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Overview

In its review of top engineering achievements of the 20th century in the United States, the National Academy of Engineering listed electrification as the top achievement.[1] Outranking other achievements such as the automobile, the Internet, and even space travel, this placement helps underscore the profound impact of electrification on everyday life and shows the remarkable effort it takes to provide electric service throughout a country.

With such a large and complex task, it is understandable that different countries are at different stages of electrification. In the United States, electric service is nearly universally available. Electric service in many developing countries is not available for large portions of citizens and does not always produce reliable electricity for those connected to the grid. Modernization seems to indicate that electricity use will continue to grow.

India offers a unique set of features for studying electricity use in the context of a developing country. First, it has a rapidly developing economy with high yearly growth rates in gross domestic product (GDP). Second, it has the second-largest population in the world and is likely to have the largest population in the future. Third, its electric system is maturing—with known difficulties (outages, shortages, issues with reliability and quality) that are characteristic of a developing country.

This article focuses on electricity use in the residential sector of India and discusses key trends and provides an overview of available usage estimates from various sources. Indian households are an interesting environment where many of India's unique features interact. The recent economic gains correlate with rising incomes and possible changes in living standards, which could affect electricity or other energy use within households. Additionally, the maturing electric system and large population in India both offer opportunities to study a range of interactions between electrification and electricity usage in a developing country.

Relationships between these factors are important for energy planning in India and around the globe. Just as electrification was a huge undertaking in the United States and transformed everyday life, these effects could be compounded in India due to the country's size and massive population. As other countries mature economically and technologically, energy needs may change in ways similar to what has and will happen in India.

[1] National Academy of Engineering. Accessed February 2014. <http://www.greatachievements.org/>.

Sectoral breakdown of electricity demand in India

This section provides the broadest view of electricity usage in India by looking at estimates of residential demand in relation to other energy demand sectors in the country. A number of studies were collected to compare electricity use estimates and the general methods toward achieving those estimates.

The two main approaches to constructing energy usage estimates are top-down and bottom-up. In the 2002 paper from the International Energy Agency (IEA), *Electricity in India: Providing Power for the Millions*, a more top-down method was used. IEA generated much of its own data for its estimates, which were largely done by collecting data from power generation facilities. Using survey results from those generators, IEA calculated various energy estimates for India—and for other global regions—including electricity usage.[2]

Stephane de la Rue du Can et al. used a bottom-up approach in their research paper from the Lawrence Berkeley National Lab (LBNL) in 2009, *Residential and Transport Energy Use in India: Past Trend and Future Outlook*. These researchers modeled end-use services (in this case, air conditioning, appliances, cooking and water heating, lighting, and other) and accounted for location (with effects from climate regions and in rural versus urban differences, for example) and technology (incorporating energy efficiency ratings, unit energy consumption measurements, and diffusion rates of household appliances and equipment). Using surveys and literature research to develop these models, they were able to build a national electricity use estimate.[3] While more inputs do not necessarily mean better results, the bottom-up approach involves more detail than IEA methods and allows for more in-depth analysis of results.[4]

[2] Specifically, IEA estimates electricity usage by taking total generation and then removing energy used to make electricity and transmission and distribution (T&D) losses.

[3] The paper cites household surveys from the National Sample Survey Organization, or NSSO (now known as National Sample Survey Office, and still the NSSO) as a major source of information, along with the National Council of Applied Economic Research (NCAER), "Comprehensive Study to Assess the Genuine Demand and Requirement of SKO."

[4] The strengths and weaknesses of each approach are beyond the scope of this paper. These estimates in Table 1 are presented to outline the methods and results.

Table 1. Comparison of historically-measured delivered electricity in India at the national level

	IEA (2002)		WEO2013		LBNL (2009b)
Year of Estimate	**1971**	**1998**	**1990**	**2011**	**2005**
Electricity Delivered (in TWh)	51	376	212	774	472
Percent to each sector:					
Residential	9	16	–	–	33
Commercial	6	8	–	–	13
Industrial	67	45	–	–	32
Agricultural	10	27	–	–	19
Transportation	3	2	–	–	2
Other	5	2	–	–	0

Sources: International Energy Agency (IEA), *Electricity in India: Providing Power for the Millions*, © OECD/IEA, 2002; data reproduced with permission from page 32 of IEA (2002). International Energy Agency (IEA), *World Energy Outlook 2013* (WEO2013), © OECD/IEA, 2013; data reproduced with permission from page 172 of WEO2013. Lawrence Berkeley National Laboratory (LBNL), *India Energy Outlook: End Use Demand in India to 2020*, 2009b; data reproduced with permission from Annex 10 and Annex 11 of LBNL (2009b). [5]
Note: Commercial sector includes energy used by public service entities.

