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Residential Energy Data Management

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Residential Energy Data Management

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Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

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Executive Summary

Demand side energy management strategies for residential buildings rely on accurate, comprehensive data that is readily available and up to date. In India, multiple organisations collect and disseminate residential sector energy data; however, this data is not consistent, granular, comprehensive, easily accessible, or collected frequently enough. The findings of the sub-group constituted by NITI Aayog highlighted this issue by, identifying the current status of energy and activity data, challenges in the existing framework, and identifying actions to overcome the data challenges.

The study builds upon the past efforts by NITI Aayog and conducts an in-depth assessment of the official data sources to evaluate the robustness of residential final energy consumption data. It assesses both macro (top-down) and survey (bottom-up) data sources published by different government agencies and departments to evaluate the completeness, timeliness, disaggregation and dissemination of the data. A large number of government agencies such as Ministry of Statistics and Programme Implementation (MoSPI), Central Electricity Authority (CEA), Ministry of Petroleum and Natural Gas (MoPNG), Petroleum Planning and Analysis Cell (PPAC), National Sample Survey Office (NSSO), Forest Survey of India (FSI) among others are involved in the collection and dissemination of residential sector energy data.

This study performs national estimates on residential energy consumption for different fuel source, and residential floor area for both rural and urban sectors by using National Sample Survey Office (NSSO) data sources. Further, the survey estimates were compared with the values reported in the macro data sources for respective fuel sources, in order to evaluate the correctness of data. Additionally, a residential energy fuel mix is estimated with the help of various top-down and bottom-up data sources. The top down data sources includes consumption of electricity, LPG, and kerosene, however, for estimating the traditional fuel sources like firewood, biomass (crop residue) and cow dung, the survey data sources of FSI, PPAC and Ministry of Fisheries, Animal Husbandry and Dairying were referred respectively. Suitable assumptions were made to estimate the total residential energy fuel mix. This analysis led to identification of several data gaps in the existing energy data management in the residential sector.

The residential energy data management faces several issues such as lack of data on biomass use quantification, discrepancy in the top-down and bottom-up data on kerosene consumption, irregularity in NSSO surveys, non-accounting of seasonal variation in collection of fuel consumption data, lack of disaggregated data essential for policymaking, and delay in the dissemination of statistical reports by governmental departments.

In order to overcome these challenges, several recommendations are made. To collect missing information, there is a need for institutionalising an exclusive Residential Energy Consumption Survey (RECS) for India, in line with the United States (US) Energy Information Administration (EIA) RECS. Before initiating the RECS, the existing Household Consumer Expenditure survey can be strengthened through the addition of questions related to biomass and appliances. Strengthening and capacity building of the national statistical institutions, like NSO under MoSPI, for data collection and compilation, growth projection modelling, reducing processing time, fast dissemination, etc. can be done, as well. Leveraging the existing digital infrastructure for smooth urban governance can also strengthen the existing residential energy data framework.

Background

Energy consumption in the residential sector accounts for 30% of the total final consumption (TFC) in India, the second highest after the industrial sector (IEA 2020). This energy is consumed in a variety of applications, such as cooking, lighting, water heating, ventilation, refrigeration, and air conditioning. The different energy sources used in households include electricity, liquefied petroleum gas (LPG), kerosene, firewood, and biomass. The types of energy sources and usage trends vary widely between rural and urban households.

Over the past few years, household consumption of electricity and LPG has grown manyfold. This is mainly due to large-scale electrification, increased penetration of consumer appliances, and the government's ambitious social programme on LPG distribution, among other factors. Electricity consumption in Indian homes has tripled since 2000, as the percentage of households with access to electricity has increased from 55% in 2001 to more than 99% in 2019 (MoP 2020). Similarly, the LPG coverage in households has increased drastically, from 61.9% in May 2016 to 94.3% in April 2019 (MoPNG 2019).

The data on household electricity, LPG, kerosene is available at the aggregated level. These energy sources are either metered (e.g. electricity by DisComs) or distributed through an organized channel (e.g. LPG, and kerosene by oil marketing companies). The consumption of these fuels is also disseminated through government official statistics. However, the data on traditional fuel sources like firewood, biomass, and cow dung is difficult to collect. This leads to challenges in estimating the actual final energy consumption in the residential sector and thus in designing appropriate policy interventions.

To improve energy consumption data collection, NITI Aayog has taken several initiatives over the past few years, ranging from signing cooperation agreements with US and United Kingdom (UK) to conduct research and identifying gaps. In 2018, it constituted a working group on "Demand (consumption) side energy data management", comprising members from institutions like the PPAC, CEA & Central Statistics Office (CSO), along with civil society organisations. The objective of this working group was to discuss data issues in different sectors and provide recommendations for building a robust energy data management system in the country. The report by the NITI Aayog sub-group on demand side building energy data highlighted the current status of energy and activity[1] data, gaps in the existing data management framework, and strategies to overcome these gaps. In addition, standard templates were designed to facilitate the collection of more granular data. Building upon these past efforts, this study tries to do an in-depth assessment to identify the several data challenges and develop recommendations to overcome them.

Access to reliable information on household energy consumption patterns and trends is crucial for future policy design to promote sustainable consumption and reduce the environmental impacts of this consumption. This data is equally important to assess the impact of existing policies and measures in the realisation of the envisaged goals and implement corrective actions, as needed. The consumption data is also needed to derive energy efficiency (EE) indicators to assess progress of energy efficiency initiatives.

1 Activity variable is essential to normalise the energy consumption value which enables comparison at a building/city/state/national level. Activity variable can be floor area, number of households, population among others.

Use Cases for Residential Energy Data

A comprehensive residential building energy consumption database will enable policymakers to track the effectiveness of related policy measures and design more robust policy interventions in the future. The table below summarises the major identified use cases for residential building energy consumption and activity data and how the data can contribute to the use cases.

Use case	Application of energy/activity data in use case
Residential energy sector modelling	• Creating baseline models for demand forecasting • Continuous model validation and refinement
Development, updating, and implementation of Building Energy Codes & Guidelines	• Creating database of predominantly used building material options in households • Establishing baseline energy consumption at the building and system levels • Evaluating the impact of existing building codes • Implementing measures for continual code improvement / refinement
Development and updating of Building EE Rating and Labels	• Creating database of equipment owned by households and its energy rating, etc. • Revising minimum energy performance benchmarks • Estimating the impact of existing rating/labelling schemes
Design, updating, and implementation of clean fuel policies	• Creating database of household fuel choices for different end-use applications • Compiling data on household access to different types of energy sources/fuels and monthly expenditure on different energy sources/fuels
Design, updating, and implementation of subsidy / incentive schemes	• Creating database of household consumption of subsidised fuels • Reforming the fuel subsidy programmes

Institutional Mechanisms

There are multiple agencies in India involved in the collection and dissemination of energy consumption data in the residential sector. This data is either a part of a ministry's official statistics or collected through national surveys. The CSO under the MoSPI publishes an annual "Energy Statistics" volume that compiles relevant data on the consumption of different energy/fuel sources across sectors, collected from different line ministries. The CEA publishes annual statistics on sector wise and state wise electricity consumption in its report entitled "General Review- All India Electricity Statistics". In the oil and gas sector, the Ministry of Petroleum & Natural Gas (MoPNG) publishes an annual volume of "Indian Petroleum & Natural Gas Statistics" that includes data on the consumption of petroleum products in different sectors, such as domestic, commercial, industrial, and transport.

