Track 3: Power Generation, Transmission and Distribution (Paper ID 231)

Evaluation of Energy Transition Readiness in the Residential Cooking Sector among the Low and Medium-Income Households in Bengaluru

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Abstract. A surge in the energy demand attributable to India's rising population and economic growth has led to concerns regarding the country's energy security and carbon footprint. There is an urgent need to enhance the efficiency of residential energy use and to shift progressively toward energy sources with a low-carbon footprint. Currently, one of the major residential energy demands comes from cooking. District-level household surveys have shown that liquid petroleum gas (LPG) is the dominant source catering to the energy demands for household cooking. There is also a substantial presence of solid biomass in the residential cooking energy mix. Since biomass burning has been widely recognized as a major source of household air pollution (HAP) and the country is dependent on imports for sourcing LPG, there is an urgent need to formulate a national strategy that addresses the issues of energy security, air pollution, and decarbonization simultaneously in an integrated and synergistic manner. This study examines the readiness of the inhabitants of Bengaluru, a metropolitan city located in the State of Karnataka in India, to shift to electricity-based residential cooking. The study also touches upon the critical knowledge gaps regarding the energy transition from an established LPG-based ecosystem to the new electric cooking ecosystem. Based on a household survey conducted in Bengaluru focusing on low-income and medium-income households, the study briefly discusses the complex interplay between culinary habits and sustainable practices that would dictate the transition readiness in the residential cooking sector on a mass scale. It is interesting to note that about 27% of the survey respondents mentioned experiencing power cuts every day, and 40% of the respondents indicated experiencing an hour-long load-shedding quite often. Also, about 42% of the respondents mentioned hearing the sound of a transformer bursting before the power cuts. Such evidence necessitates a relook into the sub-distribution infrastructure in the respective localities to examine the extent of overloading and assess the need for infrastructure strengthening. A country-wide large-scale transition to electricity-based cooking provides an opportunity to provide access to reliable electricity for low-to-medium-income households, ensuring a better quality of life for a large population in the country.

Keywords: Energy Transition, Energy Security, Pradhan Mantri Ujjwala Yojana (PMUY), Carbon Footprint, Electric Cooking, Electricity Access

Nomenclature

AT&C	Aggregate Technical and Commercial
BBMP	Bruhat Bengaluru Mahanagara Palike
BESCOM	Bangalore Electricity Supply Company Limited

BMA	Bengaluru Metropolitan Area
BMAZ	Bengaluru Metropolitan Area Zone
ckt	Circuit
CTAZ	Chitradurga Zone
DISCOM	Distribution Company
DLHS	District-Level Household Survey
eCooking	Electric Cooking
FPPCA	Fuel and Power Purchase Cost Adjustment
HAP	Household Air Pollution
KPTCL	Karnataka Power Transmission Corporation Limited
LPG	Liquid Petroleum Gas
NDC	Nationally Determined Contribution
OMC	Oil Marketing Company
PMUY	Pradhan Mantri Ujjwala Yojana
PPM	Parts Per Million
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable Renewable Energy

1. Introduction

Over the past three decades, Liquefied Petroleum Gas (LPG) has emerged as a cleaner alternative to the polluting solid biomass-based cooking fuels in many rural and urban households in India. As of March 2023, the Pradhan Mantri Ujjwala Yojana (PMUY) scheme has ensured access to subsidized LPG cylinders for more than 100 million households in India **[1]**. Currently, India has a total of over 310 million LPG cylinder consumers, and out of this, PMUY continues to serve more than 100 million beneficiaries across the country **[2]**. The estimated LPG-consuming population of about 310 million translates roughly to the annual consumption of 2,480 million LPG cylinders, assuming an average of eight cylinders per household every year **[3]**.

The PMUY beneficiaries are eligible to receive **Rs. 200** for a cylinder as a subsidy if the annual income is below ₹10 lakhs. A subsidy is provided for a maximum of 12 cylinders per year. Over the five years between FY 2017-18 and FY 2021-22, the government of India has allocated a total of ₹1, 08,862 crores towards LPG Subsidy **[4]**. Approval had also been sought for the expenditure to the tune of ₹ 30,000 crores, towards paying LPG subsidies to Oil Marketing Companies (OMCs) and for LPG connections under the PMUY, and other related expenses. Since the LPG prices are linked with the international crude prices and are sensitive to the fluctuations in Rupee-USD parity, the price of a non-subsidized 14.2 kg LPG Cylinder (averaged over the four cities – Delhi, Mumbai, Chennai, and Kolkata) has increased by about ₹ 358.7 over the 18 months between December 2020 and

May 2022 (the average price of cylinder increased from ₹ 654.6 on 02 December 2020 to ₹ 1013.3 on 19 May 2022) **[4]**. The subsidy provided (₹ 200) covers only about 20% of the current non-subsidized cylinder price (~₹ 1050). Because of the sharp price rise over the past few years, the number of nonsubsidized beneficiaries has drastically come down. Apart from the high costs of refill, an additional factor that caused a low refill rate is the inadequate area coverage of the LPG cylinder distribution networks **[2].** In addition, subsidy disbursement was also very difficult for the population without proper bank accounts, which further discouraged the consumers from pursuing LPG refills **[5]**.

Given the increasing prices of LPG cylinders and since a major share of the LPG demand in the country is met through imports, there is an urgent need to revisit the pathways in which the energy demand for residential cooking can be met sustainably in India **[2]**. The heavy dependence on LPG for household cooking in the country might turn out to be problematic from the viewpoint of energy security **[6]**. Therefore, streamlining the energy source used in residential cooking along the country's larger energy transition and energy security plans would be the most viable pathway toward achieving affordability. As India is looking towards a resilient power sector, electricity generation has been receiving ample attention from the decision-makers at the highest level in the Government **[7-9]**. Since the households belonging to the low- and medium-income category will continue to rely on LPG in the near-to-medium term based on the support received from the PMUY, the strategies to transform the cooking practices in such houses need to be planned in a thorough and pragmatic manner.

Currently, India relies heavily on coal for electricity generation, with more than 73% of the total electricity generation coming from coal **[10]**. Furthermore, about 80% of total energy comes from three sources, coal, oil, and solid biomass **[3]**. Coal's importance in India's power sector emerges from its capability to provide the baseload **[10]**, and therefore coal is envisaged to remain important for India's energy security and energy system resilience at least for the next two decades. This trend is evident from the rapid increase in the production of domestic coal over the past couple of years **[11]**. While India is looking to strengthen the power distribution infrastructure to ensure access to clean, modern, and affordable electricity for all, the use of electricity in the residential cooking sector has not yet witnessed a major pick-up. Most households with low-to-medium income levels are in the practice of using energy sources that lead to household air pollution (HAP) **[12]**. Particularly, in rural areas, there is a prevalence of solid fuels (firewood, dung cakes, crop residue, and coal/coke/lignite).

