to at least one level of failure. This is achieved by providing multiple routes to supply electricity to a consumer, through distribution rings at extra high (132 kV and above) and high (33 or 11 kV) voltages and remote switching facilities. Use of underground cables, which are relatively more reliable compared to overhead lines, is increasingly planned in all megacities. Table 4 gives a comparison between overhead line and underground cable.

Many megacities face the problem of safety hazards due to proximity of overhead lines and buildings. Fatal accidents have been reported due to accidental contact with High Tension lines from the balconies and distribution poles have been found located inside houses⁵. The root cause for all this would be unplanned and uncoordinated growth. Short term measures to address this include insulating lines close to buildings or shifting lines, while underground cabling could be a long term solution.

⁵For example see this report on Hyderabad: “Funds allotted for shifting power lines”, The Hindu – 17/05/2012 (<http://www.thehindu.com/news/cities/Hyderabad/article3428054.ece>)

Factor	Overhead Line	Underground Cable	Remarks
Accident hazard		Lower	Especially in crowded areas and due to low hanging wires near buildings or crossing roads
Losses		Lower	
Failure due to wind, rain	High	Very low	Cable faults 1/3 rd that of line. But since cable repair takes time, 100% stand-by to be planned
Fault location	Slow	Fast	In cables, location can be done in minutes
Fault repair	Fast	Slow	Cable repair can take weeks
Right of way	Required	Less of an issue	No tall structure allowed below lines. Routing of lines impact land prices. In case of cables, caution to be taken while digging and structures cannot be planned along the route as access for repair is needed.
Routine maintenance	Needed	Very little	
Aesthetics		Better	Overhead lines with un-planned connections from poles and stringing of street light/TV/internet cables can be quite unsightly.
One time cost		Costlier by 4 – 10 times	
Life - years	20-30	40	

Source: Table prepared by the authors based on Pabla (2001), articles and discussions with industry professionals

Space is a premium in megacities. There is expansion in buildings and roads in the existing space, with changes in floor space index rules and new construction – both planned and un-planned. Distribution transformers and switch boards are often constructed on footpath or common land. In addition to high cost and lack of availability of land, DISCOMs also report problems in land acquisition, unless it is from government agencies since their transactions have to be transparent and they can only offer official prices⁶. There are also instances of tariff discounts (5-10%) given to consumers who have provided space to the DISCOM to construct substations⁷.

To address the space challenge, use of Gas Insulated Substation is increasing compared to the conventional outdoor Air Insulated Substations (AIS), in megacities. Compared to the AIS option, these require only 15-30% of floor space and height, has lower maintenance cost and higher reliability. These could also be constructed under-ground. One time cost for such a substation is higher, but the overall life time cost is only 15-30% higher. The cost advantage is higher at higher voltages⁸.

High Voltage Distribution System (HVDS) is another technology option which minimises the length of Low Voltage (415 Volts), thereby reducing technical losses and theft. HVDS is being extensively used in India for power supply to agriculture and is also employed in some cities. Underground cables, gas insulated substations and HVDS could be considered as “technologically best” options, if planned and implemented properly. They are costly options and would provide the expected benefits if they are planned and implemented well. If they are taken up without integrated planning, proper cost

⁶Land paucity has power firms worried, Times of India, Mumbai, 23/01/2012, CPDCL finds it hard to acquire land for sub-stations, The Hindu, Hyderabad, 14/06/2012

⁷See DERC Tariff order for NDMC, dated August 2011. Tariff structure on page 103 mentions lower tariff for non-domestic LT consumers who have provided built up space for substation.

⁸This is consolidated from TNEB (2002) and discussions with industry professionals

benefit analysis studies and strict quality control, they could turn into problems rather than solutions.

Cities like Mumbai and Kolkata face the problem of heavy rains and flooding. The Mumbai floods of 2005 saw 12 feet water submerging many distribution transformers. It was a big challenge to restore supply and provide high platforms for transformers and distribution boards.

Mumbai has the unique distinction of having two DISCOMs in the same geographical area – Tata and Reliance, with the consumer having a choice of supplier. This presents monitoring and regulatory challenges. With the high cost of infrastructure, complexity of operation and regulatory challenges, it is unlikely that such situation would replicate in many cities. Please see the box ‘Competition in the Mumbai Power Distribution Sector’, which gives an overview.

Competition in the Mumbai Power Distribution Sector

Tata Power Company (TPC) has traditionally had licenses to generate, transmit and distribute electricity in Mumbai, which have been amended from time to time. In 1997, TPC introduced a tariff for retail consumers and was in effect supplying power in areas which were under license areas of Rlnfra (Suburbs) and BEST (South Mumbai). As per TPC’s interpretation of its prevailing licenses, it claimed to have right to supply in both these areas without needing a fresh parallel license. This claim was challenged by Rlnfra (and later by BEST) at various forums, like Maharashtra Electricity Regulatory Commission (MERC), Appellate Tribunal for Electricity (ATE) and finally the Supreme Court. The Supreme Court through its July 2008 judgment reaffirmed TPC’s right to supply to consumers in Rlnfra’s area of supply and also suggested that in order to do so it can use Rlnfra’s network for wheeling power. This judgment proved to be a watershed in Mumbai’s power sector as for the first time in India even the small retail consumers had the choice of selecting the distribution licensee.

In August 2009 TPC approached MERC to formalize detailed operating procedures necessary for implementing the Supreme Court’s order. Based on this petition MERC through an interim order dated 15th October 2009, formalized consumer switch-over mechanism allowing Rlnfra consumers to migrate to TPC or vice-versa. Migrating consumers can choose to have Rlnfra or TPC meter. Both parties should ensure that the meter is of a downloadable variety and has common specifications in case of changeover consumers but TPC will be in charge of meter reading and Rlnfra will cross-verify. As TPC’s tariff was significantly lower than Rlnfra’s, many large industrial and commercial consumers shifted to TPC. As on June 2011, about 1.6 lakh consumers (including about 83,000 domestic consumers) have migrated from Rlnfra to TPC. Out of these, only 5031 consumers are connected on TPC-D network, while the remaining continue to be connected to Rlnfra network.

Following this arrangement, consumers of BEST also approached MERC to introduce similar changeover process for them. Through its order dated February 22nd 2010, MERC allowed TPC to supply to consumers in BEST area of supply under similar arrangement and also allowed it to lay its own network for the purpose. BEST appealed against this order before the ATE. The ATE upheld MERC’s decision. BEST then appealed to the Supreme Court which in-turn directed the ATE to rule in this matter and ATE reaffirmed MERC’s order in this case.

Today, Mumbai is the only city in India where consumers have choice for selecting distribution licensee and many have benefited from this arrangement and switched over to the licensee which is offering lower tariffs. However, like any other reform process, presence of two licensees in the same area has given rise to new set of challenges. Rlnfra apart from having highest tariff (majorly on account of high cost power purchase) in the country, also had a huge regulatory asset (more than Rs.2000 cr. ~44% of their total Annual Revenue Requirement) as well as large number of small domestic consumers and hence presence of cross-subsidy in tariff structure. As the high end consumers were the first ones to switch, Rlnfra was left with smaller consumer base to recover the regulatory asset which largely includes un-recovered power purchase cost of the previous years. Subsequently, MERC through its order dated July 29, 2011 imposed cross-subsidy surcharge as well as regulatory asset related surcharge for all the migrated consumers receiving supply from TPC through Rlnfra’s wires.