Besides the official statistics, there is another important bottom-up database published by the NSSO. The NSSO conducts a national consumer expenditure survey (CES) and also national survey on housing condition in India every five years, collecting consumption data and expenditure on fuel sources and other commodities and also collecting data on the condition of houses and availability of basic facilities for different socio-economic groups in rural and urban areas. The number of households covered in the "Household Consumption of Various Goods and Services in India" survey was 1,24,644 in 2004-05, 1,00,794 in 2009-10, and 1,01,651 in 2011-12. Regarding the "Housing Condition in India" survey, 1,53,518 households were surveyed in 2008-09, 95,548 in 2012, and 1,06,838 in 2018.

The National Council of Applied Economic Research (NCAER) and University of Maryland, USA conducts Indian Human Development Survey (IHDS) particularly designed to complement the existing surveys and collects information from households covering topics concerning health, education, employment, economic status, marriage, fertility, gender relations, and social capital. This survey collects information such as hours of power supply, relative use of multiple fuels in households, improved chulha beneficiaries, and ownership of appliances and generator set. The IHDS survey represents 41,554 households in 1503 villages and 971 urban neighbourhoods.

Similarly, the FSI, an organisation under the Ministry of Environment, Forest and Climate Change (MoEFCC), provides data on the household consumption of different forest resources like fuelwood, bamboo, timber, and fodder. The household biomass consumption data was collected through a stratified sampling survey with 28,800 households in 2011 and 41,400 households in 2019.

Previous studies on energy data show that collection and dissemination of energy supply data is reasonably good in India; however, there is significant room for improvement on the demand side energy consumption data (Prayas 2014). Even MoSPI faces challenges in collecting and retrieving data from different line ministries to prepare the energy balance for the country. Many issues related to energy consumption data in India need to be addressed, such as timeliness, consistency, completeness, granularity and traceability, among others. Also, the top-down and bottom-up data is highly scattered with several government agencies.

To improve energy consumption data management, NITI Aayog constituted a sub-group to bring the different ministries/data agencies related to energy data on a single platform in order to overcome the existing data challenges.

Nevertheless, a lot still needs to be done to address the challenges and collect missing datasets, institutionalise new surveys, and develop a roadmap for comprehensive data dissemination. The key agencies responsible for streamlining the data also need to be identified.

Goal and Objectives

The overall goal of this research is to carry out an in-depth assessment of India's residential energy consumption, using official data published by ministries, governmental departments, and statistical agencies. The paper investigates the robustness of data in estimating household electricity & fuel consumption, activity details. Detailed analysis of appliance level statistics and identification of residential building energy demand drivers (like building envelop, individual/multi-family house) are not within the scope of this study.

The specific objectives of the study are the following:

- Identifying official data sources on household energy consumption patterns and activity data (both survey & administrative sources)
- Determining household electricity & fuel consumption using survey and administrative data sources, and estimating the variations between the two
- Estimating overall fuel wise residential energy consumption, taking into consideration all relevant data sources
- Finding key data gaps in deriving the fuel wise household energy consumption
- Developing recommendations on how to improve collection, analysis, and dissemination of energy consumption data in the residential sector

Review of Official Data Sources

There are many agencies, including the National Statistical Office (NSO), Registrar General Office, MoPNG, PPAC, CEA, MoSPI, FSI, and others, that periodically publish data related to residential energy consumption and activity information at the national level. This data is either collected through a bottom-up national survey or is part of the official statistics (administrative sources).

The official data sources referenced in this paper for the estimation of energy consumption and analysis of activity data are presented in Table 1.

Table 1: Official sources for residential energy consumption and activity data

Name of the publication; Source agency	Year of publication used for analysis	Available energy/activity data
Household Consumption of Various Goods and Services in India; NSSO	Jul 2004 – Jun 2005 (61st Round)	Monthly per capita consumption of the following energy/fuel sources in rural and urban areas: • Electricity • LPG, kerosene, and firewood & wood chips Appliance penetration
	Jul 2009 – Jun 2010 (66th Round)	
	Jul 2011 – Jun 2012 (68th Round)	
	Jul 2017 – Jun 2018 (75th Round)	None - results not published[2]
Housing Condition and Amenities in India; NSSO	Jul 2008 – Jun 2009 (65th Round)	Residential housing characteristics in rural and urban areas • Number of households • Average floor area per household
Drinking Water, Sanitation, Hygiene and Housing Condition in India; NSSO	Jul 2012 – Dec 2012 (69th Round)	
	Jul 2018 – Dec 2018 (76th Round)	
Population Projections For India and States; Ministry of Health & Family Welfare (MoHFW)	May 2006 (for 2001-2026 projections); Nov 2019 (for 2011-2036 projections)	• Rural and urban population projections
Indian Petroleum & Natural Gas Statistics; MoPNG	2014-15	Domestic consumption of petroleum-based fuel sources • LPG • Kerosene
Report of The Expert Group on A Viable and Sustainable System of Pricing of Petroleum Products; Government of India	February 2010	Domestic consumption of petroleum-based fuel sources • LPG • Kerosene
Growth of Electricity Sector in India from 1947-2018; CEA	June 2018	• Domestic electricity consumption • No. of domestic consumers
India State of Forest Report; FSI	2011 & 2019	• Annual household fuelwood consumption
Energy Statistics; MoSPI	2013 & 2019	• Residential consumption of electricity, LPG, & kerosene
Assessment Report: Primary survey on household cooking fuel usage and willingness to convert to LPG; Petroleum Planning & Analysis Cell	2016	• Consumption of biomass (crop residue), cow dung, and firewood in 13 Indian states with low LPG penetration
Basic Animal Husbandry Statistics – 2019; Ministry of Fisheries, Animal Husbandry & Dairying	2019	• Cattle population
Report on National Commission on Cattle; Ministry of Fisheries, Animal Husbandry & Dairying	2002	• Percentage of cow dung used as fuel
Current status of cow dung as a bioresource for sustainable development; Springer Open: Bioresources and Bioprocessing (Authors: Gupta, K., et al.)	2016	• Cow dung production per cow per day

2 MoSPI decided to not release the results of the 75th round of the household consumption survey due to data quality issues and is examining the feasibility of conducting the survey in 2020-21 and 2021-22 (Source: PIB News).

Data Analysis and Results

Residential fuel consumption analysis

The household consumption of electricity and fuel sources in rural and urban areas is calculated by multiplying the per capita consumption of electricity and fuel in a particular year by the rural & urban population estimates for the same year.

Data used for analysis

The consumer expenditure survey includes the per capita-per month consumption of electricity, LPG, kerosene, and firewood & chips for urban and rural households. The data is available for 2004-05, 2009-10, and 2011-12 and is presented in Tables 2 and 3 below. From this point forward, 2004 will be used in place of 2004-05, 2009, in place of 2009-10, and 2011, for 2011-12.