Electricity-based cooking provides an energy-efficient and cost-effective alternative to LPG in the form of a wide range of appliances, such as induction cooktops, infra-red stoves, and solar-based cooktops **[6].** Electricity-based cooking (or eCooking) reduces the carbon footprint attributable to residential cooking if the electricity is sourced from green resources (e.g., Solar, Wind, or Hydropower). Access to clean residential cooking (in terms of carbon footprint, energy-use efficiency, and household air pollution) has gained ample attention from the policymakers, governmental entities at both the state and central levels, researchers, practitioners, and several other private enterprises engaged in the various parts of the supply chain associated with the appliances and the fuels used for cooking. However, it is noteworthy that as of 2022 about 2.4 billion individuals globally and about 500 million residents in India are deprived of access to clean cooking solutions **[2]**, which further has repercussions in terms of impact on public health, environmental sustainability, and socio-economic productivity levels.

The 68th round of the National Sample Survey indicates that about two-thirds of the rural households in India still use firewood and chips for cooking. However, a changing trend is visible in cities, where about 68.4% of the surveyed households were found to switch to cleaner cooking options like liquefied petroleum gas (LPG)

[13]. Analysis of 20-year data reveals a noteworthy decline in the use of firewood and chips in urban areas, with household-level prevalence decreasing from 22.3% in FY 1999-00 to 14.0% in FY 2011-12, marking a significant reduction of 8.3% **[13]**. Simultaneously, the household-level usage of kerosene witnessed a decline from 21.7% to 5.7% within the same timeframe. On the other hand, there has been a noticeable increase in the adoption of LPG by urban households, with household coverage increasing from 44.2% in FY 1999-00 to 68.4% in FY 2011-12 **[13]**.

Individuals make decisions regarding cooking fuel selection based on several socio-economic factors such as cost, accessibility, availability, and culinary practices **[14]**. The choice of fuel is also influenced by household-level disposable income. The cooking fuel choices have a direct bearing on the health of the house dwellers and prolonged exposure to the household air pollution emanating from the cooking fuels may lead to severe health issues, including respiratory illnesses and cancer. In India, most of the cooking is done by women and the quality of life may degrade in a gender-specific manner in case of prolonged exposure to the smoke attributable to cooking fuel burning. In the case of solid biomass-based cooking, a lot of time is spent accumulating the fuel, which leads to a reduced number of productive hours that can generate marketable work. Therefore, the idea of energy transition in the residential cooking sector should aim at addressing the issues of poverty, equity, and social justice at the higher level of development.

In this study, the authors have attempted to evaluate the readiness of low-to-medium income households in the city of Bengaluru (Karnataka) in transitioning to electricity-based cooking, which is a modern and cleaner cooking solution as compared to the currently established (or traditional) pathways. Electric cooking appliances not only offer enhanced energy efficiency and reduced operational costs but also contribute to lower carbon emissions, especially if powered by green energy sources. Our study develops a ground data-based understanding of the opportunities and challenges for the transition toward electricity-based cooking considering household-level diversity in cooking practices, variations in fuel usage patterns, and penchant for adopting modern cooking technologies through a pilot household survey (n=62) conducted within the Bruhat Bengaluru Mahanagara Palike (BBMP) administrative boundary. The key novelty of this study stems from the efficient design of the household survey that helped capture detailed household profiles, encompassing information on socioeconomic profile (family structure, household configuration, income levels), cooking habits (culinary traits, cooking fuels used, and types of vessels used for cooking major meals), quality of life and aspirations (access to electricity, electrical infrastructure available in the house, electrical appliances used in daily lives, and willingness to pay for cleaner cooking options such as electricity-based cooking appliances). The survey also captured nuanced behavioral information on the number of major meals cooked daily, trends of fuel usage for different food items, the average number of hours spent cooking daily, gender roles in residential cooking, exposure to technology, and extent of vernacularity while using technological solutions (e.g., web-searching using a mobile phone), etc. Apart from the thematic stock-taking of infrastructural enablers and necessary strengthening measures, granular information on socio-cultural and behavioral traits of a diverse population residing in a cosmopolitan or metropolitan city of a fast-growing developing country would be crucial for a data-driven assessment of the possible entry barriers for the mass uptake of a new technological solution. Such an exploratory study would also help the policymakers at the highest level of the government to come up with an approach toward formulating appropriate costed strategies for successful large-scale techno-and-socio-economic transitions across a diverse population mix.

The organization of the rest of this paper is as follows: **Section 2** of this paper discusses the approach adopted in this study using a schematic diagram. **Section 3** presents a thematic and elaborate literature review encompassing the various relevant aspects of this work. **Section 4** presents the broad economic profiling of the population belonging to the study area. **Section 5** briefly discusses the energy use patterns in household cooking in India. **Section 6** highlights the design and deployment of the household survey. **Section 7** highlights a few key findings from the survey and the insights derived from them. **Section 8** concludes the study by emphasizing a few salient findings and the over-arching importance of such exploratory research. This section also highlights the future scope of this work.

2. Approach Adopted in the Study

The approach adopted in this study is encapsulated in the conceptual flow diagram presented in **Figure 1**. On one side the information on electricity distribution infrastructure is gathered from the published literature and open-source information. This information pool comprises the current status of the electricity mix of the State of Karnataka, the power distribution scenario in Bengaluru city, and the system-level challenges toward ensuring reliable power supply. On the other hand, the on-ground survey provides information regarding household configurations, monthly income levels and savings, general aspirations, aspirations for gadgets and appliances, and aspirations for modern cooking appliances. The survey also captures information regarding the educational qualification of the respondents and their daily life technological know-how. The survey specifically delves into cooking habits, and cooking amenities present in the households. Further, the current status of access to reliable electricity at the household level is also captured through the survey questionnaire. The whole information package is thematically segregated for further analysis (see **Figure 1**). Following the assessment of the transition readiness, recommendations are provided for formulating a multi-pronged intervention plan comprising strategies for knowledge dissemination and sensitization, strengthening of the electricity sub-distribution network, strengthening of modern cooking device ecosystem (encompassing the safety features, and support system for appliance maintenance and repairing), as well as a long-term strategy for gradual cultural nudge through confidence-building and continued community interactions.