Source: MERC and ATE orders, TPC and Rlnfra business plans

Capital investment in distribution infrastructure in megacities has been high. This is captured in Table 5, which shows the Gross Fixed Assets (GFA) and average annual capital expenses (Capex) for the distribution infrastructure in megacities.

Table 5: Distribution investment

City	Bengaluru /BESCOM	Chennai / TANGEDCO	Hyderabad / CPDCL	Kolkata	Mumbai	New Delhi
Gross Fixed Assets (Rs. Cr)	3,908	7,811	5,783	4,622	6,813	8,992
Capital Expenditure (3 Year Average)(Rs.Cr/Year)	403	726	521	441	700	1,062
Sales (MU/Year)	18,736	58,449	28,741	8,135	17,963	20,684
Gross Fixed Assets/Unit Sold (Rs./Unit)	2.09	1.34	2.01	5.68	3.79	4.35
Avg. Annual Capital Expenditure/Unit Sold (Rs./U/Yr)	0.22	0.12	0.18	0.54	0.39	0.51
Note:						
1. Data for Bengaluru, Chennai and Hyderabad is for BESCOM, TNEB and CPDCL respectively						
2. Calculated from the ARR submissions of the respective DISCOMs. CESC includes EHV network also						

Figures for Bengaluru, Chennai and Hyderabad are for the respective DISCOMs, which also cater to large rural areas and hence would also be investing in agriculture supply. High Capex typically correlates to high consumer and load density, high revenues, high supply quality and low losses. An earlier Prayas study of urban private distribution companies (Prayas 2003) had also brought out these details. In recent years, the Central government urban distribution improvement program R-APDRP has also been contributing to higher distribution investment in cities, which have government owned DISCOMs. In case of megacities having separate DISCOMs, this cost is shared by the megacity consumers, but in case of Bengaluru, Chennai or Hyderabad, the cost of investment in the megacity is shared by all consumers of the DISCOM – which covers urban and rural areas. Detailed studies are required to ascertain if the investment in cities is comparatively higher and if rural consumers are cross subsidising the urban.

Deregulation and privatisation in similar urban sectors – water supply, sewerage, telephone, internet, roads, metro-rail and piped gas pose more challenges in planning and maintenance of distribution network by sharing the limited urban right of way. There have been suggestions of planning a common utility corridor to share expenses in construction and maintenance. Setting up a coordinating agency to assist in planning, cost sharing, optimised investment and operation of all service providers in the megacity will also help. Very high rise buildings with 50+ floors pose another challenge. In case of very high rise building with high load consumers, it becomes necessary to locate the transformer and meter on a floor half way up the building and therefore have the point of supply there. But, as per the current rules and regulations, the point of supply is to be at the ground floor where the transformer and all meters would be located⁹.

⁹This is based on discussions with industry professionals and articles

4. Electricity Use and Tariff

This section covers electricity use and tariff by different consumers in megacities. State regulatory commissions fix the consumer tariff periodically and the latest tariff orders are used for this comparison.

4.1 Introduction

Consumers are grouped into different categories (like domestic, commercial, industrial, agriculture) and in each category, there are different slabs based on the monthly consumption limit and connected load. Thus, each DISCOM would typically have 30-50 tariff classes with wide variations in consumer categories and slabs (which are like sub-categories) across companies and States. To get a broad idea of electricity use and tariff across cities, a few representative consumer categories and slabs have been chosen based on the study of tariff orders applicable to the six megacities and using the standard norms suggested by CEA in their “Estimated Average Rates of Electricity” for all DISCOMs (CEA 2009). Table 6 gives the selected consumer categories and slabs.

Tariff figures given include variable and fixed charges and are corrected for any government subsidy. There are multiple DISCOMs in Mumbai, Kolkata and New Delhi. In Mumbai weighted average has been taken for tariff and aggregate values for proportion of sales and growth rate. In Kolkata, CESC figures are given since they supply to 70% of the city. Tariff for the consumers supplied by the West Bengal DISCOM is around 10% lower. In New Delhi, the tariffs of three DISCOMs are same, and aggregate has been taken for proportion of sales and growth rate. In case of Bengaluru, Hyderabad and Chennai tariff in the city is that of the respective DISCOM.

Table 6: Representative Consumer Categories

Assumption to calculate average tariffs across cities			
Category	Groups	Units/Month	Connected Load (kW)
Domestic	BPL	30	N/A
	Small	50	
	Average	180	
	Big	300	
Commercial	Small	100	1
	Average	1,500	10
	Big	7,500	50
Industrial	LT	1,500	10
	HT	7,500	50
Railway Traction		2,500,000	12,500
Water Supply		Energy Charges Only	

Notes:

Domestic	BPL	Assuming a normative consumption of 1 unit per day per household as envisaged in the National Electricity Policy,2005. Tariff calculation does not depend on connected load for Domestic
	Small	Consumption of a small household which is not BPL assuming usage of 2 fans,2 tube lights and 1 TV
	Average	Across cities the average consumption of domestic consumer for the year 2010-11 was close to 180 units per month
	Big	Consumption of a household (with 4 or more rooms) using an AC, water heater, washing machine , refrigerator ,TV, 4 Tube lights, 4 Fans,4 CFLs, computer
Commercial	Small	A small commercial establishment using 1 Fan,1 Tube light and a refrigerator or motor load
	Average	Corresponds to CEA classification of second smallest consumer category.
	Big	Corresponds to CEA classification of biggest commercial consumer
Industrial	LT	Corresponds to CEA classification of small industry
	HT	Corresponds to CEA medium industry category
Railway Traction	HT	Corresponds to CEA assumption to determine average tariff

4.2 Tariff comparison

Figures 4 and 5 give the tariff data for domestic and non-domestic consumers in the six megacities.