Table 2: Per capita-per month rural household fuel consumption

Year	Electricity (kWh)[3]	LPG (kg)[4]	Kerosene-PDS[5] (L)[6]	Kerosene -other sources (L)	Firewood & chips (kg)
2004	5.67	0.22	0.48	0.14	21.44
2009	7.93	0.30	0.51	0.08	21.21
2011	8.90	0.38	0.43	0.10	19.04

Source: NSSO Household Consumer Expenditure Survey- 61st, 66th, & 68th Rounds

Table 3: Per capita-per month urban household fuel consumption

Year	Electricity (kWh)	LPG (kg)	Kerosene-PDS (L)	Kerosene - other sources (L)	Firewood & chips (kg)
2004	19.96	1.60	0.35	0.27	6.29
2009	24.27	1.82	0.30	0.17	5.20
2011	25.80	1.93	0.23	0.17	4.29

Source: NSSO Household Consumer Expenditure Survey- 61st, 66th, & 68th Rounds

For the population data, the rural and urban population projections by the Ministry of Health and Family Welfare, summarised in Table 4 below, are used.

Table 4: Rural and urban population projections

Population as on	Rural	Urban
March 1, 2005	78,14,88,000	31,42,34,000
March 1, 2010	82,61,73,000	35,05,69,000
March 1, 2012	84,04,93,000	38,62,38,000

*Source: Population Projections for India and States 2001-2026 & 2011-2036 by MoHFW (*Data points are taken from dates matching NSSO energy consumption report dates; hence, the population estimates are taken from March 1st in 2005, 2010, and 2012.)*

3 kWh = kilowatt-hour

4 kg = kilogramme

5 PDS stands for Public Distribution System.

6 L = litre

Data analysis

The energy consumption data, as mentioned above in Tables 2 and 3, is for one month. To estimate annual consumption, it is assumed that the consumption pattern remains uniform across all months, since data on seasonal variations is not available. The estimated annual household consumption of electricity, kerosene, LPG, and firewood & chips in rural and urban areas for 2004, 2009, and 2011 is presented in Figures 1-4.

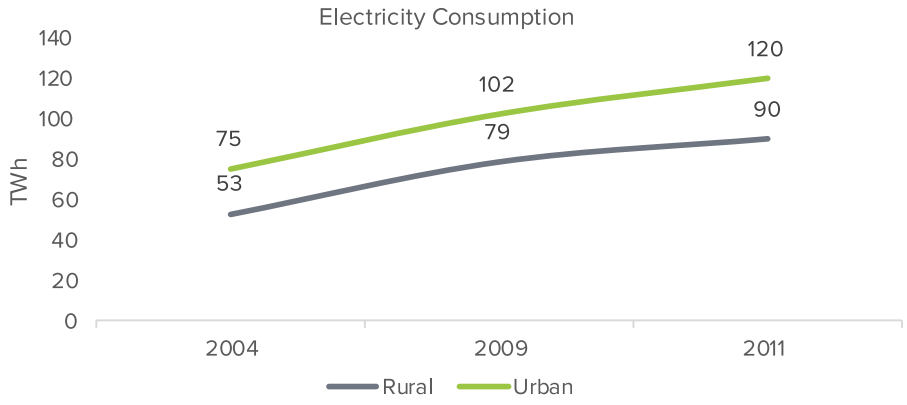

Figure 1: Estimated household electricity consumption in rural and urban areas[7]

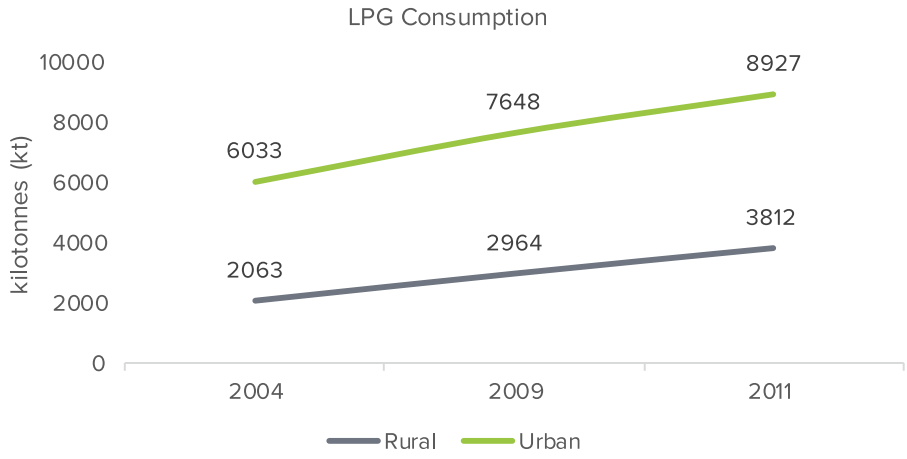

Figure 2: Estimated household LPG consumption in rural and urban areas

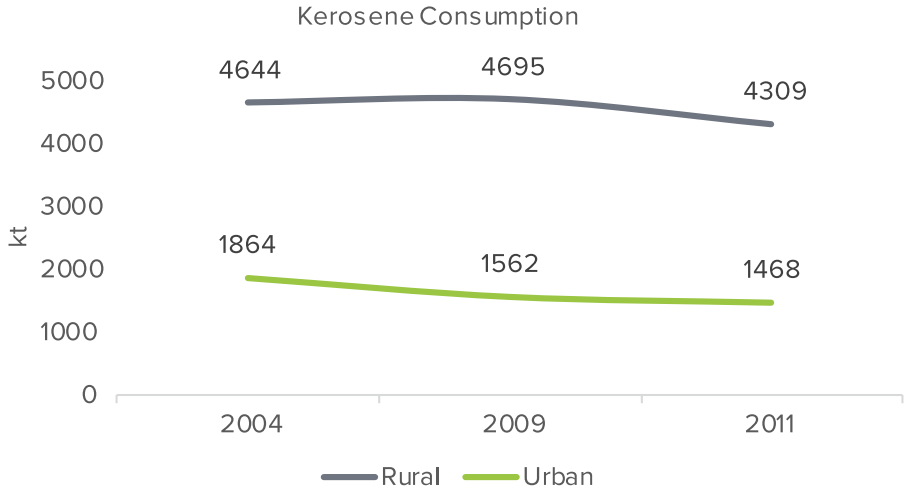

Figure 3: Estimated household kerosene consumption in rural and urban areas

7 TWh = terawatt-hour

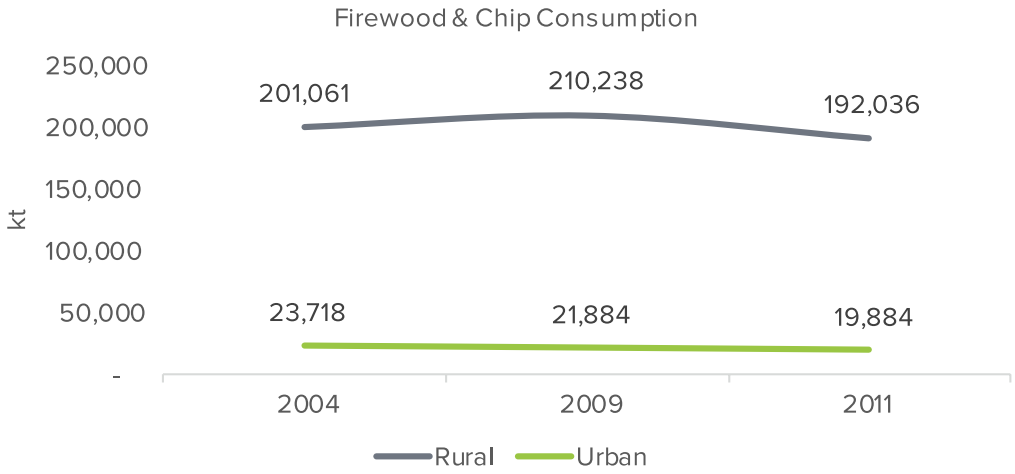

Figure 4: Estimated household consumption of firewood & chips in rural and urban areas