Table 1 presents results from various studies about total electricity usage and how it breaks down by sector. While data methods and time periods between the studies are different, trends can be seen in the data. Overall, electricity consumption seems to be growing exponentially. Historically, the industrial sector had the highest electricity use, but the other sectors have become much more important since the 1970s. The industrial sector was still one of the top two users of electricity in the mid-2000s, but continued growth in the residential sector has become equal to industrial demand or has become slightly greater. The share going to agricultural use grew between the 1970s and 1990s, but that share decreased by the mid-2000s.

While growth in electricity use appears strongest in the residential sector, growth in the commercial sector may also warrant further examination. Each study in Table 1 shows the commercial sector using a low percentage of electricity compared with many of the other sectors.

This share has grown to 13% in 2005 according to LBNL (2009b), but it still represents a minor change since the 1970s, especially when compared to the growth in the residential sector. More growth in electricity usage may have been expected because India's economy is largely driven by the commercial sector—about 54% of India's GDP in 2005-06 (LBNL, 2009b). While there are a number of factors that could be responsible for the low share of electricity to the commercial sector, the share will also likely change as the economy keeps growing and electric service expands and improves. [6]

[5] LBNL (2009a) provides the bottom-up analysis for the residential sector, while LBNL (2009b) looks at broad electricity use in all energy demand sectors in India.
[6] Another aspect to consider in the commercial sector is captive generation (the smaller, more portable electric generators that enterprises can buy to generate their own electricity from an input fuel, which is usually distillate fuel oil in India). While the amount of captive generation is difficult to quantify, sources report that it is rare in the residential sector, common in the industrial, and somewhat common in the commercial sector (IDFC, 2010; USAID, 2006). It is likely more common in the latter, because profit-seeking entities put a premium on reliable electricity sources to run their operations.

Electricity use in Indian households

From the sectoral breakdown of Indian electricity usage in the previous section, this section characterizes electricity use within Indian households. Two studies with bottom-up modeling detail are presented to demonstrate these trends—LBNL (2009a) and World Bank (2008). After comparing these analyses, this section discusses some available expenditure data to help provide further understanding of electricity use.

In Table 2, LBNL (2009a) provides the residential detail behind the broad sectoral numbers that appear in Table 1 under LBNL (2009b). The first feature of this analysis is the distinction between urban and rural energy use patterns. The urban-rural distinction appears in many Indian energy studies and in National Sample Survey Office (NSSO) household survey data, which is used in many of these studies and demonstrates the importance of urbanization rates. Another feature is the identification of how Indian households use energy in four end-use services (cooking, water heating, lighting, and appliances),[7] but how households use electricity for only two of these services (lighting and appliances).[8]

Table 2. Residential energy consumption in India with end-use level detail, 2005

Fuel	End-use	Rural (TWh)	Urban (TWh)	Total
Electricity	Appliances	33.4	58.2	91.6
	Lighting	29.7	36	65.6
Kerosene	Lighting	68.2	18.3	86.5
	Cooking and water heating	24.5	33.4	57.9
LPG	Cooking and water heating	26	113.6	139.5
Wood	Cooking and water heating	894.6	47.4	942

TWh = Terawatthours

Source: Lawrence Berkeley National Laboratory (LBNL), *Residential and Transport Energy Use in India: Past Trend and Future Outlook*, 2009a; data reproduced with permission from Annex 8 of LBNL (2009a).[9]

Note: Electricity is considered delivered energy; kerosene, liquefied petroleum gas (LPG), and wood are considered primary energy.

Table 2 shows that electricity is the least used energy source in Indian households behind petroleum liquids (kerosene and LPG) and biomass (wood)—wood use is especially prevalent in rural areas. Electricity use accounts for about 157 terawatthours (TWh). Appliances and lighting consume similar amounts of electricity in rural areas, but appliances significantly outweigh lighting in urban areas. Overall, 58% of electricity is consumed for appliances and 42% for lighting.

[7] While LBNL (2009a) uses these four categories to characterize residential energy use, different studies often use different categorizations.

[8] LBNL (2009a) notes that electricity is used for cooking and water heating to some degree, but this electricity was categorized as electric appliance use for LBNL (2009a).

[9] The data are presented in petajoules (PJ) in the original source. In order to convert to terawatthours (TWh), LBNL (2009b) cites a conversion factor of 1,654 PJ = 472 TWh.

When considering all fuels, electricity makes up about 11% of residential consumption, but this increases to 36% if wood is taken out.[10] Both rural and urban households have significant lighting service coming from both electricity and kerosene.[11] Lighting is likely to be affected by the electrification process taking place in India (possible income and substitution effects as electrification continues).

Table 2 also reveals a demographic trend in electricity issues. LBNL (2009a) reports an urbanization rate of 29% in 2005—World Bank (2008) reports a similar rate, 28.9%, in 2006. This means that more than twice as many people live in rural areas than in urban areas in India. Notwithstanding costs, income, and preferences for efficiency, one would expect more electricity use in rural areas than urban areas because the overwhelming majority of the population lives there. Table 2 shows that the opposite is happening.[12]

LBNL (2009a) developed a separate model to break down electricity use in the typical Indian household.[13] Results from this separate analysis are presented in Figure 1. The first thing to note about Figure 1 is that this is a model of the typical Indian house and does not differentiate between rural and urban houses. Second, from this analysis the three largest uses for electricity were lighting, fans, and refrigeration, with lighting accounting for almost half of the total. Third, Figure 1 offers more detail about electricity use than Table 2, but the overall usage level and trends are similar.[14]

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[10] Many studies remove wood when drawing comparisons because of the distorting effect of the very high rural wood use.