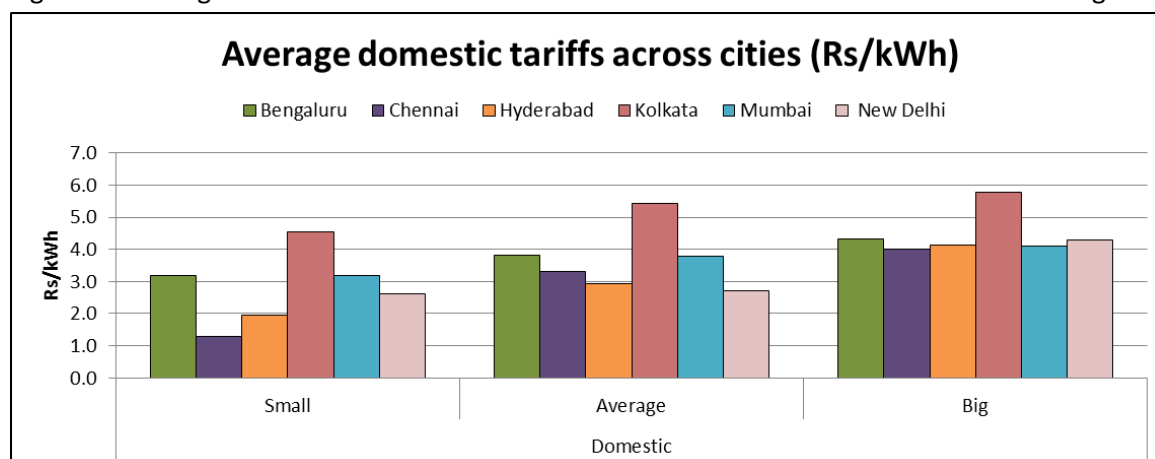


Figure 4: Tariff for Domestic consumers across megacities

Source: Tariff orders of DISCOMs

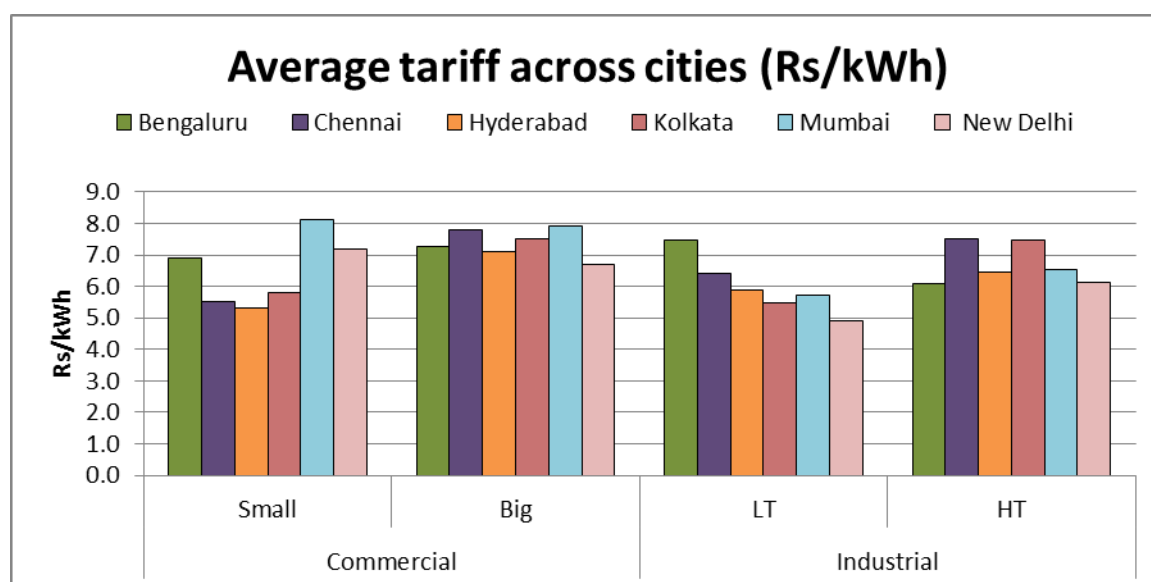


Figure 5: Tariff for Commercial and Industrial consumers across megacities

Source: Tariff orders of DISCOMs

All cities have a separate category for very poor households – called Kutir Jyoti in Bengaluru, Jhuggi Jhopri (New Delhi), Domestic BPL in Hyderabad and Lifeline/BPL in Kolkata- with very low tariff, varying from Zero in Bengaluru (with State subsidy) to 40 P/Unit in Mumbai to Rs.1.45/Unit in Hyderabad. The respective State government provides revenue subsidy to the DISCOM or there is cross subsidy to keep the tariff of the BPL, small and average domestic consumers low. Majority of the domestic consumers belong to average domestic group. From Figure 4 and 5, it can be seen that there is large variation of tariff across cities, except for HT industry. Tariff for railway traction (not shown in the figure) is more or less same across cities, varying Rs. 5.5 – 6.5/unit, whereas for water supply tariff (not shown) varies from Rs.2.0/unit (Hyderabad) to Rs.5.6/Unit (Delhi).

From Figure 4, it can be seen that small domestic tariff is highest in Kolkata and the high domestic tariff for all cities is in the range of Rs. 4-6/Unit. Tariff difference between small and big domestic is lowest in Kolkata and Mumbai, while it is highest in Chennai. From Figure 5, it can be seen that commercial consumers pay the highest tariff and the tariff for big commercial is Rs.7-8/Unit. Looking at the variation in tariff for different consumers in a city, it can be seen that there is cross subsidisation, with industry and big commercial consumers partially supporting low tariff for small consumers. There is difference in tariff across consumer categories (say small domestic to big commercial) and also in a category across classes (small domestic to big domestic). It is seen that the difference across categories is minimum in Kolkata implying similar tariff for all consumer categories. Difference across classes in domestic and commercial consumers is minimum in Kolkata and Mumbai.

In addition to the tariff figures shown, there are some rebates as well as additional charges based on the pattern of consumption. Rebates are given for high load factor (higher hours of use of the connected load) and additional charges for violation of maximum demand limit, low power factor etc. Consumers also have to pay fuel cost variation charges to compensate the DISCOMs for unforeseen variations in fuel prices. This is about 30-90 paise/Unit for all consumers in Mumbai, New Delhi and Kolkata. Most cities have the provision of time of the day/time of the season tariffs especially for the industry to incentivise electricity use during low load periods.

To encourage green power, Hyderabad and Bengaluru have a green tariff option. HT consumers can opt for this and have to pay a higher tariff – Rs.7/Unit in Hyderabad and one rupee more than their current tariff in Bengaluru. Bengaluru offers a rebate of 50 paise/unit for consumers who have installed solar water heaters with a maximum of Rs.50/month. It can be seen from Figure 5 that the tariff for big commercial is high at Rs.8/Unit, quite close to the current grid connected Solar PV tariff. Demand profile of commercial consumers more or less matches the intensity of sunlight. Hence there is a strong case - from economy and ecology perspectives - for big commercial consumers to opt for roof top solar to partially replace grid power.

4.3 Proportion of sales

Figure 6 gives the proportion of electricity sales to different consumer categories across megacities. Data for Bengaluru, Chennai and Hyderabad are for the respective DISCOMs. Proportion of consumption by domestic and commercial consumers is high at 60 to 70% in Mumbai and New Delhi. Kolkata has significant industrial demand. Consumption by railway traction is around 2-4 % in megacities, and is expected to grow due to the on-going plans for metro rail. Proportion of electricity consumed by water pumping and street lighting is around 2-3%.