Discussion

The above graphs show that the consumption of electricity and LPG has been constantly increasing over the years, whereas kerosene and firewood consumption dropped from 2004 to 2011.

There are several other biomass products besides firewood, e.g. dung cakes, biogas, crop residue, etc., that are used extensively in rural households. Data on consumption of these biomass products is neither available in government publications nor collected in the consumer expenditure surveys. Hence, the overall biomass consumption trend in the residential sector cannot be accurately estimated based on the available data; only firewood consumption can be analysed. As per IEA estimates, a significant amount of biomass is used in Indian households, accounting for 68% of total residential energy consumption in 2017, but the data used to determine this is not publically available for analysis (IEA 2020).

Pradhan Mantri Ujjwala Yojana (PMUY)

The national clean fuel policy scheme Pradhan Mantri Ujjwala Yojana, launched by the Government of India in May 2016, has been successful in increasing LPG penetration in rural and urban households. It resulted in the addition of 80 million new LPG users up to September 2019, resulting in an increase in nationwide LPG coverage to 94.3%, as of April 2019, up from 61.9% in May 2016 (MoPNG 2019).

Furthermore, the ministry data shows that 87% of PMUY beneficiaries have returned at least for a second refill, and the total number of refills, including installations against PMUY connections, crossed 400 million in December 2019 (Rajya Sabha 2019). From this data, the average number of annual refills per household connection can be approximated to be four cylinders.

However, due to unavailability of survey data beyond 2012, the actual potential shift from traditional fuels to clean energy sources in rural and urban areas in India cannot be assessed.

Activity data analysis

The activity data considered here is the total floor area which is derived from data provided in the NSS survey reports. The total floor area is estimated by multiplying the average floor area per household by the total number of households in rural and urban areas.

Data used for analysis

The housing condition survey report publishes information on the average floor area per household and number of households in rural and urban areas. These data for 2008, 2012, and 2018 are shown in Figures 5 and 6 below.

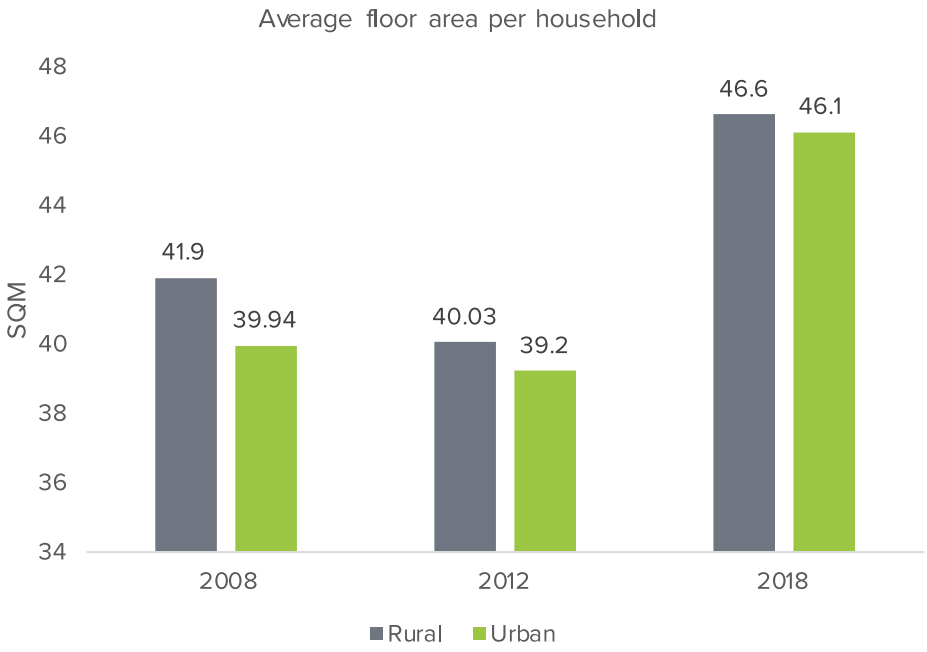

Figure 5: Average floor area for rural and urban households[8]

Source: NSSO Housing Condition Survey - 65th, 69th, & 76th Rounds

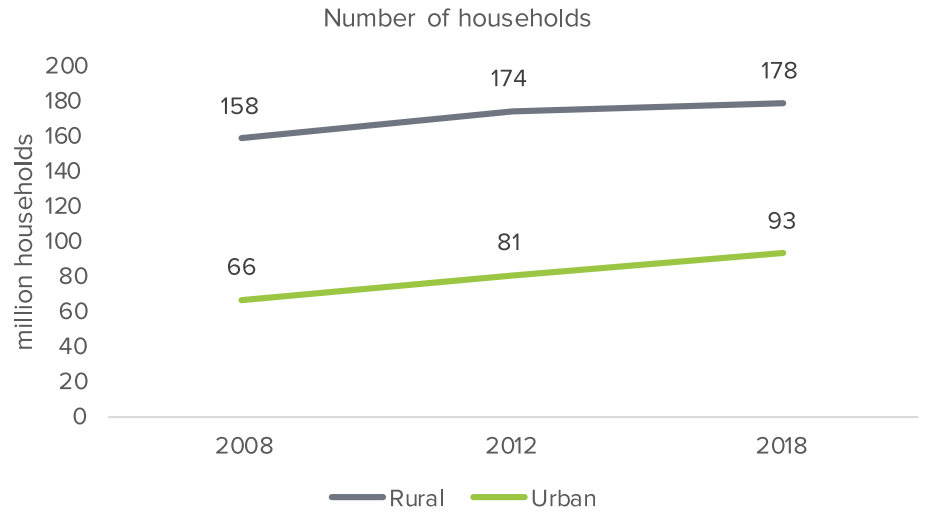

Figure 6: Number of households in rural and urban areas

Source: NSSO Housing Condition Survey - 65th, 69th, & 76th Rounds

Data analysis

The floor area trends in rural and urban settings are presented in Figure 7, based on the average floor area per household and number of households shown above.