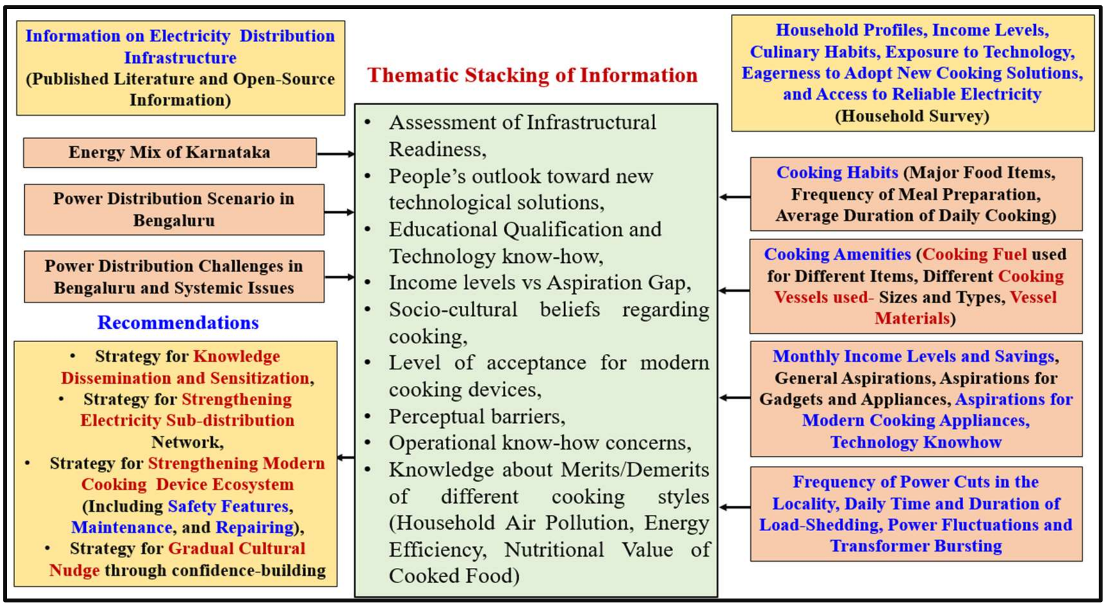

Figure 1. Conceptual flow diagram of the approach adopted in the study

3. Literature Review

3.1 Overview of Power Distribution in Bengaluru

Energy plays a pivotal role in both economic growth and human development. Despite being the third largest electricity generator in the world, India currently holds the 106th position in per capita consumption. The distribution of power, a crucial link in the power sector value chain, is predominantly managed by Government-owned DISCOMs, despite the deregulation of power generation in 2003 (Das & Srikanth, 2020) **[15]**. In India, electricity distribution is a shared responsibility between the Central and State Governments. In the initial phase of restructuring India's power sector, the Government unbundled State Electricity Boards into separate entities for generation, transmission, and distribution, except in specific regions with historical private sector involvement.

Bangalore Electricity Supply Company Limited (BESCOM) covers a total area of 41.092 sq. km with a population of over 207 Lakhs (census 2011), whereas the larger Bengaluru Metropolitan Area (BMA) spans over an area of 1294 sq. km with 90 Lakhs population (Census2011) **[16]**. BESCOM has three operating Zones, Bengaluru Metropolitan Area Zone (BMAZ), Bengaluru Rural Area Zone (BRAZ), and Chitradurga Zone (CTAZ). A total of 9 Circles, 28 Divisions, 119 Sub-divisions, and 453 Section Offices come under the BESCOM command. **Table 1** summarizes the different power distribution control areas under BESCOM. It is to be noted that BMA and BESCOM BMAZ do not exactly correspond to each other, although the acronyms sound similar. BMA is covered by both BESCOM BMAZ and B RAZ. BMAZ of BESCOM is divided into twelve divisions which include, i) Indiranagar, ii) Shivajinagar, iii) Vidhana Soúdha, iv) Hebbal, v) Malleshwaram, vi) Peenya, vii) H.S.R. Layout, viii) Jayanagar r, ix) Koramangala, x) Kengeri, xi) Rajajinagar and xii) Rajarajeshwari Nagar.

Table 1. Profiling of different Power Distribution control areas under BESCOM

Electricity Service Provider (DISCOM)	Zones	Circles	Number of Divisions	Number of Subdivisions
BESCOM	**BMASZ**	**South**	3	20
		West	3	15
	BMANZ	**North**	4	13
		East	4	15
	BRAZ	**BRC**	2	9
		RMGC	4	18
		KLRC	4	17
	CTAZ	**TMKC**	4	19
		DVGC	4	21
Total	**4**	**9**	**32**	**147**

The power is supplied to the city of Bengaluru through four 400/220 kV power stations located at Hoody, Nelamangala, Bidadi, and Somanahalli, respectively **[16].** Further, electricity is supplied to different parts of the city through 220/66 kV sub-stations, which are equally distributed to all parts of the city. The power is supplied to consumers primarily at 11 kV, after a voltage step-down through the substations. However, the 33 kV supply is also available for the bulk consumers/industries. BMAZ has 4 nos. of 400/220 kV Substations, 25 nos. of 220/66 kV Substations, and 52 nos. of 66/11 kV Substations, amounting to a total installed capacity of 13245 MVA. On the transmission side, BMAZ has 9690.32 ckt km and 18006.94 ckt km of HT and LT lines, respectively. There are 2801 Distribution Transformers within the BMAZ. Further, the Karnataka Power Transmission Corporation Limited (KPTCL) has planned 18 sub-stations of different capacities (i.e., 400kV, 220kV, 66kV sub-stations) in the BMA Zone of BESCOM **[16]**. The 400 kV Substations play a critical role in the energy transmission network, serving as key reception points for high-voltage electricity from distant power generation sources or other high-voltage substations. Their primary function involves stepping down this incoming high-voltage electricity to a lower, more manageable voltage level that aligns with the distribution requirements within the BMA Zone. In a hierarchical network, the 220 kV and 66 kV Substations further contribute to the voltage regulation process. These substations are strategically positioned to facilitate additional voltage reduction, tailoring the electricity to meet the specific requirements of various distribution zones. This includes but is not limited to industrial areas, commercial districts, and residential neighbourhoods, ensuring an organized approach to voltage distribution across diverse sectors within the designated geographical areas.

To provide households with reliable electricity, it is necessary to assess the overall *electrical load* emanating from various home appliances. For this assessment, it is necessary to take stock of the major electricity-driven appliances being used in the households and the average electrical loads associated with each of them **[17].** To assess the typical electrical load in a house, an electrical load calculator is employed. This tool measures the total electricity required to operate appliances, machines, lights, and other outlets within the house. The calculation involves determining the amps (current), volts (voltage), and watts (power generated) for each piece of equipment. The fundamental expression used in calculating electrical load is provided in **Equation 1**.

$$W = V.I \qquad (1)$$

Where W is the electrical load or *apparent power* (in VA, Volt-Ampere), V is the supply voltage (in Volt (V)) at the household level, and I is the line current (in Ampere (A)). Using the above expression, an illustrative calculation for a representative urban household is presented in **Table 2**. Such estimation would inform the decision makers regarding the expected load and the wiring capacities required in case a mass transition to electric cooking is envisaged. Some households may opt for induction cooktop appliances of lower power ratings instead of microwave ovens, while some may choose to have both. Considering these variabilities, two circuits for cooking appliances have been assumed for load estimation.