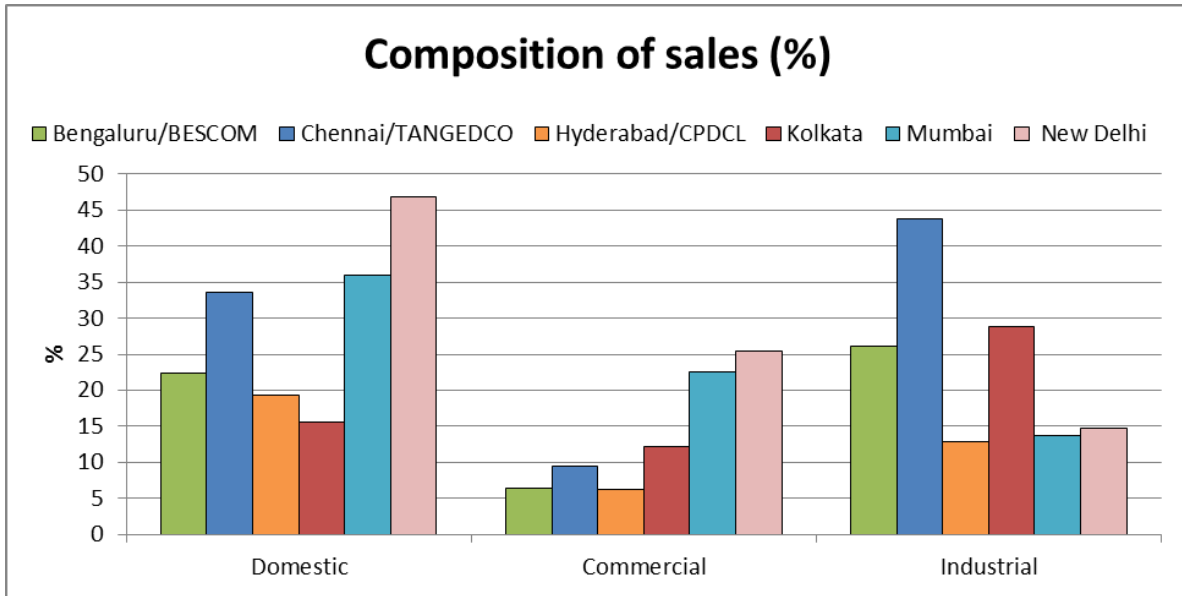


Figure 6: Composition of sales to different consumer categories

Source: Tariff orders of DISCOMs

4.4 Consumption growth rates

Figure 7 gives the consumption growth rates across megacities for the period 2007-2011.

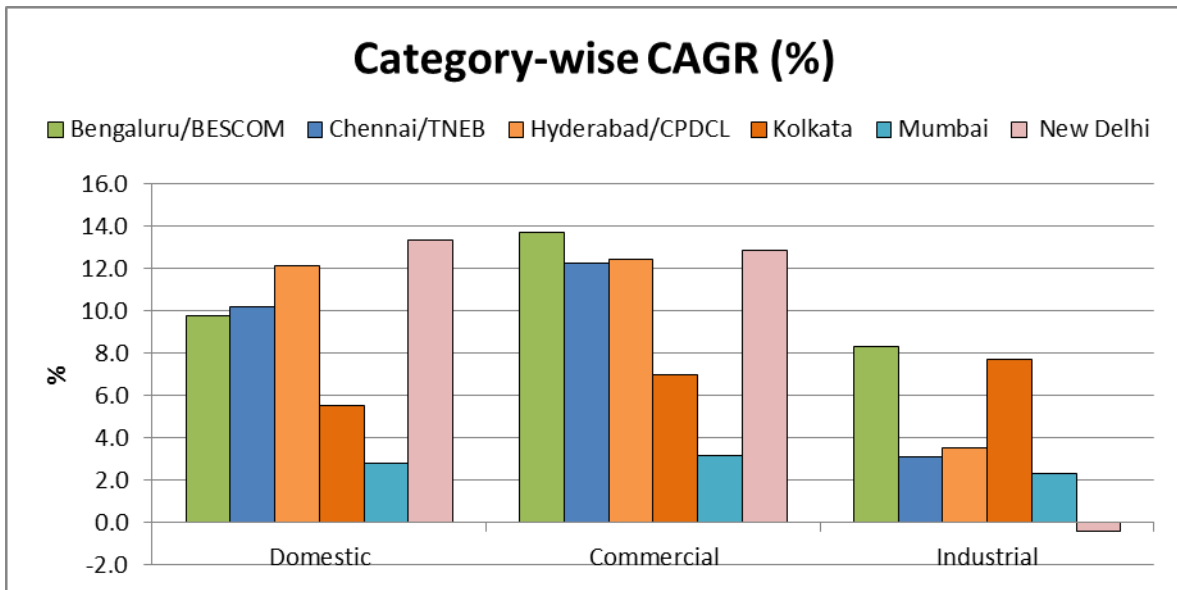


Figure 7: Growth of consumption of different categories

Source: Tariff orders of DISCOMs

Data for Bengaluru, Chennai and Hyderabad are for the respective DISCOMs. It can be seen from Figure 7 that growth rate is low for industry in Mumbai and New Delhi. New Delhi has the highest growth rates for domestic and commercial consumers. Industry demand growth is low or neutral, especially of the HT industry. This is a matter of concern for the DISCOM since Industry demand is typically round the clock whereas the demand of domestic and commercial consumers is for a few hours in a day. Load surveys in Mumbai and New Delhi have indicated that Air Conditioners and

water heating are major contributors to peak loads. The Mumbai survey reported that air conditioning load is growing fast and contribute to 40% of the demand¹⁰. DISCOMs have been exploring options of load management like staggered holidays, time of the day tariff, end use efficiency promotion programs, shifting water pumping to non-peak hours if there is sufficient water supply and consumers have sufficient water storage etc. The 12th Five Year Plan recommends load survey by all major DISCOMs for end use efficiency and peak power management, with the Bureau of Energy Efficiency (BEE) given the role of consolidation (Planning Commission 2012a).

5. Operation and Efficiency

DISCOMs operate the city distribution system and all megacities have well equipped Supervisory Control and Data Acquisition (SCADA) systems, Geographical Information Systems (GIS), Customer Call Centres, Mobile repair crews, IT based metering, billing and collection systems and Management Information Systems (MIS) to assist them. The distribution system itself is comparatively robust with high redundancy. High media visibility, good political patronage and presence of quality conscious high-end consumers have contributed to good reliability and efficiency of megacity distribution systems. Large load variations in the course of the day and year pose severe challenges for system operation. Table 7 gives some efficiency and reliability indicators for Hyderabad, Kolkata, Mumbai and Delhi.

It can be seen that the figures for efficiency and quality indicators are high in megacities. This is to be expected since they are the commercial capitals and many essential services (rail transport, water supply etc) depend on high quality electricity supply. The reasons for high figures could be traced to a combination of high investment, use of advanced technology (infrastructure, monitoring, metering, billing, collection) and management practices (availability of staff, political support). Mumbai DISCOMs have the lowest Aggregate Technical & Commercial (AT&C) losses and Distribution Transformer (DT) failure rates. Consumer reliability indicators (SAIFI, SAIDI and CAIDI) are available for DISCOMs in Kolkata, Mumbai and New Delhi. Here again the Mumbai DISCOMs report low number and time of interruptions, in line with the general impression that supply reliability is good in Mumbai. The number of fuse-off calls per consumer is low in Mumbai and Kolkata. These figures are taken from DISCOM reports and ideally should be cross checked through independent third party validation. CEA regularly prepares 11 kV feeder availability and consumer reliability figures. The 2009-10 annual report and the March 2011 monthly report indicate 99+% reliability for cities (CEA 2010).

Even though the macro indicators for efficiency and reliability are good in megacities, there is wide variation across different areas in the cities. Examples are the 50-60% AT&C loss reported in few distribution divisions of New Delhi, 40% AT&C loss reported by one distribution circle in Hyderabad, 15-70% distribution loss reported by Reliance in Mumbai or the anecdotal evidence on the poor quality of supply in slum areas. These can be addressed only through technical and management innovations from DISCOMs as well as political support from the government.

¹⁰Tata Power presentation: Utility perspective –Load growth in urban centres and opportunities to optimize energy use in retail sector, January 13, 2011

Table 7: Efficiency and Reliability indicators

City	BESCOM	Chennai	Hyderabad	Kolkata	Mumbai	New Delhi
AT&C Losses (%)	14.3	8 to 10	17.3	13.5	5 to 9	12 to 23
DT Failure Rate (%)	N/A	N/A	7.8	1.4	0.8	0.4 to 1.4
SAIFI (number)	N/A	N/A	N/A	30.5	4 to 39	150 to 269
SAIDI (minutes)	N/A	N/A	N/A	41.4	64 to 137	179 to 379
Number of Fuse off calls	N/A	N/A	1,018,468	14,829	92,854	1,068,711
Fuse off calls per consumer	N/A	N/A	0.33	0.01	0.02	0.26
Note: AT&C Losses is not BESCOM and not Bengaluru.						