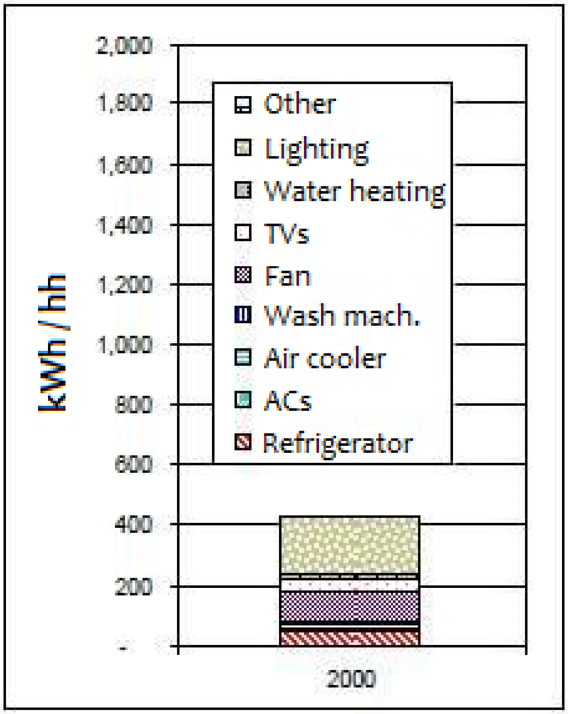
[11] LBNL (2009a) cites the finding from NCAER (2005) that credits continued kerosene use in electrified houses due to subsidized kerosene (through the Public Distribution System or PDS), frequent outages of electricity requiring an alternative lighting ability, and incomplete electrification of a home (electricity only available in one or a few rooms and not in others). In terms of lighting service, NCAER (2005) estimates that electrified households use 27% less kerosene for lighting than non-electrified households.

[12] Additional evidence for electrification comes from NSSO (2001) statistics reported by LBNL (2009a): in 2000, 90% of urban households used electricity as the main lighting fuel, 10% use kerosene. In rural areas, the split is about 50% to 50%. The share of rural homes using electricity for lighting went from 37% to 50% between 1993 and 2000.

[13] For full documentation see LBNL (2009a). In brief, the separate model (results shown in Figure 1) used income regression, electrification rates, unit energy consumption rates (UECs), and models for diffusion of electricity-using products.

[14] Data for Figure 1 were not included in LBNL (2009a), but the approximate 50% share of residential electricity going to lighting is similar to the 42% reported in Table 2. Furthermore, using demographic data that was included in LBNL (2009a) for Table 2, per household electric consumption is calculated out to about 440 kilowatts. The exact number cannot be determined from Figure 1, but, visually, total per household electric consumption in Figure 1 is slightly above 400 kilowatts.

Figure 1. Electricity consumption per household in 2000



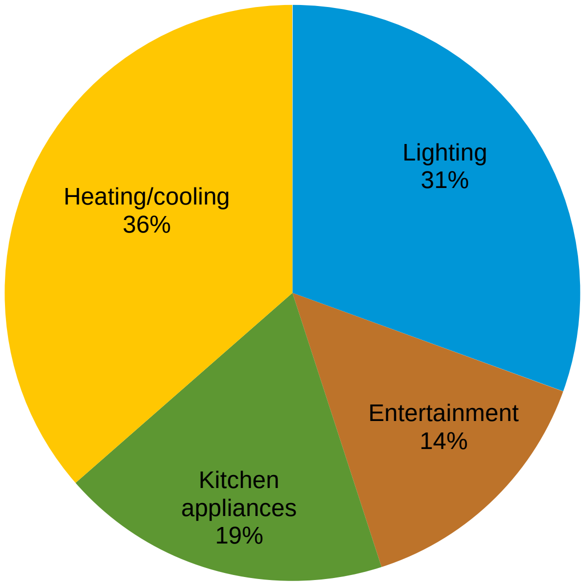
Source: Lawrence Berkeley National Laboratory (LBNL), *Residential and Transport Energy Use in India: Past Trend and Future Outlook*, 2009a; figure reproduced with permission from page 16 of LBNL (2009a).

Similar to these analyses from LBNL, World Bank (2008) employed a bottom-up, end-use modeling approach. The main components used by World Bank (2008) were household surveys, electrification rates, and appliance ownership rates. This model produces a historical estimate of 136 TWh of electricity used in the Indian residential sector in 2006,[15] which is lower than LBNL (2009a).[16] While it is hard to determine which estimate is more accurate, World Bank (2008) has more extensive input into its appliance model.