8 SQM = square metre

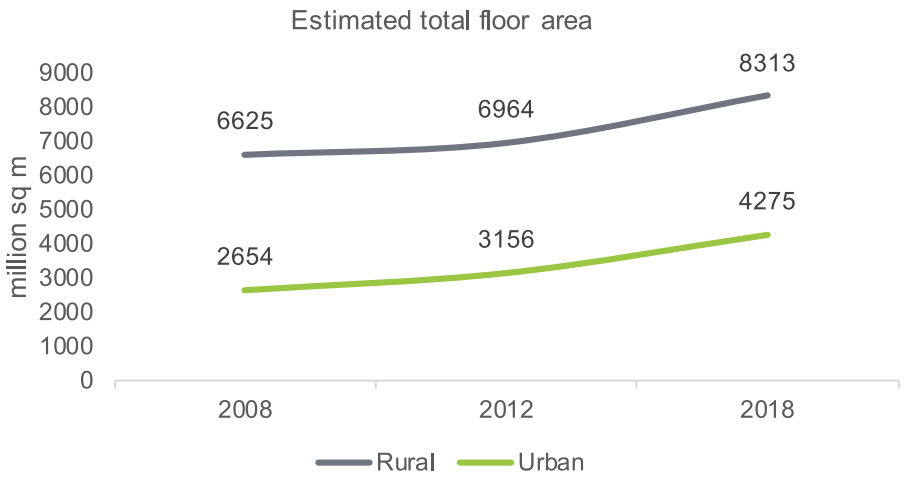

Figure 7: Estimated total floor area in rural and urban areas

Discussion

The floor area is increasing in both rural and urban areas in India, with steeper growth in urban areas. Between 2008 and 2018, the floor area in rural households increased by 25% (from 6.6 billion to 8.3 billion sqm), whereas in urban households, it increased by 61% (from 2.6 billion to 4.2 billion sqm). The possible reasons for steep growth in urban floor area include urbanisation, natural population increase, and the growth of nuclear families, resulting in the growing demand for new housing and expansion of floor area.

Comparison of household fuel consumption across data sources

In Section A, the household electricity and fuel consumption was estimated by projecting the bottom-up survey data to the national scale. However, government agencies like CEA and MoPNG also publish macro data on household consumption of different energy/fuel sources, often termed as administrative data, as part of their official statistics.

The table below provides a comparison of the two datasets, i.e. the extrapolated NSS survey data and administrative data sources, from 2004, 2009, and 2011. The percent variation of the administrative data from the extrapolated NSS data is also presented.

Table 5: Comparison of household electricity and fuel consumption across data sources

Year	Energy/fuel source	Unit	Consumption estimation from NSSO & census data	Consumption reported by CEA & MoPNG	Percent variation
2004	Electricity	TWh	128	98	24%
	LPG	kt[9]	8,096	8,946	-10%
	Kerosene	kt	6,508	9,318	-43%
2009	Electricity	TWh	181	158	13%
	LPG	kt	10,612	11,641	-10%
	Kerosene	kt	6,257	9,013	-44%
2011	Electricity	TWh	209	177	15%
	LPG	kt	12,739	13,579	-7%
	Kerosene	kt	5,777	7,772	-35%

9 Kt - kilotonne

Discussion

The variation in household electricity consumption between survey estimates and CEA data is in the range of 13 to 24%, with survey estimates being on the higher side. In the case of LPG consumption, the data is quite consistent across survey estimates and MoPNG statistics; there is a small variation of 7 to 10 percent. The inconsistency in kerosene consumption data is the highest, with variation of 35 to 44% and survey estimates being on the lower side. For the correctness of the data, the variation between the data sets must be within a reasonable limit. If this variation exceeds a certain range, which is in case of kerosene, there is certainly an issue with one or both datasets.

The possible reasons for these variations are highlighted below:

- The NSS collects information on household consumption of electricity and other fuels over the past 30 days, from the date of survey. However, in order to calculate the annual electricity consumption, it is assumed that it remains uniform throughout the year, which is not the case due to seasonal variations in household heating and cooling needs. This leads to a definitive variation in extrapolated data on the annual consumption of electricity & fuel when compared to the administrative data.

- The survey is entirely based on consumer responses to the survey questions, and there is no process of checking or verifying the answers provided. There is always a possibility of error in consumer responses regarding their actual consumption, as most energy/fuel sources are not metered, with the exception of electricity.
- Several past studies have indicated a significant leakage in the kerosene allocated for the domestic category, i.e. consumption of this kerosene in the commercial sector. Based on a study by the International Institute for Sustainable Development (IISD), the national average for kerosene leakage is estimated to be 45% of the total PDS kerosene allocation for 2011-12 (Gupta, 2014). A study by the World Bank Energy Sector Management Assistance Programme (ESMAP) also estimated kerosene leakage at about 50% based on NSS data from the 50th and 55th survey rounds and kerosene allocation data. Hence, MoPNG statistics are possibly reporting higher consumption of kerosene compared to the survey estimates because they are using the allocation data.

Residential energy consumption by source

This section focuses on estimating the final energy consumption breakup by energy/fuel source in the residential sector. As the energy consumption data is widely scattered, inconsistent, and intermittent in nature, a mix of administrative and survey data sources are used, with reasonable assumptions and approximations, as discussed below.

Data used for analysis

The different data sources used for this analysis are as follows:

- Electricity, LPG and kerosene: Electricity, LPG and kerosene consumption are periodically provided in official statistics published by the CEA and PPAC, respectively. These administrative data sources have been used for this analysis.
- Firewood: The consumption of firewood is only found in the NSSO, FSI, & PPAC surveys. The FSI data is more recent, comprehensive, and also nationwide, and has therefore been used in this analysis.
- Biomass: Data on biomass consumption is not collected or reported by any government agency. The NSSO consumer expenditure survey collects data on household expenditure on fuels like dung cake and gobar gas, but does not provide the consumption numbers. The only available data source on biomass consumption is the survey conducted by PPAC in 2015-16. This survey was conducted across 13 states with low LPG penetration in 2015. It estimates significant usage of dung cakes and crop residue in households as cooking fuel.

- Biomass (crop residue) - Average biomass consumption value per household is taken from the PPAC survey. The data on biomass fuel usage as a primary source of energy in households is also taken from the PPAC survey. Number of households are estimated from the census report.
- Cow dung - For cow dung, the cattle population reported in "Basic Animal Husbandry Statistics – 2019" by Ministry of Fisheries, Animal Husbandry and Dairying is used. Estimates of dung production per day per cow are taken from a research paper entitled "Current status of cow dung as a bioresource for sustainable development" by Gupta, K., et al., and the percentage of cow dung used as fuel, from the "Report on National Commission on Cattle 2002" by Ministry of Fisheries, Animal Husbandry and Dairying. Based on this data, the total cow dung quantity used as a household fuel for cooking and heating is estimated for 2015.