Notes:

1. Information regarding Efficiency and Reliability Indicators could not be obtained for Chennai and Bangalore. Other data is collected from SoP reports and ARR submissions of DISCOMs for 2010-11.
2. AT&C loss: Aggregate Technical & Commercial (AT&C) losses indicate the technical & commercial efficiency of the DISCOM. It combines technical loss on distribution system and non-technical losses in metering, billing and revenue collection (loosely called theft). It is calculated using the cost of energy purchased by the DISCOM and the revenue realised. AT&C losses for Bengaluru is about 8.3% (Personal communication with KERC) and for Chennai city is about 8 to 10%. The national average for AT&C loss is 27.5% (PFC 2010)
3. DT Failure rate: Distribution Transformer (DT) yearly failure rate is a good indicator of the consumer power supply reliability. State/DISCOM average figures for this are 10-15%.
4. SAIFI and SAIDI: System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) are indices indicating reliability of consumer supply. Interruptions are sustained interruptions (lasting typically more than 3 or 5 minutes) and these indices are calculated for a year using consumer data. Thus SAIFI is the average number of interruptions/consumer in a year and SAIDI is the average duration of interruption in minutes. There are exceptions given for planned load shedding, bad weather etc. CESC data is per-feeder and not consumer

6. Planning Challenges

Electricity is a high quality resource with strong correlation to quality of life and multiplier effect on economic growth. Electricity planning involves demand forecasting based on policies and past demand trends, followed by planning the generation and distribution infrastructure to meet the demand. Time horizons employed in planning are typically perspective (10-20 years), long term (5 - 10 years) and operational (few hours to few years). Country-wide perspective and long term plans are prepared by the CEA based on inputs from State utilities. Urban bodies also prepare Master plans covering land use and broad plans for different utilities (transport, electricity, water etc). The State transmission and distribution companies have to fine tune this plan to prepare long term and operational plans. Power purchase agreements and investment plans of the distribution companies are to be approved by the Electricity Regulatory Commissions.

Indian megacities are fast growing compared to the mature megacities of Tokyo, London or Paris (Murayama 2006). Demand growth in core megacity area is low, but is high in newly developing areas. This is due to additional connections and increasing penetration of appliances. There is

growing demand of high-end consumers who push for world class quality of supply as well as that of community services (water supply, railway traction, street lighting, hospitals etc, which have no option other than electricity, thus making it an essential service) and small consumers (households, shops, workshops). Since commercial and domestic consumers account for 60% of the demand, demand has strong correlation to weather and time of the day.

Power purchase planning for megacities is a challenge especially since there is wide variation between peak and off –peak demands and load shedding is not easy to implement. In the absence of proper planning for long term contracted power purchase, city DISCOMs have to depend on short term market power purchase, which results in high tariff. This is a sign of poor planning since power purchase for a significant portion of the demand (base and intermediate demand) can be tied to long term contracts.

Distribution planning needs to ensure that power can be purchased from sources outside the city and conveyed to all consumers. There is an expectation of high reliability and the challenge of shortage of space. Many Indian megacities have to expand the legacy infrastructure to cater to growth using technology innovations. In these cities, there are also areas where green field infrastructure is being set up, with the associated challenge of coordination with many other agencies. Planning for utility corridors to house electricity, water supply, sewerage, telephone, internet and piped gas is an important requirement for megacities. This will optimise investment and ease maintenance in the long run¹¹.

Considering the climate challenge and the impending fossil fuel shortage, it is important that megacities take the lead in ‘green power’, which includes renewable energy and end use efficiency. Box “Megacities to pioneer green power” gives the outline of the challenges and opportunities in this area.

The following sections look at the City master plans, businesses plans of some DISCOMs and issues of small consumers.

6.1 City master plans and DISCOM business plans

Looking at the city master plans of New Delhi, Chennai, Hyderabad and Bengaluru prepared by the urban development authorities, we find that electricity planning does not find detailed coverage in these. These documents largely cover land use guidelines and in electricity sector, have only very broad demand projections and suggestions, based on inputs provided by the DISCOMs.

The New Delhi master plan projects demand growth from 3265 MW to 8800 MW between 2001 and 2021. It suggests measures like: a) setting up a 400 kV transmission ring around Delhi, b) use of non-conventional energy sources like solar for street lighting, traffic signals, hoardings, etc., c) making solar energy mandatory for all establishments with floor area of more than 300 sqm. In March 2012, the Delhi Electricity Regulatory Commission has initiated the process of appointing a consultant to study the distribution system and prepare a perspective plan. The Chennai master plan projects a

¹¹Mumbai DISCOMs report that the cable reinstatement charges of the municipal authorities are comparatively high and nearly 4-5 times the cable cost (Business Plans of TPC-D, Reliance Infra-D)

demand growth of 1067 to 3498 MW from 2001 to 2021 and includes plans for waste to energy plants.

Megacities to pioneer green power

In January 2011, the United Nations Secretary-General, Ban Ki-Moon, declared that 2012 will be the International Year for Sustainable Energy for All. He called for “*a global clean energy revolution – a revolution that makes energy available and affordable for all*”, adding that this was essential for minimising climate risks, reducing poverty and improving global health, empowering women and meeting the Millennium Development Goals, for global economic growth, peace and security, and the health of the planet.

It is clear that we cannot continue the current model of producing and consuming energy. Fuel supply is fast depleting and the irreversible impact of energy sector on ecology, including climate change, has nearly reached a dangerous breakdown situation. It is important that there is significant reduction in our energy use (especially the luxury consumption), increase in electricity generation using renewable sources and improvement in end use efficiency. These measures in ‘green power’ are relevant for megacities as much as for the rural areas. In fact, megacities, with high consumption, availability of resources, high consumer density and political visibility have a greater responsibility in pioneering green power.

Current initiatives in green power include central government programs like National Solar Mission to promote renewable energy and energy labelling and building codes of Bureau of Energy Efficiency to promote efficient appliances and buildings. Most DISCOMs have DSM cells. Some DISCOMs have taken up awareness programs, campaigns to replace appliances (LED based street lights, CFLs or efficient tube-lights, replacing fans with energy efficient fans etc), initiatives to shift water pumping load etc. Regulatory commissions have taken measures like tariff concessions for consumers with solar water heater (Karnataka), green tariff for those who opt for costly green power (Karnataka and AP), tariff incentive for reducing monthly consumption (tried in Maharashtra) and time of the day tariffs (with peak tariff 1.5 to 2 times the off-peak tariff). Load research and demand side management studies have been done in Mumbai (R-Infra), Delhi (Tata Power), Gujarat etc (RInfra 2009, Tata Power 2010, USIAD 2010). Many cities are planning waste-to-energy plants. With the increase in tariff for commercial consumers and fall in solar PV prices, roof top solar is fast becoming a good option from economy and ecology aspects, especially since the air conditioning load profile matches that of sunlight.