Figure 2 shows the electricity consumption results from World Bank (2008). The way end-uses were categorized allows for a simple comparison with LBNL (2009a). In LBNL (2009a), 58% of residential electricity went to appliances and 42% went to lighting. In World Bank (2008), 69% went to appliances (combination of heating/cooling, kitchen appliances, and entertainment) and 31% went to lighting.

[15] Calculated from Table 6 in Annex 8 of World Bank (2008).
[16] LBNL (2009a) estimated 157 TWh in 2005 (as shown in Table 2).

Figure 2. Electricity consumption for the residential sector in 2006



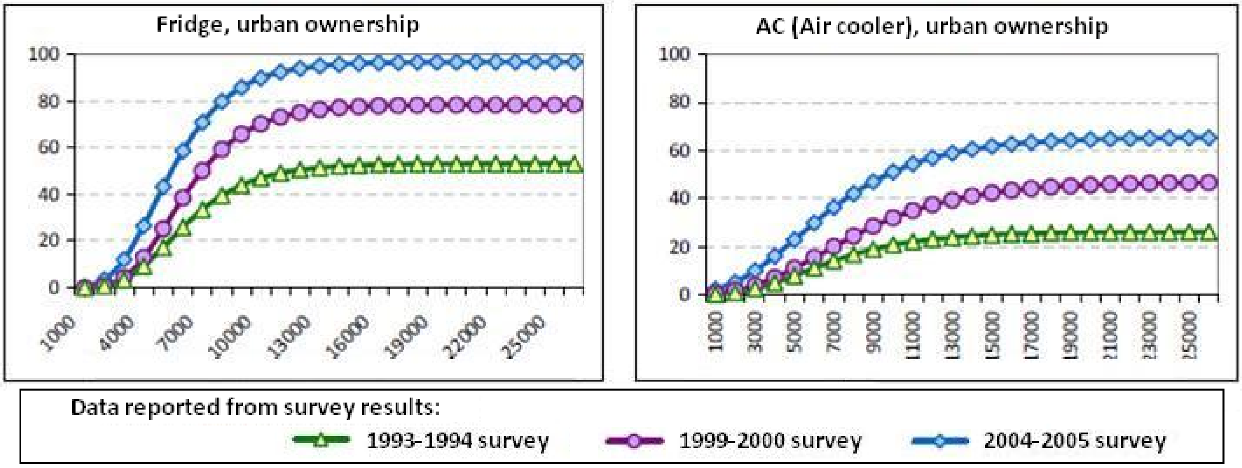
Source: The World Bank, *Residential Consumption of Electricity in India, Document of Data and Methodology*, 2008; data reproduced with permission from page 56 of World Bank (2008).

The biggest difference between LBNL (2009a) and World Bank (2008) is the level of detail within the appliance portion. LBNL (2009a) includes the energy characteristics of one average technology type in each of its end-use service categories (lights, water heaters, TVs, fans, washing machines, air coolers, air conditioners, and refrigerators). World Bank (2008) offers more technology types within each category.

The studies also have some similarities. Both studies point to the importance of lighting, fans (part of heating/cooling in Figure 2), and refrigeration (part of kitchen appliances in Figure 2). Both studies also see appliance ownership to be a major indicator in current and future residential electricity trends. And both studies use NSSO survey data in its analysis of appliance ownership. LBNL (2009a) notes:

- TV ownership: went from 13% of rural households in 1993 to 26% in 2002; rose from 49% to 66% of urban households in the same time period (page 9)
- Refrigerator ownership: rare in rural households, going from 1% in 1993 to 4% in 2001; rose 12% to 28% in urban households during that time (page 9)
- Air conditioner ownership: 18% of urban homes in 2002 (page 12)
- Fans and TVs were the most evenly distributed appliance across household income levels, while water heaters, clothes washers, air conditioners, and other appliances were less common and considered luxury goods (page 10)