Table 2. Illustration of load calculation in a house (assuming typical average loads at the aggregate level for provisioning purposes)

Load-type	**Rating**
General Lighting and Receptacles: 1,000 sq. ft. home x 3 VA per sq. ft.	3,000 VA
Small Household Appliance Circuits: (2 circuits x 1,500 VA)	3,000 VA
Laundry (or Heavy Consumer Durable) Circuit: (1 circuit x 1,500 VA)	1,500 VA
Microwave Oven and Other eCooking Appliances: (2 circuits x 1,500 VA)	3,000 VA
Electric Water Heater (or any other heat load): 1 circuit x 3,000 VA	3,000 VA
Subtotal Existing Load	13,500 VA

First 8,000 VA of existing load at 100%	8,000 VA
Remaining existing load at 40% (13,500 VA – 8,000 VA = 5,500 VA) (5,500 VA x 40% = 2,200 VA)	2,200 VA
Total Existing Load	10,200 VA
Convert 10,200 VA to amperes (10,200 VA divided by 240 Volts = 42.5 Amps)	**A 70-ampere service is more than adequate for this home**

3.2 Issues with Electricity Distribution in Bengaluru

Despite Karnataka's surplus electricity generation where more than 50% of electricity generation takes place through renewable sources, the city of Bengaluru, India's tech hub, grapples with frequent power cuts (Chatterjee, 2021) **[18]**. The major bottlenecks are ailing distribution infrastructure, overworked transformers, and cable faults. While unplanned outages occur due to weather conditions (e.g., excessive rainfall or windstorms) or equipment failures, planned outages are mainly attributed to the transitioning of overhead lines to underground cables and routine infrastructure upgrades (Fathima,2023) **[19]**. The looming coal shortage crisis has raised concerns regarding reliable baseload power supply across the country. However, Karnataka's diversified energy mix comprising contributions from thermal, renewable, nuclear, and hydro enhances the potential availability of reliable power. Although the transition to underground power cables has led to a significant reduction in transmission losses, thereby improving reliability **[20]**, power interruptions are still prevalent in Karnataka, especially during scorching summers when the demand peaks. Recently, smart meters have emerged as a promising solution in the context of efficient power management. However, the large-scale rollout is yet to be achieved (Ramesh & DNHS, 2023) **[21]**. The reduction in the Fuel and Power Purchase Cost Adjustment (FPPCA) charges rolled out in September 2023 is likely to benefit the consumers **[22]**.

India's ambitious renewable energy targets, aimed at attaining Net Zero Carbon Emissions by 2070, present steep challenges for grid stability, storage, and integration. Higher penetration of the Variable Renewable Energy (VRE) sources in the overall energy mix necessitates innovative and progressive planning to achieve an optimal electricity mix. For effective utilization of the awash generation capacity created in the country, the interventions need to be multi-pronged. On a larger scale, ensuring efficient transmission corridors is a major technical intervention. At a local level, timely land allocation for sub-stations and resolving right-of-way issues are of paramount importance considering the current situation in the Bengaluru area. Additionally, reforms in the power distribution sector are also essential. Overall, Bengaluru's power distribution issues call for interventions from multiple angles, including infrastructure upgrades, deployment of smart meters and other improved technologies, and adopting a sustainable energy mix with a specific focus on reliability.

3.3 Household Air Pollution (HAP) from Traditional Cooking Fuels and Cleaner Options

Developing countries like India, which are characterized largely by low-to-medium household incomes, face significant challenges in providing affordable and efficient energy services for cooking and lighting. The global transition to clean cooking fuels has not been promising, with only a 1% increase in the population accessing clean fuels between 2010 and 2019. Despite progressive initiatives to promote clean cooking, 52% of the global rural population still relies on solid, polluting energy sources. Solid fuels, such as firewood, dung cakes, crop residue, coal, and coke/lignite, serve as the primary cooking energy source for over 75% of the rural population and about 25% of the urban population in India (Ravindra et al., 2020) **[23]**. The combustion of solid fuels contributes to indoor air pollution, causing significant health issues. It causes 3.2 million deaths per year globally, of which 237,000 are less-than-5-year-old children **[24]**. Individuals who spend considerable time indoors (especially, children, the elderly, and women) during periods of major meal preparation face heightened health risks. The incomplete combustion of solid biomass fuels releases toxic indoor air pollutants, contributing to conditions like chronic obstructive pulmonary disease, acute lower respiratory infections, lung cancer, stroke, and ischaemic heart disease **[25]**. To shift cooking practices from biomass fuels to LPG across India, the Pradhan Mantri Ujjwala Yojana (PMUY) was launched in 2016. Between 2016 and 2019, the adoption of LPG in rural households almost doubled from 20% to 39.7%, attributed to initiatives like the Pratyaksh Hanstantrit Labh Scheme and Pradhan Mantri Ujjwala Yojana. Currently, LPG and traditional biomass fuels dominate residential and commercial cooking in India **[26]**.

Several Asian countries (including India) have initiated efforts to reduce reliance on solid biomass fuels, and this presents a unique opportunity to explore the possibility of shifting towards electricity-based residential cooking which is devoid of any primary emissions. This will potentially translate to substantial health and environmental benefits if the transition happens at scale **[26]**. Since rural electrification in India increased from 56.6% to 99% in 2020 **[27]**, there is an opportunity to encourage residential electric cooking in low-to-medium-income households in rural areas as well. This would prove to be crucial to attain the scale of transition. However, major issues regarding the quality, affordability, or reliability of the electricity being supplied in India continue to persist. Only 66% of households in India are satisfied with the overall level of service from their state utility providers, while the satisfaction levels for reliability and quality of power are 63% and 55% respectively. This is especially true in rural areas where 50% of households experience 8 hours of power cuts a day and agricultural users only receive 7-8 hours of supply in most states (that too mostly during late hours of the night and with frequent interruptions) **[28]**. Also, the mass roll-out of any new initiative (e.g., electric cooking) would face the entry barriers that emerge from the socio-economic concerns such as affordability, social acceptability, education levels, total disposable income, behavioral and cultural traits, and general perceptions **[27]**.