It has been pointed out that about 70% of the infrastructure in 2030, such as buildings, will be added in next two decades – between 2010 and 2030. The case is similar for appliances and equipment, however, with faster growth and shorter life than infrastructure (Prayas 2011). Hence it is important to increase attention to end use efficiency now, especially in megacities, which are witnessing high growth. As seen in section 4.4, consumption growth rates are highest in the commercial segment, followed by domestic. Load research reports have pointed out that nearly 40% of the electricity consumption is by ACs, which have high growth rate and contributing to long summer peak hours due to increasing use by commercial and high end domestic consumers. Water heating contributes to winter morning peak (Rinfra 2009, Tata Power 2010). The potential for savings are as high as 30% in these segments, with 40% in newly constructed buildings and 40-50% by use of super-efficient appliances, which are already commercially available. In the commercial segment, retail traders, restaurants, hotels, education institutions and government offices, which together account for 60% of the commercial electricity consumption could be short listed for energy efficiency measures. Multi-State large scale program (as opposed to DISCOM level pilots) and incentivisation of the equipment manufacturers, as opposed to the consumers could be more effective (Prayas 2011, Prayas 2011a).

It is important that megacities take the initiative in piloting green energy programs to quickly demonstrate results and stabilise the technology and institutional aspects, thus facilitating easy adaptation all over the country.

CESC- Kolkata projects a demand growth of 1280 to 2925 MW from 2002 to 2021. CESC's current installed capacity of own generating stations is 1225 MW (Coal based) and there are plans to purchase about 400 MW from Haldia Energy Limited in 2015, under long term agreement. Balance requirement is planned to be met from WBSEDCL and other sources viz. traders and power exchanges. CESC plans to develop the necessary infrastructure for this¹².

The Mumbai DISCOMs plan to add about 4000 MW capacity by 2015-16. There are plans to remove the transmission constraint into the city, set up condition monitoring systems, enhance the underground cable network, plan mobile DG sets, improve consumer interface systems, augment the distribution network and add roof- top solar systems. Reliance has initiated a study project with IIT-Bombay to assess the maximum demand upto 2030 and improve the distribution network (Business Plans of TPC-D and Rlnfra).

6.2 Issues of small consumers

For the urban poor, electricity is closely linked to quality of life and livelihood. Consumers living in slums, small shops and workshops constitute the urban small consumer group. To quote from the 12th plan working group report on urban issues on Urban Poverty, Slums, and Service Delivery System: *"In addition to being an indicator for quality of life, basic services provision such as electricity, water, sewerage, transport, health care are crucial to the success of micro and small businesses. When coupled with the constraints of segregation, financial exclusion, insecurity and lack of space, inadequate service provision can act as a deterrent for the proliferation of micro-enterprises and employment generation of the urban poor."* (Planning Commission 2012)

Urban small consumers are large in number, but consume only a small proportion of the electricity sold and since their tariff is low, contribute only a small proportion of the DISCOM revenue. In Mumbai domestic consumers (consuming less than 300 units/month) constitute half the total number of consumers, consume 30% of the electricity and contribute 15% of the revenue. In Delhi, they are again half in number, consume 10% of the electricity and contribute to 5% of the revenue. (ARR 2012). Revenue from big consumers is high and the commercial orientation of the DISCOM compels it to allot higher resources to serve them better and increase their consumption further. Unlike industry, commercial, colony welfare associations or farmer groups (not relevant for megacities), there are very few organisations representing their long term interests and their political voice is low. Ensuring adequate, affordable, quality electricity supply to community and small consumers require special attention by the DISCOM, supported by the State government, through policy directive and subsidy support.

The urban small consumer is directly affected by service delivery issues in the short term and indirectly by governance issues (high cost power purchase, poor planning or power theft) in the long term. Figure 8 is a schematic representing the challenges in providing affordable quality electricity to the urban small consumer. This is adapted from Electricity for all: Ten ideas for turning rhetoric into reality (Prayas 2010).

¹²Source: Discussions with CESC

Electricity network is available in almost all areas of the city and household connection is near universal in megacities, as per Census 2011, but it is not clear if all the consumers are legal. As per Census 2011, household access in megacities is 98-99%, except in Kolkata, where is 96%. But a rough calculation using the number of domestic consumers reported by the DISCOMs (ARR 2012), average household size (NSSO 2010) and population (Census 2011), gives access figures varying from 75 – 85% for Delhi, Mumbai and Kolkata. This indicates the presence of shared or un-authorised connections. There is a need to improve the quality of data on small consumers. The very poor, or migrant population, who do not have legal connection resort to shared connections, use kerosene/ battery operated lights or do not own any form of lighting. Once they get legal connection, if the bills cannot be paid in time due to high tariff or wrong billing, they lose legal access and have to depend on hooking or shared connection. If the quality of supply or service is bad, they have to live with no electricity supply for long time or buy costly power conditioning or back up devices. It is also a serious safety hazard causing shock, fire accidents and equipment damage. Only if there is legal connection, electricity bills are affordable and quality of supply & service are good, do the small consumer get sustained access to electricity.

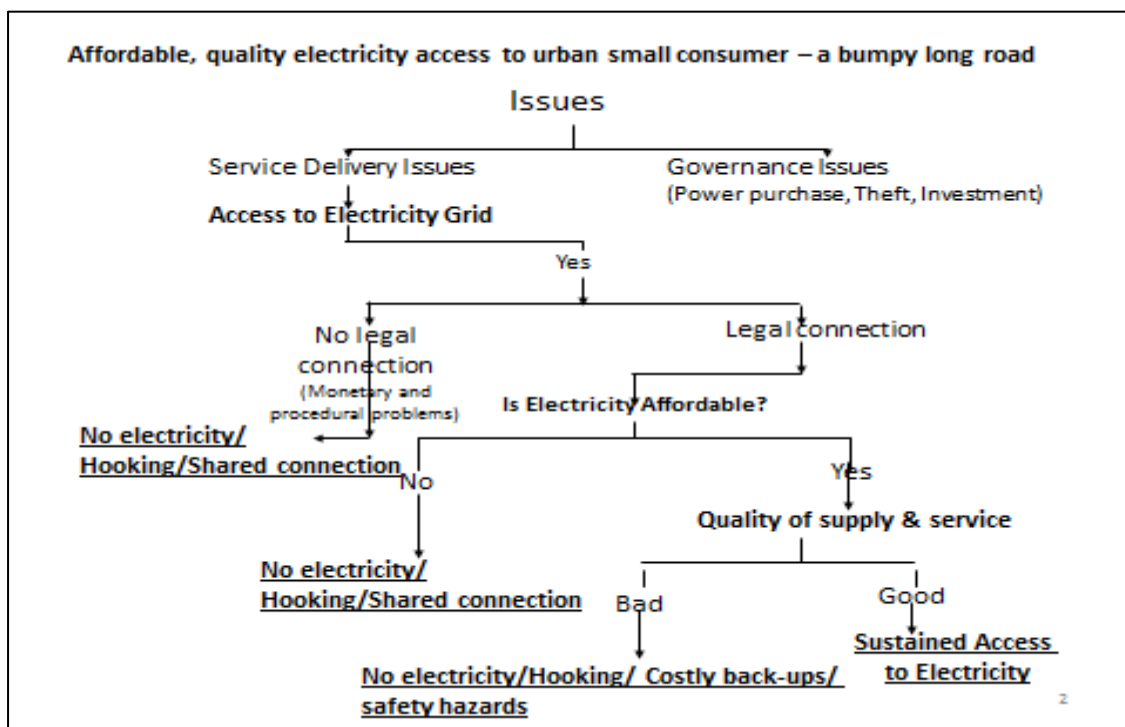


Figure 8: Issues of the urban small consumer

As per Census 2001, it is reported that nearly 1/3rd population in the cities live in slums, with varying population in the megacities – Mumbai (55%), Kolkata (33%), Chennai, New Delhi & Hyderabad (15-20%) and Bengaluru (10%). There are very few detailed studies on issues of the urban small consumers. One of them is the Mumbai Slum Electrification and Loss Reduction (SELR) project taken up by the World Bank, USAID, Reliance Energy and International Copper Promotion Council India, which brings out many issues of electricity service delivery in Mumbai slums. It points out the high consumer growth, low revenue returns, low availability of data, high risk to DISCOM employees, tenancy issues, migration and cash flow issues for the consumers. In the survey area near Chembur, it noted that one-third connections were illegal (paying Rs. 30-300/month to retain the