Figure 3. Appliance ownership comparison across national surveys



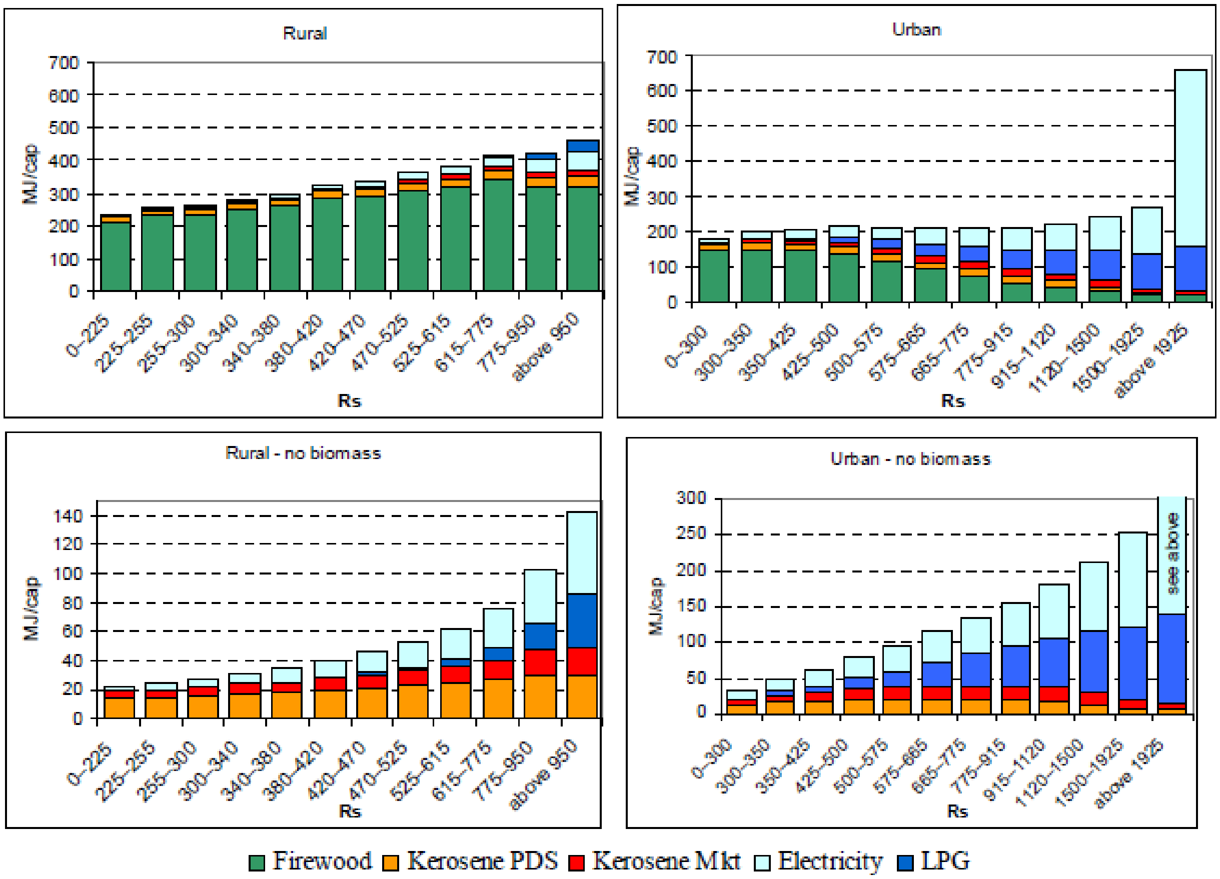
Source: The World Bank, *Residential Consumption of Electricity in India, Document of Data and Methodology*, 2008; figure reproduced with permission from page 25 of World Bank (2008).[17]

World Bank (2008) puts particular importance on refrigerators and air cooler. Using NSSO household surveys from multiple years, these researchers developed Figure 3. The horizontal axis in these figures delineates an income level measured in 2004 rupees, and the vertical axis reports the percentage of appliance ownership in households with at least that income level. First, the figures show the classic S-curve for purchases of new consumer goods. Second, the figures show that owning a refrigerator is more common than owning an air cooler. Third, as surveys get more recent, the S-curves get steeper, indicating that appliance ownership increases across income levels over time.

Other than appliance ownership, income also plays a role in the amount and type of energy purchased. Reporting residential usage according to levels of MCPE (monthly per capita expenditure), Figure 4 shows that households that spend more rupees on a monthly basis use more electricity. This is particularly evident in the urban section.

[17] Years indicate the time period for which survey data were collected; for example, the "1993-1994" survey corresponds to the 50th round of surveys, which was collected between July 1993 and June 1994.

Figure 4. Monthly final energy use per capita according to MPCE in 2000



Source: Lawrence Berkeley National Laboratory (LBNL), *Residential and Transport Energy Use in India: Past Trend and Future Outlook*, 2009a; figure reproduced with permission from page 4 of LBNL (2009a).[18]

Among fuels in Figure 4, kerosene shows low price responsiveness (i.e., a low elasticity) with monthly per capita expenditure (MPCE), while LPG and electricity show higher elasticities. Many attribute these phenomena to the *energy ladder*, a concept that describes the ascendancy of modern fuels (marked by being more convenient and cleaner for the end user) with improving economic development. [19]