Data analysis

The final residential energy consumption breakup is shown in Figure 8 below and is based on the following assumptions:

- The total biomass consumption in 2015 is estimated by using the following data:
  - The average value of biomass consumption reported for 13 states in the PPAC survey is used for national level estimates.
  - The percentage of households consuming biomass as a primary fuel taken from PPAC survey report.
  - The total number of households in 2015 is estimated using the data on the number of households in 1991, 2001, & 2011 in the census report.
- In the case of cow dung, the total consumption in 2015 is estimated using the following data:
  - Cattle population in 2015 based on 2012 and 2019 data reported in "Basic Animal Husbandry Statistics – 2019"
  - Per day per cow average dung production value of 12 kg, from the "Current status of cow dung as a bioresource for sustainable development" study
  - The estimated percentage of cow dung used as fuel (33.33% in 2002) in the "Report on National Commission on Cattle" There is a possibility that the percentage of cow dung used as a fuel may have changed after 2002, but as this was the latest data available, it was used in the analysis.
- The firewood consumption data from 2011 and 2019 in the FSI survey is used to estimate the consumption in 2015, applying a Compound Annual Growth Rate (CAGR) of -11 percent.
- Regarding kerosene, there is a significant difference between the survey estimates and the data from the administrative sources, as mentioned above, possibly due to the fact that the data sources cannot capture possible leakage of kerosene meant for domestic consumption. Thus, the consumption is estimated using the MoPNG data and assuming 45% leakage. Further, the 2015 kerosene consumption data is estimated by taking the average of the consumption in 2014-15 and 2015-16.
- The 2015 electricity and LPG consumption data are estimated by taking the average of the consumption in 2014-15 and 2015-16.
- The fuel and energy data has been standardised by converting the data points into energy units (tonne of oil equivalent) using the appropriate calorific value for each respective energy/fuel source.

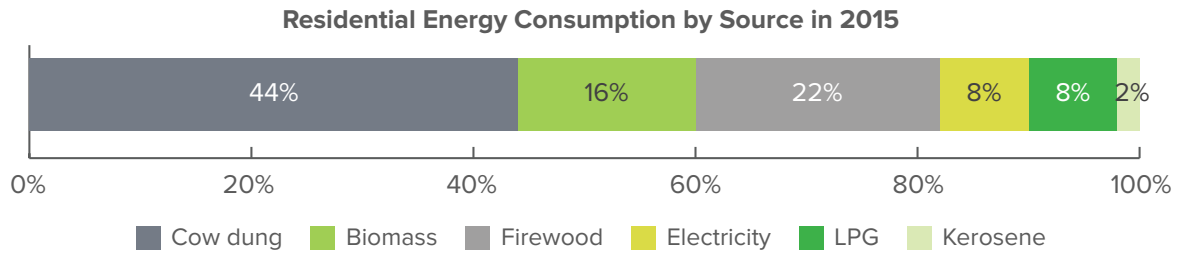

Figure 8: Share of residential energy consumption by source in 2015

Discussion

The above analysis shows that there is a lack of sufficient, updated data on traditional fuel sources like biomass, cow dung, firewood, etc. Hence, the results of the analysis on final energy consumption per energy/fuel source in the residential sector remain uncertain.

Moreover, the Pradhan Mantri Ujjwala Yojana, as discussed earlier in this report, has significantly increased the penetration of LPG in urban and rural households, but due to lack of data, the actual shift from traditional fuels to clean fuels since 2016 could not be estimated. There are no datasets to estimate the fuel mix in India's total final residential energy consumption as of 2020.

The gaps in the availability of data, notably with regard to breakdown by energy/fuel source and end-use in the residential sector, is one of the biggest challenges that needs to be addressed. The breakdown of total final consumption by source/fuel, in particular, is essential to the design of better policies and in evaluating the impact of existing policy measures.

Data Gaps

Previous studies have highlighted the data gaps in overall energy data management in India at a macro level. Various recommendations have been provided in these studies on how to improve energy data quality and usability. This study takes a closer look at energy data management specifically in the residential sector, and the following section highlights the data gaps that were identified during the estimation of total final energy consumption.

Insufficient biomass consumption data

All the existing data sources fail to accurately estimate the biomass consumption in the residential sector. As a result, many assumptions need to be incorporated on traditional fuel consumption when estimating the total final energy demand in India's residential sector, and, ultimately, the total demand cannot be accurately calculated.

Divergence across different data sources

The energy data provided by different data sources lacks consistency. As highlighted in the "Results and Analysis" section, there is a huge variation, ranging from 35 to 44 percent, between the kerosene consumption data reported by PPAC/MoPNG and that estimated using NSSO survey data.

Irregularity in data collection and dissemination

The household consumer expenditure survey is meant to be conducted every five years, but the latest disseminated survey data was collected over 8 years ago, in 2011-2012. The 75th round survey was done in 2017-18, but the survey results were withheld by the government due to data quality issues. Therefore, the 2011-12 data is the latest bottom-up resource available for household consumption analysis, which is of little relevance in the current timeframe.

Non-uniformity in the time period for energy data reporting across administrative agencies

The NSSO survey is conducted in the agricultural crop year, i.e. from July to June, whereas the sector wise energy consumption data collected by other administrative agencies is based on the financial year (i.e. from April to March). Therefore, comparing these two datasets involves difficulties and assumptions in the energy analysis.

Seasonal fluctuations in energy consumption data not taken into account

The consumer expenditure survey asks respondents to provide data on their electricity and fuel consumption over the past 30 days from the survey date. Hence, the seasonal variability associated with the consumption of different fuel/energy sources in households does not get captured in the survey. As a result, estimation of annual energy consumption based on NSSO survey data may lead to some error, as it is based on the assumption of uniform energy consumption throughout the year. However, it is recognised that this is not easy to capture in a limited survey format.

Lack of accurate data for estimation of energy efficiency indicators

To calculate the energy efficiency indicator (e.g. energy consumption per unit area), energy consumption and floor area data for the same year should ideally be available. However, these data points are collected in different surveys, which are conducted in different years. For example, the energy consumption data is available in consumer expenditure surveys, which were carried out in 2004-05, 2009-10, and 2011-12, whereas the household floor area data is available in the housing condition and amenities surveys carried out in 2008-09, 2012, and 2018. As a result, assumptions need to be made to estimate energy efficiency indicators, by projecting either of the two datasets to a particular year.

Insufficient data for policymaking

The existing residential energy consumption data lacks granularity and critical information on end-use energy consumption, equipment, etc., which is essential for policy evaluation and formulation:

- Critical data on household appliances, e.g. capacity, efficiency, star rating, number of appliances per household, usage hours, etc., is not available.
- The sector wise consumption data for different energy/fuel sources published by different data agencies (e.g. MoPNG, CEA, etc.) gives a combined picture of rural and urban households at a national level. Further splitting the residential sector into rural and urban, different states, cities/panchayats, etc. will enable the derivation of granular energy indicators.
- At present, there is no top-down mechanism for tracking residential floor area growth in India, which is an important data point, as domestic energy demand is directly linked to the floor area. This data is also crucial to the development of energy efficiency benchmarks across different cities, states, etc. and the design of appropriate EE interventions.

Delay in data dissemination

There is a significant delay of about 1 - 1.5 years in data agencies disseminating their data through publications such as the Energy Statistics report, PNG Statistics report, CEA General Review, etc. For example, the “Energy Statistics 2020” publication only contains data up to 2018-19. Moreover, “PNG Statistics 2018-19” is yet to even be published, as of May 2020. The delay in data publishing creates a deficiency in updated data for analysis.