connection), distribution system was overloaded and phase imbalance was of the order of 1:3, losses were as high as 40% and 75% of the consumers pay less than Rs. 300/month. Unplanned settlements, narrow roads with no corridors for cables or lines and poor quality overloaded distribution infrastructure made maintenance a big challenge. Meeting this challenge require considerable investment, political support, proper planning, use of appropriate technologies and innovative management. This project also outlines some steps taken in this direction (Reliance Energy 2009, Limaye 2009).

7. Conclusion

This paper has given a thumbnail sketch of electricity issues in megacities. With high growth and high expectations on quality of electricity service, planning and operating the system is a big challenge. Issues of urban small consumers are different and need special attention.

The electricity demand profile of megacities is quite different from that of the State, with peak occurring during day time and wide variation between peak and minimum demands. With very low in-city generation capacity, meeting this demand is a big challenge. Megacities have severe space shortage challenge which has to be met through technology and management innovations.

Megacities consume a high proportion of electricity and the tariff is comparatively high. Consumer density and paying capacity are also high. It is therefore important to take up load use surveys and extensively promote green power - end use efficiency and renewable systems - in the megacities. This will also help to stabilise the technology and institutional arrangements so that country-wide rolling out would be smoother.

Planning, construction and operation of the megacity electricity system is largely the responsibility of the DISCOMs, though they have to manage this in coordination with many other institutions. This includes generators, transmission companies, power traders, power exchanges, regulators, municipalities, State government, Central government and other service providers in the city. A facilitating role of the municipalities in improving the urban planning process by catering to the requirements of electricity service providers and institutionalising the coordination between various service providers would improve electricity service delivery in megacities.

Annexure 1: Load Curves

This Annexure gives the daily load curves for Hyderabad (Figure A1), Kolkata (Figure A2 for CESC) and Mumbai (Figure A3) along with those of the respective States. The horizontal axis gives hours in a day in 24 hour format. The vertical axis is in percentage, giving the un-restricted demand as a percentage of the respective peak demand. This helps to compare the load curves of the city and the State on the same graph.

Hourly load data was not available for Bengaluru. But BESCOM sources and press reports¹³ indicate that the peak demand for Bengaluru is 1800-2000 MW occurring in the morning hours whereas the minimum demand is 1000 W at early morning hours. The ratio of peak to minimum demand is nearly 2. For the Karnataka State, this ratio of peak to minimum is 1.3, indicating a flatter load demand (data from SRLDC report for March 2012).

Figure A1 gives the load curves for Hyderabad and AP. AP Load curve is from SRLDC March 2012 report, demand met on 30.3.2012. Hyderabad load curve is prepared from data in the CPDCL website, demand met for Hyderabad and Rangareddy districts on 9.4.2012. It can be seen that the peak demand occurs during the day at 11 AM for Hyderabad and early morning 5 AM or night at 10 PM for Andhra Pradesh State. AP load curve is flat compared to that of Hyderabad. We could not obtain winter data for Hyderabad.

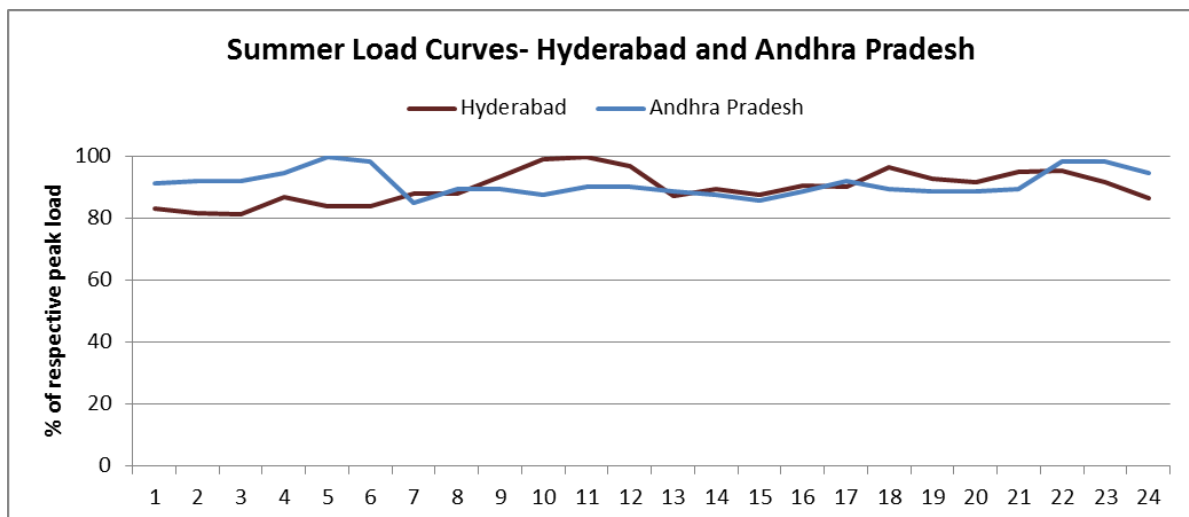


Figure A1: Hyderabad and Andhra Pradesh Load Curves

¹³Newspaper reports quoting Karnataka Energy Minister in Hindu Business Line – 5/5/12 and quoting CMD-BESCOM in DNA – 13/9/11

Figure A2 gives the load curves for CESC-Kolkata and West Bengal for summer and winter. CESC data is collected from CESC for 12/05/2011 in summer and 20/12/2011 in winter. West Bengal data is from monthly reports of ERLDC for 05/06/2011 for summer and 20/12/2011 for winter. It can be seen that the State load curve is relatively flatter compared to the city curve. For Kolkata, peak demand is at 4 PM in summer and 6 PM in winter. For West Bengal, it is at 8 PM and 6 PM respectively.