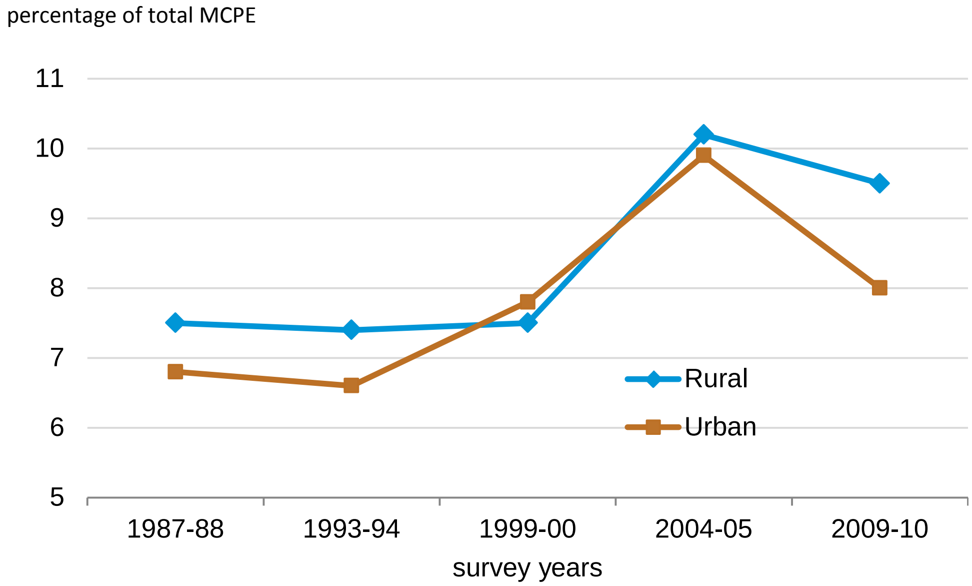
Besides income, the geographical location of a house may also determine whether electricity can be purchased. Figure 5 presents household survey data about household expenditure for fuel and lighting (NSSO, 2011). The data in Figure 5 represents the average consumer expenditure for fuel and light as a

[18] In Figure 4, the bottom two graphs show the same energy data as the top two graphs, except that the bottom two graphs have energy from wood/biomass removed. As noted before, wood/biomass is sometimes removed from graphs due to its distorting effect when visualizing data. Also, the Public Distribution System (PDS) is a subsidy program in India designed to aid low-income citizens and has a kerosene component. So, one category in Figure 4 is kerosene purchased by citizens through the PDS and another is kerosene purchased on the open market.

[19] The energy ladder is a concept mostly used in the context of international development, but not specifically designed for energy analysis.

percent of MPCE. Rural and urban expenditures follow similar paths; however, urban areas experience a rise in this share before rural areas. While the reasons for this earlier rise in urban households are not discussed in the survey, this would correlate with an increasing availability of electricity in urban areas before rural areas. Both areas see larger percentages of monthly expenditures going to fuel and light in the late 1990s and early 2000s.

Figure 5. Percent of MPCE for fuel and light across survey years



Source: National Sample Survey Office (NSSO), *Key Indicators of Household Consumer Expenditure in India 2009-2010*, 2011; data reproduced with permission from page 18 of NSSO (2011).

The implication that electricity use is becoming more common in urban areas than it is in rural areas is supported by specific data on electricity usage in the most recent NSSO household survey. NSSO (2011) reports that urban households spent an average of 138 rupees on fuel and light in 2009-10, of which 70 rupees was for electricity (51% of fuel and light); for rural areas, average spending for fuel and light was 85 rupees, with a little less than 19 rupees going to electricity (about 22% of fuel and light).[20] Urban and rural households spend similar percentages of their monthly expenses on fuel and light (Figure 5), yet urban households spend more—almost four times as much as rural households—and spend a higher percentage on electricity. This result would also correlate with higher incomes and more electrification in urban areas of India compared with rural areas.

[20] Statistics from Tables 4U (page 110) and 4R (page 104) in NSSO (2011).

Electricity demand not met: Load shedding (rolling blackouts)

The electrification process in India has clear implications for residential electricity demand—people cannot use electricity if the grid has not yet reached where they live. Thus, increased electricity use would be expected as electrification progresses. Researchers and analysts recognize this and usually include electrification factors when studying electricity consumption.[21] But, in addition to connecting and installing wires in a home, electricity use is also affected by the ability to deliver electricity reliably to areas serviced by the grid. India's power sector is maturing, but has received much scrutiny in this area—for outages, shortages, and unreliable service, to name a few.[22]

Many power companies purposely plan service stoppages, also called load shedding. These controlled service stoppages help to keep larger problems from occurring, such as widespread blackouts or wire damage from an overloaded system. The effect on residential electricity consumption is straightforward—load shedding prevents customers from using electricity.[23] For these reasons, it is important to consider the effect of these supply-side issues on electricity demand in India and other developing countries, especially if trying to plan for energy needs or develop projections for future electricity consumption.

LBNL (2005) provides load shed estimates for the state of Maharashtra in India. Maharashtra extends eastward from the Arabian Sea to the central part of India. The state is known for a strong, industrial economy. It is the second largest state by land area and contains a large population with many major cities (notably, Mumbai, Pune, and Nagpur). About 20% of Maharashtra's generated electricity in 2002-03 came from the national power companies, the National Thermal Power Corporation and the Nuclear Power Corporation (LBNL, 2005). The rest was generated in-state; the Maharashtra State Electricity Board (MSEB) generated 60%, and private companies, Tata and BSES (Reliance), provided about 18% (LBNL, 2005).