Household emissions can be expressed in terms of Per Capita Carbon Footprint. The Carbon Footprint of any anthropogenic activity can be defined as the total amount of greenhouse gases produced by direct as well as indirect means, and it is expressed in *tonnes of carbon dioxide equivalent* ($tCO2_{eq}$). The concentration of carbon dioxide in the atmosphere has risen significantly since the post-industrial revolution era. It currently stands at approximately 419 parts per million (ppm) (as of January 2024), as against the preindustrial level of 280 ppm **[25]**. Being a developing nation, India's energy consumption and associated emissions are expected to grow rapidly in the coming two decades. The CO_2 emissions per capita in India grew by 5.5% over the one year between 2021 and 2022 **[29]**. Therefore, the energy transition trajectory of the country needs to be aligned with India's long-term low-carbon development strategy **[30]**. Also, in its updated Nationally Determined Contribution (NDC) under Paris Agreement (2021-2030) communicated to the United Nations Framework Convention on Climate Change (UNFCCC) in August 2022, India to reduce Emissions Intensity of its GDP by 45% by 2030, from 2005 level **[31]**. Energy transition in the country's residential cooking sector and a shift toward electric cooking (or eCooking) would prove to be crucial for realizing the country's climate goals.

4. Economic Profiling of the Study Area (BBMP boundary)

Although the National Economic Surveys provide valuable district-level average income data, a more nuanced understanding of income disparities that exist across the different professions in a cosmopolitan city like

Bengaluru is essential to understanding the 'household-level energy transition readiness' in the residential cooking sector. Since the Seventh Economic Census (2019) data is not presently available in the public domain, the data from the Sixth Economic Census (2013) has been used to understand the monthly income profiles existing across different sectors in the study area of interest (the BBMP area). Key insights from the Sixth Economic Census (2013) for Bengaluru are:

1. The BBMP area encompasses a total of 360,785 establishments, representing a significant economic landscape.

2. The combined workforce within these establishments is substantial, with a total of approximately 1.5 million individuals actively contributing to the economic activities in the region.

3. Within the total workforce, around 11 lakhs are men, and nearly 4 lakhs are women.

4. Formal employment, characterized by assured wages through contractual arrangements, constitutes a significant segment of the population. Approximately, 7.6 lakh men and 3.4 lakh women are part of this formally employed sector, as documented **[32]**. The remaining segment of the population is engaged in informal and/or unorganized employment, contributing to the intricate employment fabric of the BBMP area.

The data indicates that approximately 73.39% of the total population (1.5 million) in the BBMP area is formally employed. Bengaluru offers a varied range of occupations with a varied salary structure across distinct sectors. The indicative monthly salary ranges for different sectors have been obtained from openly available data sources (see **Table 3**) **[33]**. The table indicates varied wage levels across sectors, underlining the economic diversity within the city. The data shows higher wage offerings by the IT sector and management consultancy as compared to others.

Table 3. Monthly salary levels of the people working in various sectors in Bengaluru **[33]**

Employment Sector	Salary range (INR)	Average salary (INR)
Retail Sales Sector	12,900 -74,500	38,300
Apparel Manufacturing	10,300 - 61,700	28,500
Food Servicing	8,740 - 64,300	23,800
IT Sector and Computer Programming	18,000 -56,500	35,600
Management Consultancy	15,400 -77,100	47,200

5. Energy Use Patterns in Household Cooking in India

The upfront challenge faced by a family while planning to shift toward a new energy source for residential cooking is multi-fold. The first issue is the availability of cooking appliances and fuel in the neighbourhood. The second issue is the affordability of the cooking appliance and the fuel used for cooking. The third important consideration is the maintainability, of the cooking appliance as well as the accessibility of the servicing and repairing personnel for the appliances. It is noteworthy that despite the strong support from the Pradhan Mantri Ujjwala Yojana (PMUY), 24% of PMUY beneficiaries were not able to have even one refill during the first year **[26]**. **Figure 2** depicts the key findings from the India Residential Energy Survey (comprising 14,850 respondents) conducted in 2020 through face-to-face interviews. The report shows that although most households have LPG or PNG connections, around 50% of the households in India still use firewood **[34]**.

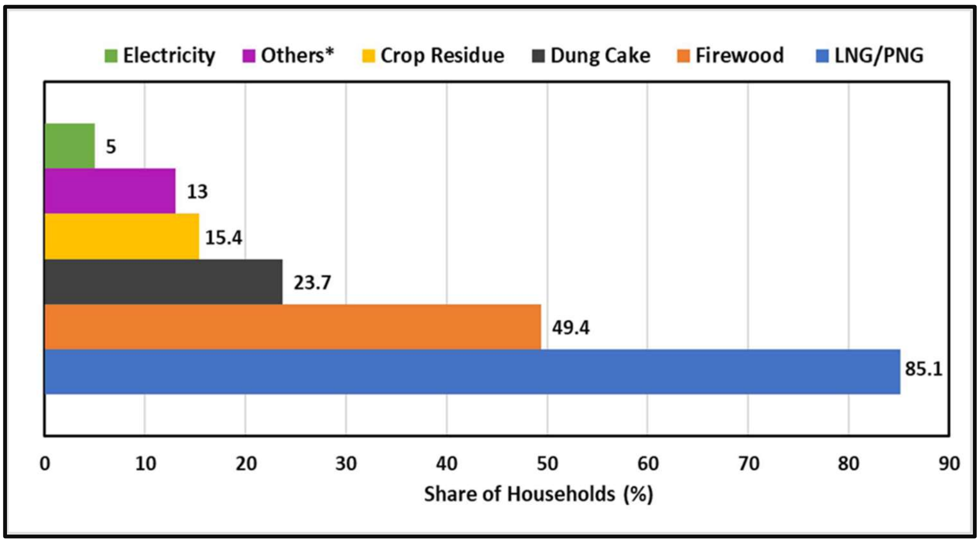

Figure 2. Breakdown of household cooking fuel in India in 2020 by type

Recently, a gradual shift has been witnessed toward the adoption of electric cooking (eCooking) devices in several states across India (e.g., Delhi, Tamil Nadu, Telangana, Assam, and Kerala), as highlighted by a study from CEEW in 2021 **[35]**. In both Delhi and Tamil Nadu, around 17% of households have welcomed various electric cooking appliances such as induction cooktops, rice cookers, and microwave ovens. Telangana indicated a 15% eCooking appliance adoption **[35]**. The CEEW study also found that 93% of e-cooking adopters continue to rely on LPG as the primary cooking fuel and use eCooking devices as a backup **[35]**. This study points out a noteworthy difference between the urban and the rural areas. Among urban households, about 10.3% have been found to adopt eCooking, whereas the adoption rate in rural areas stood at 2.7% **[35]**. This shift towards electric cooking devices provides an important insight into the different lifestyles and reflects how technological products make their way into our daily lives.

6. Deployment of Household Survey within the Study Area

To capture the socio-economic as well as behavioral variabilities that dictate household-level culinary habits, a ***Pilot Survey*** was carefully designed and commissioned to receive the initial inputs regarding culinary preferences, kitchen facilities, and access to reliable electricity. **Figure 3** schematically shows the stepwise design of the survey for capturing the energy-transition readiness of the Bengaluru households in connection with residential cooking. The survey also helped to understand the current fuel consumption patterns and factors affecting the household's decision to switch to an alternate option for cooking (e.g., electric cooking). This study is limited to the analysis of the Pilot Survey (n=62) data.