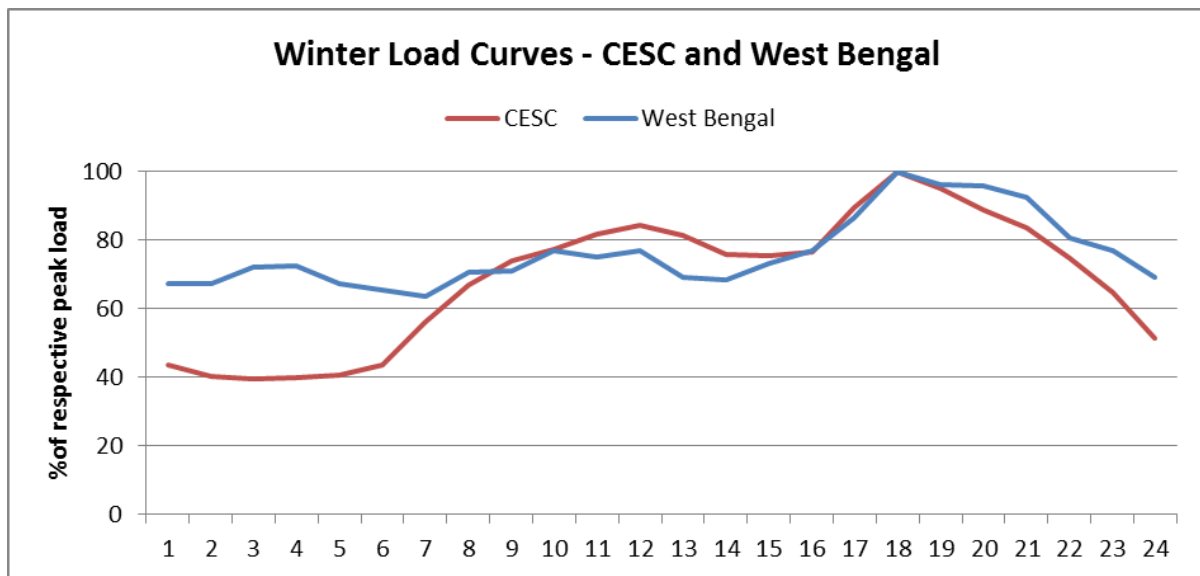
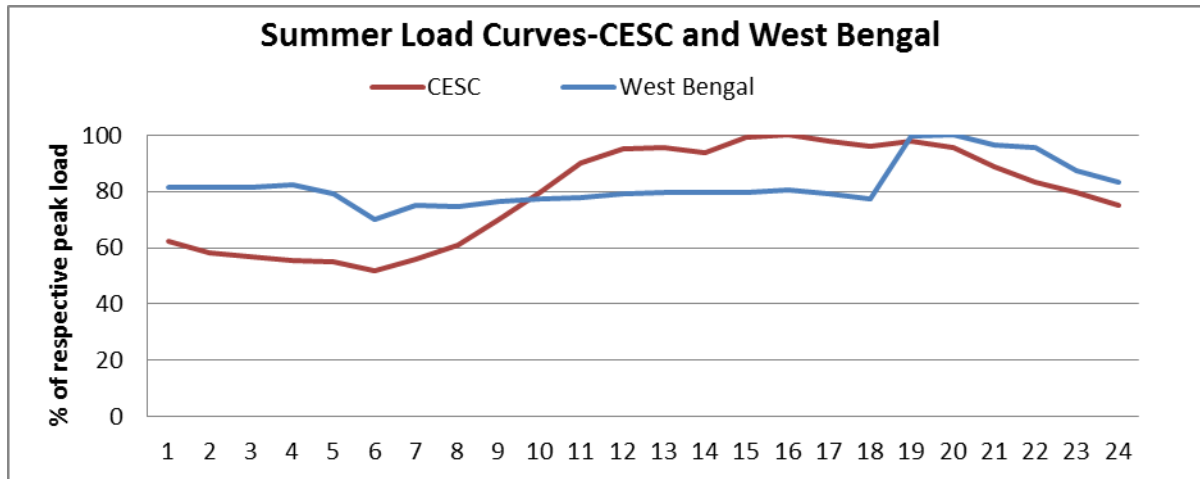


Figure A2: Summer and Winter load curves for CESC and West Bengal

Figure A3 gives the load curves for Mumbai and Maharashtra for summer and winter. These are prepared from the Maharashtra SLDC daily reports of 02/06/2011 (summer) and 05/12/2011 (winter). It can be seen that the Mumbai peak demand occurs during the day at 4 PM in summer and 12 O'clock in winter. For Maharashtra, it is also in the day time, at 2 PM and 1 PM respectively. The Maharashtra load curve is flat compared to that of Mumbai.

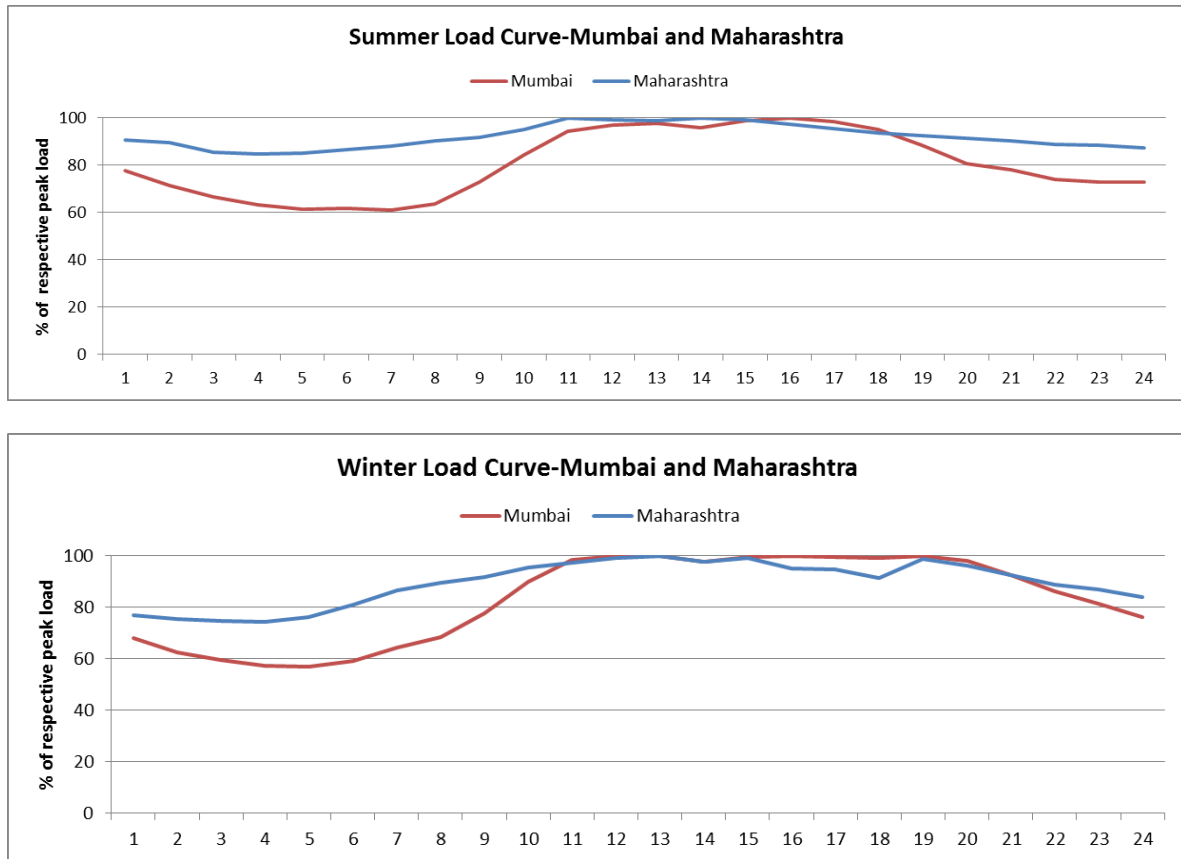


Figure A3: Summer and Winter load curves for Mumbai city and Maharashtra

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