The sectoral breakdown of Indian electricity use was included earlier in Table 1; Table 1a is a modification of that table with categories added for additional service areas (Maharashtra and MSEB) and supply-side metrics for comparison purposes. LBNL (2005) reports that MSEB was able to meet its peak demand until 1998-99. Since that time, load shedding has occurred regularly, growing to 20.2% of delivered electricity in 2002-03.[24]

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[21] For example, electrification factors were included in LBNL (2009a) and World Bank (2008).

[22] Such issues would be expected for a country in the process of electrifying (as the power system matures, these conditions will likely improve and electricity will be more available to citizens).

[23] IEA calls this "latent demand" in its annual publication, *World Energy Outlook*.

[24] LBNL (2005) considers load shed as being taken away from delivered electricity—other studies take it away at electric generation or other stages. LBNL (2005) also notes that some MSEB customers are fully or partially protected from experiencing load shedding.

Table 1a. Comparison of historically measured national electricity use levels

	IEA (2002)		WEO2013		LBNL (2009b)	LBNL (2005)	
Year of Estimate	**1971**	**1998**	**1990**	**2011**	**2005**	**2002-03**	**2002-03**
Service area	Nat'l	Nat'l	Nat'l	Nat'l	Nat'l	Maharashtra	MSEB
Electricity delivered (in TWh)	51	376	212	774	472	49.9	38.8
Percent to each sector:							
Residential	9	16	–	–	33	25	19
Commercial	6	8	–	–	13	14	9
Industrial	67	45	–	–	32	36	40
Agricultural	10	27	–	–	19	21	26
Transportation	3	2	–	–	2	3	3
Other	5	2	–	–	0	1	3
Supply-side metrics:							
Generation (TWh)	61	442	–	–	618	80.5	48.6
Load shed (% peak)	–	–	–	–	–	–	20.2

Sources: International Energy Agency (IEA), *Electricity in India: Providing Power for the Millions*, © OECD/IEA, 2002; data reproduced with permission from page 32 and page 34 of IEA (2002). International Energy Agency (IEA), *World Energy Outlook 2013* (WEO2013), © OECD/IEA, 2013; data reproduced with permission from page 172 of WEO2013. Lawrence Berkeley National Laboratory (LBNL), *India Energy Outlook: End Use Demand in India to 2020*, 2009b; data reproduced with permission from Annex 10 and Annex 11 of LBNL (2009b). Lawrence Berkeley National Laboratory (LBNL), *Economic Benefits of Reducing Maharashtra's Electricity Shortage through End-Use Efficiency Improvement*, 2005; data reproduced with permission from page 3, page 5, and page 12 of LBNL (2005).[25]

Other supply-side statistics can be found throughout the literature. Table 3 provides a comparison of electricity shortage estimates (shortage defined as the lack of supply below total demand, expressed as a percentage) between a few such studies with different service areas (national, state of Maharashtra, or MSEB). While shortage and amount of load shed may be similar values, there does not necessarily need to be an exact, one-to-one relationship between the amount of shortage and load shed.[26]

[25] Page 3 presents generation data for Maharashtra and MSEB; page 5 presents consumption data for Maharashtra and MSEB; page 12 reports load shed by customer category in MSEB, which was used to calculate load shed for MSEB.

[26] Depending on the load shedding plan of the power provider, the load shed may be slightly more or less than the estimated shortage. Shortage, basically, indicates a need for load shedding to take place and represents an approximate value below expected demand.

Table 3. Comparison of electricity shortage estimates

	LBNL (2005)			USAID (2011)	USAID (2006)	IBEF (2007)
Service area	National	MSEB	MSEB	National	National	Maharashtra
Period	**2002-03**	**2002-03**	**2003-04**	**2003**	**Apr 05 - Jan 06**	**2005-06**
Shortage						
(% of demand):						
Average	9.1	–	–	16	8	–
Peak hours	12.2	20.2	17.8	24	11.6	23.1

Sources: Lawrence Berkeley National Laboratory (LBNL), *Economic Benefits of Reducing Maharashtra's Electricity Shortage through End-Use Efficiency Improvement*, 2005; data reproduced with permission from page 1, page 3, page 5, and page 12 of LBNL (2005).[27] *Evaluation of DRUM and WENEXA*, an evaluation prepared for USAID, 2011; data reproduced with permission from page 3 of USAID (2011). *Implementing End-use Efficiency Improvements in India: Drawing from Experience in the US and Other Countries*, a paper prepared for USAID, 2006; data reproduced with permission from page 9 of USAID (2006). India Brand Equity Foundation (IBEF), www.ibef.org, "Maharashtra," 2007, <http://www.ibef.org/download/Maharashtra_24Apr_08.pdf>; data found on slide 12.
For a discussion of sources for Table 3 see Appendix.

The data in Table 3 show a wide range in numbers within a relatively short time period. Overall, most estimates for Maharashtra, or the MSEB specifically, are higher than the national estimates. However, USAID (2011) cites a high national estimate.[28] Despite the variability, Table 3 shows the persistence of high electricity shedding in Maharashtra between 2002 and 2006. Furthermore, the studies show a sizable amount of electricity being shed, and also the uncertainty that can arise from accounting and reporting these statistics.