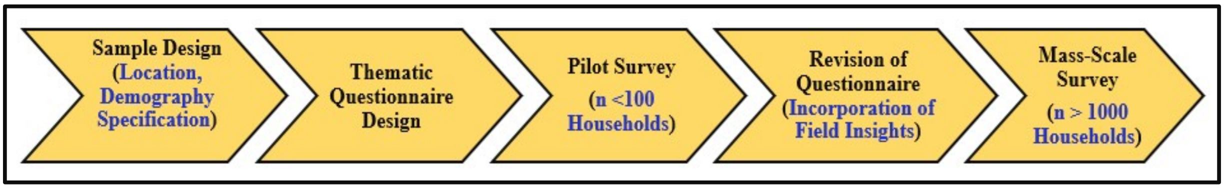

Figure 3. Steps involved in the household survey

The detailed questionnaire included information on family structure, socioeconomic profile, household configuration, culinary traits, fuel used in cooking, types of vessels used for cooking major meals, access to electricity, electrical infrastructure available in the house, electrical appliances used in daily lives, and willingness to pay for cleaner cooking options in general (including electricity-based cooking appliances), etc. Deeper household information collected during the survey comprised information on the number of major meals cooked daily, whether different fuels are used for different food items in a day, the average number of hours spent cooking every day, involvement of male or female members of the household in cooking, level of exposure to technology, and extent of vernacularity while using technological solutions (e.g., web-searching using a mobile phone), etc. In the cases where the households were found to use LPG, they were asked if they were covered under the PMUY, and the timeliness of receiving the subsidy was inquired.

7. Results and Discussion

7.1 Analysis of Household Survey Data

During the Pilot Survey, the respondents shared varied perspectives on induction cooktops and electric cooking. While some found eCooking convenient and efficient, others cited operational constraints from an individual point of view. Many respondents highlighted the importance of an uninterrupted power supply as a prerequisite condition for the adoption of electric cooking. Larger families found the LPG stoves more convenient for preparing major meals. Some respondents were concerned regarding the electricity bills that might drastically increase due to the additional electricity usage attributable to eCooking. Challenges such as cookware safety issues were highlighted by the respondents as a major concern. Most of the respondents mentioned that they are likely to consider using eCooking if they do not have to pay any extra electricity charges for the same. **Figure 4** shows the age distribution of the population sample belonging to the pilot survey. About 52% of the surveyed population belonged to the age group of 25-40 years, and 34% of the respondents belonged to the age group of 15-25 years. The share of the survey sample belonging to the age group of 40-65 years was found to be 11%. About 3% of the respondents comprised people aged 65 years and above. **Figure 5** indicates the gender mix in the pilot survey sample population. Among the respondents, 52% were male and 48% were female. The gender mix of the pilot survey population augurs well with the gender mix of the overall population of Bengaluru City.

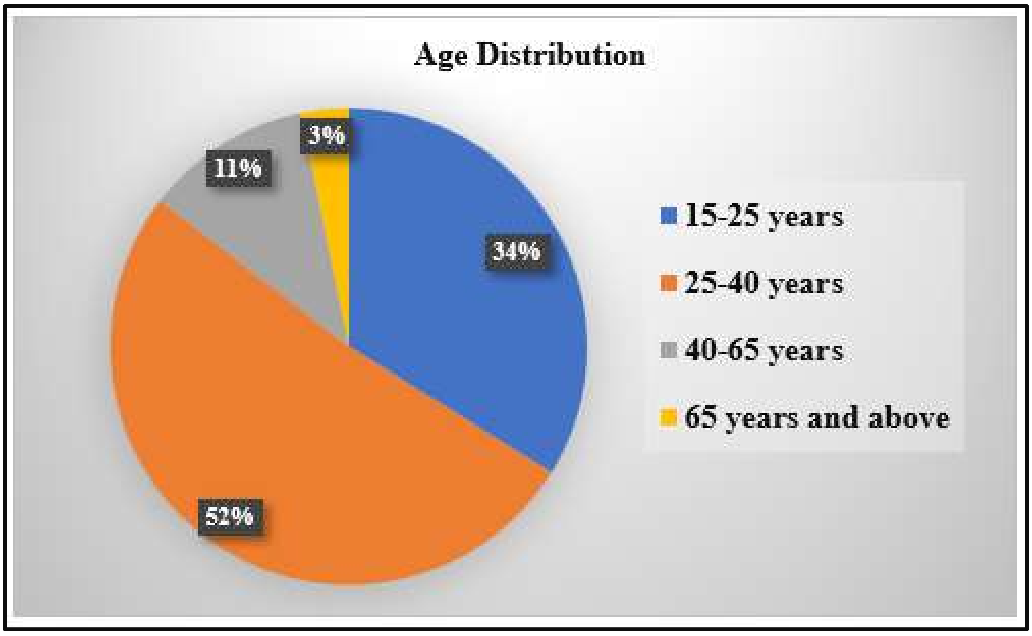

Figure 4. Age Distribution of the Population Sample (Pilot Survey, n=62)

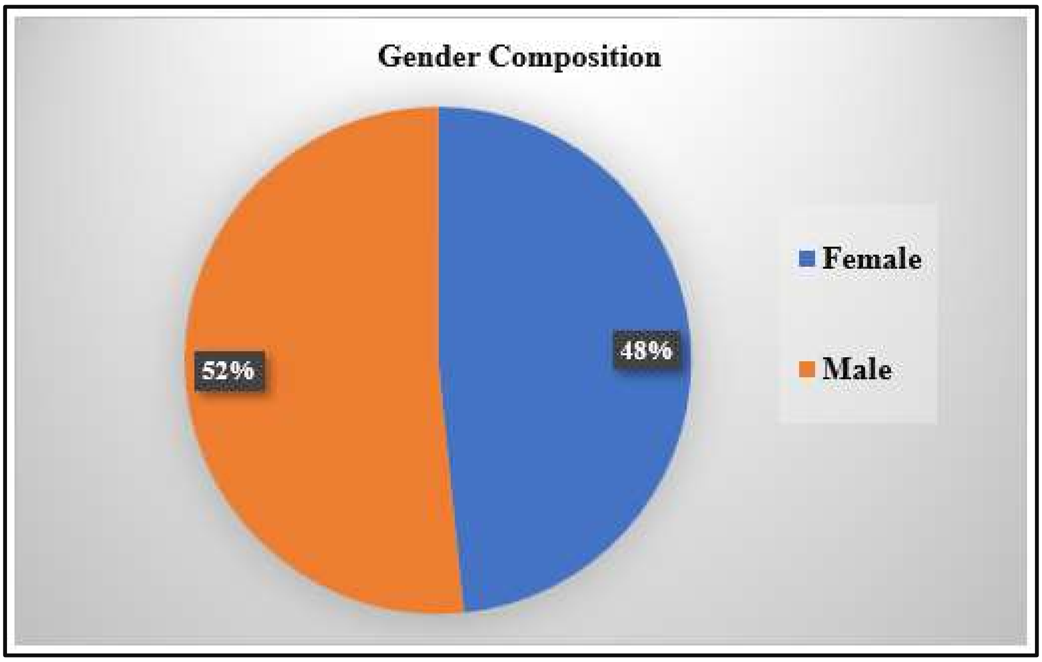

Figure 5. Gender Mix of the Population Sample (Pilot Survey, n=62)