Lack of self-generated electricity data from CEA

A new element is entering the energy data space: rooftop solar PV systems. India has an ambitious goal of achieving 40 gigawatts (GW) of installed rooftop solar capacity by 2022. As a result, electricity self-generation through rooftop solar PV systems is expected to increase in the near future. However, comprehensive data on electricity self-generation (from solar system) is not being

collected by any agency. When net metering is used, the data on electricity imported from the grid and exported to the grid is provided in the electricity bill. However, there is additional solar power generated and consumed by the building owner, and this is not recorded anywhere. Furthermore, there is a possibility that only the net sale of electricity is reported to CEA by the DISCOMs. As a result, the CEA data does not give a comprehensive picture of electricity consumption in residential buildings. If, in the future, rooftop solar accounts for a significant share of the total electricity mix, it will be crucial to collect this self-generation data at the national level.

Digital Initiatives by Urban Local Bodies

This section presents the data-related initiatives being implemented by Urban Local Bodies (ULBs), namely, "GIS for Property Tax Mapping" and "Digital Door Number Framework," which aim to interlink data on built up area, electricity and gas bills, etc. with the unique property identification number. This existing framework can be further leveraged to complement the existing residential energy data management system and thus create an energy data repository. A section on "Smart Meters" is also included which can enable to fetch accurate real time electricity consumption data, appliance wise electricity consumption data if used with Non-Intrusive Load Monitoring (NILM) technique.

GIS for Property Tax Mapping

The Jawaharlal Nehru National Urban Reforms Mission (JNNURM) mandates reform of the property tax system to make ULBs efficient units of self-governance, as property tax is a significant source of revenue for them. In order for the ULBs to have a complete record of all the properties in the city, proper Geographic Information System (GIS) property mapping has been promoted. This has led to several ULBs integrating GIS into their property tax collection systems.

The Bruhat Bengaluru Mahanagara Palike (BBMP), in collaboration with Indian Space Research Organisation (ISRO), created a comprehensive database of 19.45 lakh total properties (including residential and commercial) with the help of the GIS Enabled Property Tax Information System (GEPTIS). ISRO provides updated satellite data on the properties to the BBMP every six months. A unique property identification number (PID) is given to each property, and a database is created based on a combination of information from aerial maps, door-to-door surveys, and existing ULB data. The data on property ownership, building usage, type of construction, built up area, number of floors, etc. is linked to the PID number, along with the GIS map. The Hyderabad, Mumbai, Kolkata, Delhi, Vishakhapatnam, Bhopal, Kanpur, and Patna ULBs, among others, have initiated similar property geotagging, but the property-related information that is linked to the PID or GIS maps varies across ULBs.

Digital Door Number for e-Governance

The "Digital Door Number" (DDN) initiative has been taken up by the municipal corporations of New Delhi, Bengaluru, Pune, Vijayawada, Hyderabad, etc. In DDN framework, addressing or numbering of all properties follows a uniform system or technique. DDN combines the latest geospatial and cloud computing technologies with standard methodologies in street addressing and door numbering. This unique property number can be linked to services such as electricity, gas, water, property tax, sanitation, emergency services, postal services, etc. to improve governance. The benefits of DDN include ease in locating property and hassle free governance, among others. DDN is already linked with utility data, furthermore, linkage of floor area data from ULBs with DDN will enable estimation of the Energy Performance Index (EPI) at the building and city level.

Smart Meters

Smart meters measure energy flow like conventional meters but have the ability to collect and transmit the consumption and supply related data at specified intervals, on a real-time basis. Many DISCOMs in the country are deploying smart meters in their licensing area with support from Energy Efficiency Services Limited (EESL). These meters are based on General Packet Radio Services

(GPRS) technology, and help the DISCOM to improve billing and collection efficiency. Customers can also benefit from a better understanding of their real-time energy usage, along with accurate bill readings. However, these smart meters are currently not compatible with the NILM technique, which determines what appliances are being used in a building and their individual energy consumption; this information would be helpful in collecting appliance energy consumption data.

Recommendations on Residential Energy Data Management

Strengthening existing household consumer expenditure survey by adding new questions for robust residential sector energy analysis

The household consumer expenditure survey is conducted by the NSO every five years (ideally). The objective of this survey is to understand the level and pattern of household expenditure in different socio-economic groups nationwide and in different states. Although the objective of this survey is not to study energy consumption trends, it does collect useful data on the consumption of energy sources, as well as appliance ownership. This data is vital in understanding household energy consumption trends for different energy/fuel sources.

In the past, the survey questionnaires were modified by deleting / adding questions. For example, the data on air coolers and air conditioners was collected as a single data point in the 61st, 66th, and 68th round surveys, but has now been separated into two different items from the 75th round survey onwards. In addition, new appliances, like electric air heaters & blowers, geysers & hot water systems, water coolers, air cleaners & dehumidifiers, generators/inverters, microwaves/ ovens, solar power systems, and water purifiers, have been added into the survey questions.

Therefore, it is recommended that the existing NSSO survey be further strengthened by potentially including some additional questions, until a dedicated survey on residential energy consumption in India can be carried out. This could significantly enhance the usability of the existing survey for energy analysis. The new questions recommended for inclusion are as follows:

- Consumption of traditional fuel sources, e.g. dung cake, biomass (crop residue), and others
- Number of appliances owned by each household (collection of this data was discontinued after the 50th round)

Strengthening existing institutional framework for data compilation and modelling

Household energy data is collected through various surveys, including the NSSO surveys on "Household Consumption of Various Goods and Services in India and "Energy Sources of Indian Households for Cooking and Lighting", National Council of Applied Economic Research (NCAER)'s "India Human Development Survey", FSI's "India State of Forest Report", etc. In addition, administrative bodies like PPAC, CEA, etc. report on sector wise trends in energy consumption in their annual publications. Hence, efforts towards compilation, harmonisation, avoidance of duplication, and dissemination of the results from different datasets are urgently needed.

The CSO under MoSPI issues an annual publication called "Energy Statistics", where the data from multiple ministries and agencies—MoPNG, CEA, Office of the Coal Controller, Ministry of New and Renewable Energy (MNRE), Office of the Economic Adviser, Ministry of Commerce and Industry, etc.—is collected and disseminated[10]. Along with the dissemination of this data, CSO creates an energy balance, which is a framework that compiles data on all energy products entering, exiting, and being used within the country during a reference period (e.g. a year).

10 The indicators are selected based on the guidelines/approach followed by International Atomic Energy Agency (IAEA) in their publication "Energy Indicators for Sustainable Development: Guidelines and Methodologies", which was developed in corporation with the United Nations Department of Economic and Social Affairs (UNDESA), IEA, Eurostat, and European Environmental Agency (EEA).

Therefore, in addition to the existing data compiled by CSO through administrative agencies, CSO could consider adding a section on data collected through various surveys (e.g. through NSO) to generate more insights from the data. CSO can collaborate with NSO and generate estimates on household energy consumption trends and patterns by evaluating different data sources and performing energy demand forecasting for household energy consumption.