Shortages and other power supply problems have had distinct effects on electricity usage. It has driven some customers (notably in the industrial and commercial sectors) to purchase captive generators, which they can operate on their own using a secondary fuel to ensure a reliable source of electricity. It has also driven power companies to develop load shed plans. As a result of tariff structures and other economic and political considerations, these load shed plans tend to affect electricity customers differently.

[27] National estimate for 2002-03 reported on page 1. MSEB estimate for 2002-03 reproduced using electricity consumption and load shedding estimates (see Table 1a above). MSEB estimate for 2003-04 reproduced from page 5.
[28] It is hard to evaluate this statistic since USAID (2011) does not provide documentation for this specific statistic (the authors reference Ministry of Power reports, but do not source this specific number).

Table 4. Gigawatt hours (GWh) of MSEB load shed by consumer category (2002-2003)

	Urban	Rural	Total
Residential	614	963	1,577
Commercial	154	159	313
Industry (low tension)	176	257	433
Industry (high tension)	308	868	1,176
Agriculture & irrigation	90	3,653	3,743
Street lights	39	102	141
Railway traction	0	0	0
Railway non-traction	0	0	0
Public water works	38	150	188
Military	16	6	22
Mula Pravara	NA	243	243
	1,435	**6,401**	**7,836**

Source: Lawrence Berkeley National Laboratory (LBNL), Economic Benefits of Reducing Maharashtra's Electricity Shortage through End-Use Efficiency Improvement, 2005; data reproduced with permission from page 12 of LBNL (2005).
Note: Low and high tension refers to the different voltage of the power line servicing those customers.

LBNL (2005) provides insights about the implementation of load shedding in Maharashtra, specifically in the MSEB service area.[29] Table 4 gives a breakdown of the total load shed by customer type and distinguishes between a rural or urban customer.[30] As a basic rule, electric load is shed more often from lower paying customers, which are in the residential and agricultural sectors.[31] Together, residential and agricultural account for about 68% of load shed—particularly weighted against rural agricultural customers. About 20% of load shed comes from the residential sector, with more load shed coming from rural households rather than urban ones.[32] Overall, estimates from Table 4 show a large bias of load shed in rural areas, because about 82% of shed electricity demand came from rural areas, compared with 18% in urban areas.

[29] Because of the cyclical and oftentimes predictable electricity usage during the day, these shed periods can be modeled with utility-level data. Implementing a load shedding plan is usually based on such estimates.
[30] LBNL (2005) notes that actual load shed may differ from these reported numbers, as the load being turned off at the time of disconnection is assumed constant until the service area is reconnected; therefore, changes in demand that would have occurred during the period are not fully reflected.
[31] Industrial and commercial electricity users pay a higher rate on average because of tariff structures.
[32] More shedding may be expected in urban households because LBNL (2009a) estimates that urban households use about 50% more electricity than rural households (see Table 2).

Conclusion

While gasoline is the most-used fuel for mobile energy services globally, electricity is becoming the preferred fuel choice for stationary energy services, particularly in non-industrial applications such as commercial and residential buildings. Despite the availability of electricity in the developed world, WEO2013 estimates that in 2011 there were about 1.3 billion people worldwide who did not have access to electricity (IEA, 2013). This statistic indicates that electrification and electric service improvement present many challenges around the world and will continue to be a main focus around the world, particularly for developing countries.

To have a well-functioning electric power system, it is important to understand electricity demands. Among all countries of the world, India is the seventh-largest country by area, second-largest country by population, and tenth-largest economy.[33] India is also the fifth-largest user of electricity[34] and the fourth-largest user of energy overall.[35] Beyond these basic statistics, this article discussed some important data sources for residential electricity use in India (for example, the NSSO and Ministry of Power) and some key trends on which to focus (for example, appliance ownership rates, household income growth, urbanization rates, and the progress of electrification). While these do not constitute a final or comprehensive list of data and trends, they are important for understanding electricity issues and the related challenges in energy planning and the global energy trade.

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Appendix: Data discussions on Indian household electric demand

The national estimates in LBNL (2005) refer back to national survey data from a Ministry of Power report; that survey period covers April 2002 through January 2003. The MSEB estimates come from surveys going from one mid-year to the next, similar to Government of India reports. Overall, the study attributes the increase in load shedding in Maharashtra during this time to rises in demand while supply stayed relatively constant.

USAID (2011) provides a national estimate for the year 2003. The data source for this estimate is not specified, however, the authors reference Ministry of Power reports similarly used by LBNL (2005). A similar evaluation applies to USAID (2006) where the specific statistic is not cited, but the authors do reference related Ministry of Power reports. The authors also make an additional point that supply satisfied demand only between midnight and 6:00 a.m. local time.

IBEF (2007) cites a specific report from the Ministry of Power for its load shed estimates. The report is *State-wise Power Sector Profile Western region*.