Figure 6 shows the mix of education qualifications as observed in the pilot survey sample. The analysis of the educational qualifications of the pilot survey respondents showed that 50% of the respondents had an educational qualification level of Post-graduation (PG) or above. About 32% indicated Graduation as the educational qualification level. About 8% of the total respondents indicated Intermediate as their educational qualification, whereas about 7% of the pilot survey sample population reported Matriculation as the education level. About 3% of the respondents reported their educational qualification to be up to the 8th Standard (Primary Level). This shows that even the pilot-scale sample population exhibited a certain range of diversity in educational qualifications, which indeed will evolve further as the large-scale household survey progresses. **Figure 7** presents the different monthly income levels as obtained from the Pilot Survey. About 23% of the total respondents reported a total monthly income of less than Rs. 35,000. About 32% of the respondents reported a total monthly income in the range of Rs. 35,000 - 60,000. About 29% of respondents reported a total monthly income of Rs. 90,000 or more. The relative share of different monthly income levels would certainly be different as the large-scale survey progresses.

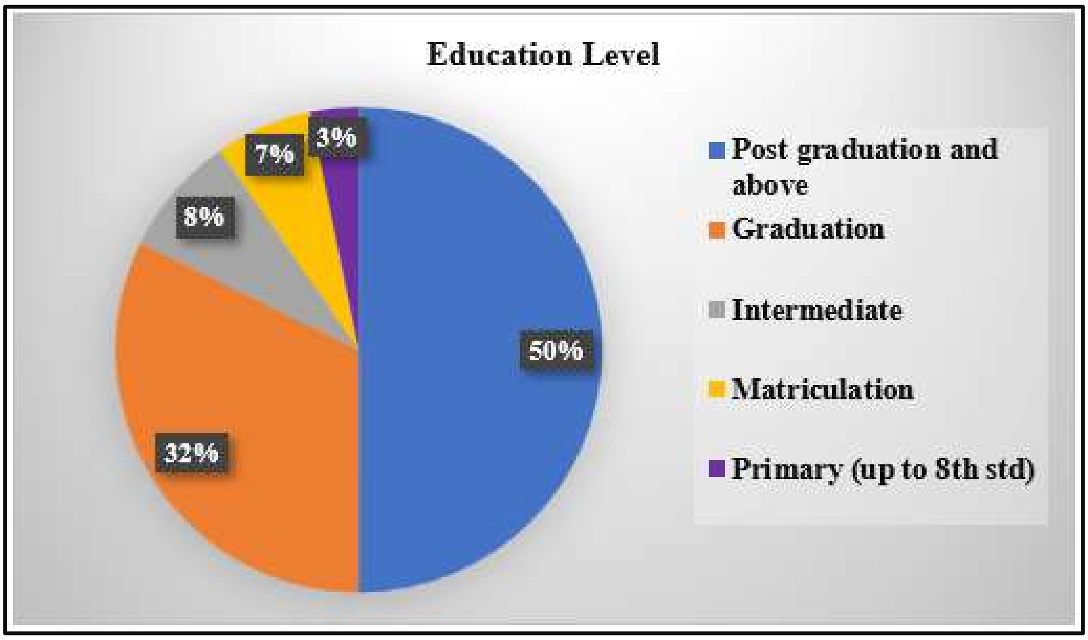

Figure 6. Educational Qualifications in the Population Sample (Pilot Survey, n=62)

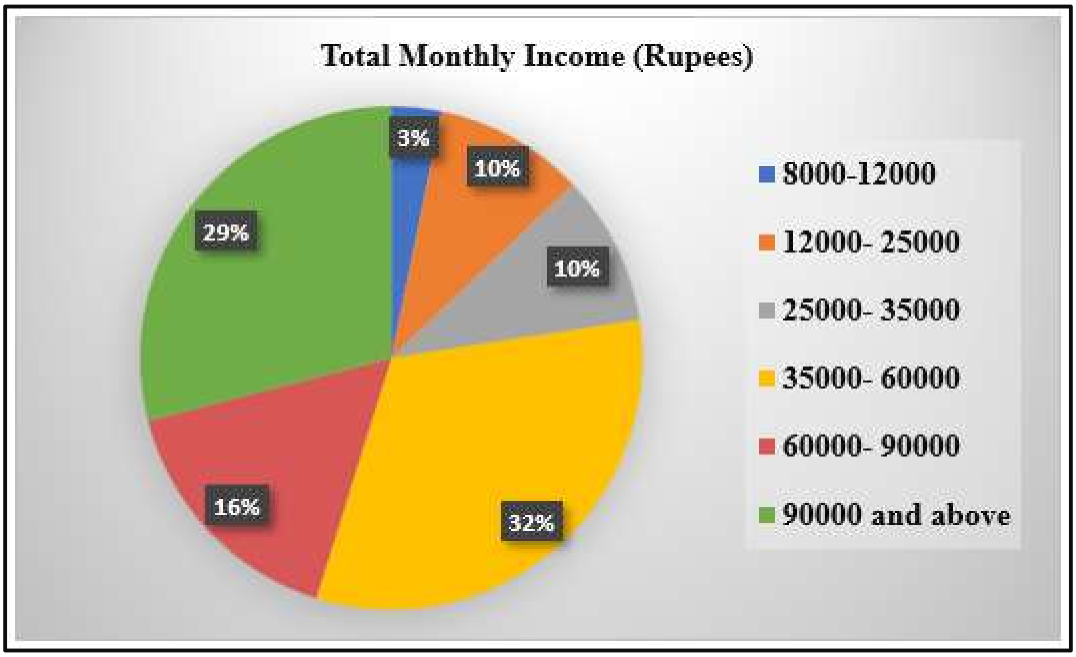

Figure 7. Different Levels of Monthly Income in Population Sample (Pilot Survey, n=62)