Strengthening institutional capacity of administrative bodies and survey agencies for proper energy data dissemination

As discussed in the "Data Gaps" section, the data collected by MoPNG, CEA, etc. is disseminated 1-1.5 years after the collection date. Hence, there is a need to strengthen the statistical division of these organisations, by building their statistical capability or increasing the human resources available, to enable them to reduce the data processing time and disseminate the data within a year. Furthermore, the institutional capacity of survey agencies like NSSO, needs to be strengthened to reduce the data quality issues and processing time and facilitate fast data collection and dissemination. Services like data collection, processing, and dissemination can be outsourced if in-house capacity building is not feasible.

Leveraging existing digital infrastructure to create energy data repository

As discussed in the previous section, several ULBs in the country have initiated property geotagging and interlinking of governance-related services via a Digital Door Number. The GIS framework will result in the creation of a digital database for property wise built-up area information. Moreover, the utility bills (electricity, gas, water), property tax details, etc. are going to be interlinked with the DDN. Hence, this DDN framework can be further leveraged to interlink the built-up area information obtained from the geotagging exercise with the utility bills. This will result in the creation of a property wise database for electricity bills, gas bills, built-up area, etc. and enable determination of the EPI at the building and city level. Furthermore, in the future, if all ULBs in India adopt GIS mapping and DDN, this database will facilitate the estimation of the EPI at the state and national level, as well. The Ministry of Home and Urban Affairs (MoHUA) can designate a central agency to coordinate data collection with the ULBs across the country and thus create a national data repository. Additionally, smart meters with NILM can be deployed to obtain data on end-use wise or appliance wise energy consumption.

Initiating exclusive "Residential Energy Consumption Survey"

Although the consumer expenditure survey collects information on household energy consumption, it is not energy focused and is primarily used to evaluate socio-economic indicators like Monthly Per Capita Expenditure (MPCE), distribution of households and persons across MPCE classes, and share of expenditure on different goods and services. Adding a lot of new questions on energy sources and appliance usage to the regular survey, while a viable interim measure for energy data collection, will ultimately dilute the actual purpose of the survey. Therefore, it is recommended that a separate national residential energy consumption survey in India be initiated, similar to the US EIA RECS. A pilot survey could be launched in select Class A, B, and C cities.

The proposed residential energy consumption survey should be comprehensive in nature, to collect data on energy sources, energy systems, housing characteristics & activity, and occupant behaviour, with separate data on urban and rural areas. The survey will estimate energy consumption patterns, energy source mix, fuel wise end-use energy consumption, appliance penetration, equipment efficiency, thermal comfort, floor area, and other indicators. It could also establish energy efficiency indicators at the sectoral level, end-use level, and equipment level.

The results from the survey will help policymakers and government officials evaluate the impact of numerous policies, such as the clean fuel policy, appliance labelling programme, building rating programme, and various incentive schemes. This will facilitate decision making regarding either the design of new policies or improvement of existing policy measures to accelerate EE initiatives in

the residential sector, as well as capture efficiency trends in this sector. As NSSO has a wealth of experience in conducting nationwide surveys, its statistical expertise can be leveraged to initiate this survey in India.

The following are key questions that could be included in the residential energy consumption survey:

Appliances:

- Number of appliances per household
- Equipment capacity (e.g. air conditioner- tonne of refrigeration (TR); lighting – Watt; geyser – L; refrigerator- L)
- Fuel type (e.g. for geyser, gas or electric)
- Power input (rated power)
- Usage per day and per year (no. of months/year and hours/day)
- Energy label category (star rating)
- Appliance age
- Type of lighting equipment (compact fluorescent lamp (CFL), light-emitting diode (LED), incandescent, etc.)

Energy Consumption

- Types of energy/fuel sources being used (e.g. electricity, firewood, cow dung, kerosene, etc.)
- Preferred fuel source for cooking, water heating, lighting, and other end-uses
- Annual consumption of electricity, LPG, and other fuels

However, it may not be feasible for a survey respondent to provide all the detailed information regarding household energy consumption. Thus, the survey questionnaire needs to be designed to put the respondents at ease regarding survey time and data collected. It could also include observation of household appliances and energy sources by the survey team, where possible. After consultation with the relevant stakeholders, a suitable questionnaire should be designed for the residential energy consumption survey.

Conclusion

India has extensive experience in collecting nationwide data on a wide range of variables. There is great potential to add value to the data that is being collected and disseminated, specifically in the domain of residential energy consumption. The strengthening of the NSSO could also contribute to this. There is also a need to reduce the lag in the final analysis and dissemination of the survey findings. Digitisation efforts are moving towards contributing to the linkage of households to their energy/fuel consumption across sources. These efforts need to be stepped up, as this could facilitate data collection at the household level, thus supporting NSSO's work in general, along with energy data management in particular, and provide significant leads for planning energy efficiency interventions in the country.

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Annexure

Energy data collected in "Household Consumption of Goods and Services in India (2011-12)" survey

[6] consumption of energy (fuel, light & household appliances) during the last *30* days ended on
.....

item	code	consumption out of home produce		total consumption		source[$]
		quantity@ (0.000)	value (Rs.)	quantity@ (0.000)	value (Rs.)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
coke	330					
firewood and chips	331					*
electricity (std. unit)	332					
dung cake	333					
kerosene – PDS (litre)	334					1
kerosene – other sources (litre)	335					*
matches (box)	336					*
coal	337					
LPG [excl. conveyance]	338					*
charcoal	340					
candle (no.)	341					
gobar gas	342					
petrol (litre) [excl. conveyance]	343					*
diesel (litre) [excl. conveyance]	344					*
other fuel	345					
fuel and light: s.t. (330-345)	**349**					

[11] expenditure for purchase and construction (including repair and maintenance) of durable goods for domestic use

description	code	whether possessed on the date of survey *()(yes-1,no-2)*	during the last 30 days						during the last 365 days						
			first-hand purchase			cost of raw materials and services for construction and repair (Rs.)	second-hand purchase: value (Rs.)	total expenditure (Rs.) [(6)+(7)+(8)]	first-hand purchase			cost of raw materials and services for construction and repair (Rs.)	second-hand purchase		total expenditure (Rs.) [(12)+(13)+(15)]
			no. purchased	whether hire-purchased *()(yes-1,no-2)*	value (Rs)				no. purchased	whether hire-purchased *()(yes-1,no-2)*	value (Rs.)		no. purchased	value (Rs.)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
stainless steel utensils	570														
other metal utensils	571														
casseroles, thermos, thermoware	572														
other crockery & utensils	573														
crockery & utensils: sub-total (570-573)	**579**														
electric fan	580														
air conditioner, air cooler	581														
inverter	582														
lantern, lamp, electric lampshade	583														
sewing machine	584														
washing machine	585														
stove, gas burner	586														
pressure cooker/ pressure pan	587														
refrigerator	588														
water purifier	590														
electric iron, heater, toaster, oven & other electric heating appliances	591														
other cooking/ household appliances	592														
cooking & other household appliances: sub-total (580-592)	**599**														

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