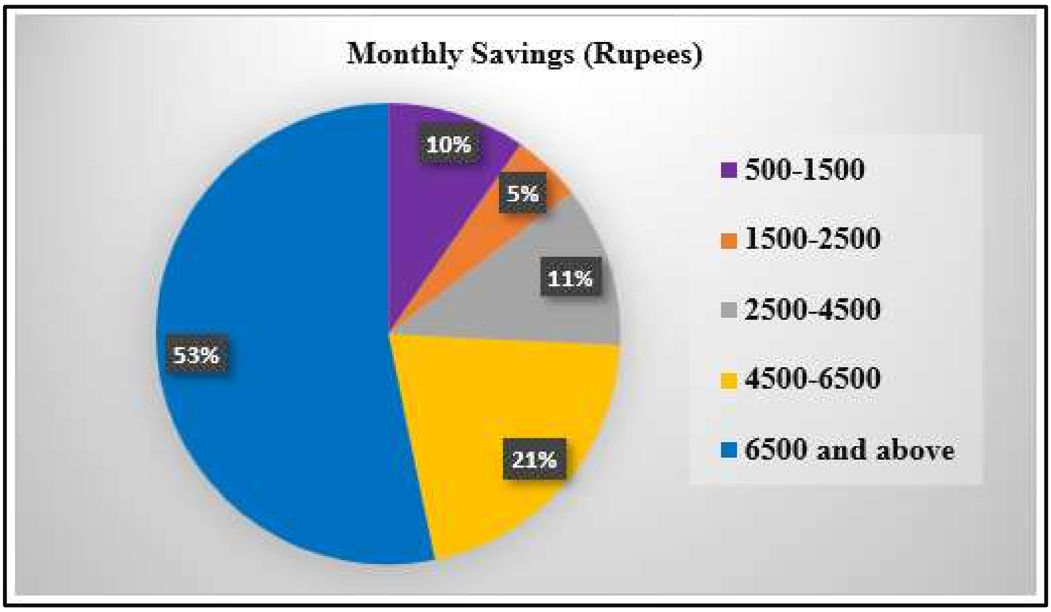

Figure 8. Different Levels of Monthly Savings in Population Sample (Pilot Survey, n=62)

Figure 8 depicts the different levels of monthly savings as obtained from the Pilot Survey. About 53% of the respondents indicated a monthly savings of Rs. 6500 or more. About 15% of the respondents reported monthly savings of less than Rs. 2500. About 32% of the respondents reported monthly savings in the range of Rs. 2500-4500. This mix is quite expected given the cost of living in Bengaluru City. People would be able to think about fulfilling aspirations only when they have adequate monthly savings.

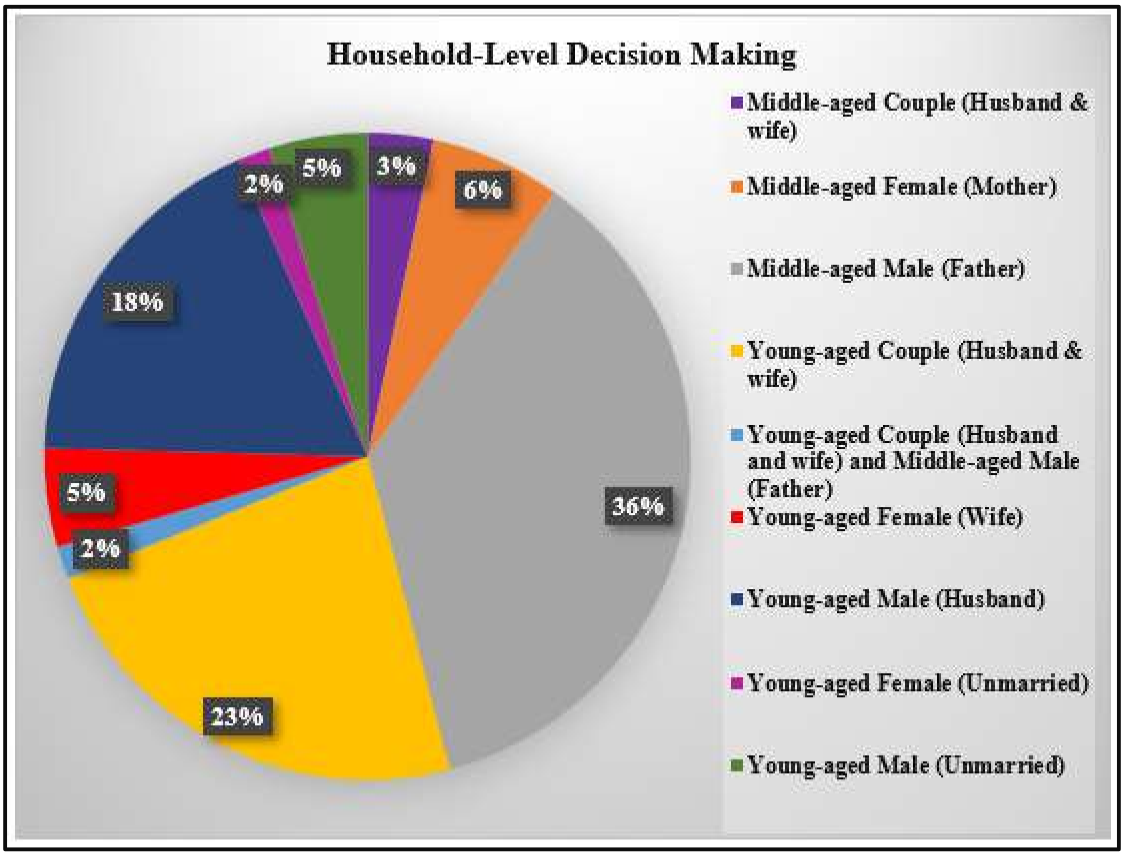

Figure 9. Decision Making in Population Sample (Pilot Survey, n=62)

Figure 9 depicts the roles played by the different family members in the general decision-making regarding various household matters. This gives an overview of relative bargaining power within the household setting. About 36% of the respondents indicated the patriarch (usually a middle-aged male and a father) as the head of the family whose consent matters for any major decision in the family. About 23% of respondents reported that the house is run by a young couple, and both husband and wife make the decisions together. About 18% of respondents indicated that the young male (main earning member and husband) is responsible for all the major decisions. About 6% of the respondents (middle-aged) reported that the woman of the house (wife) decides on all the major household matters, and 5% of the respondents (young-aged) indicated that the young female (wife) makes all the major household decisions. The use of a new device in the house for the preparation of food is a major household decision that requires a consensus amongst the members or consent from the head of the family. In the context of residential cooking the pivotal role of women needs to be understood and acknowledged. Women's involvement and influence in deciding kitchen-related changes and new adoptions are nuanced factors that need to be accounted for while planning for energy transition in residential cooking.

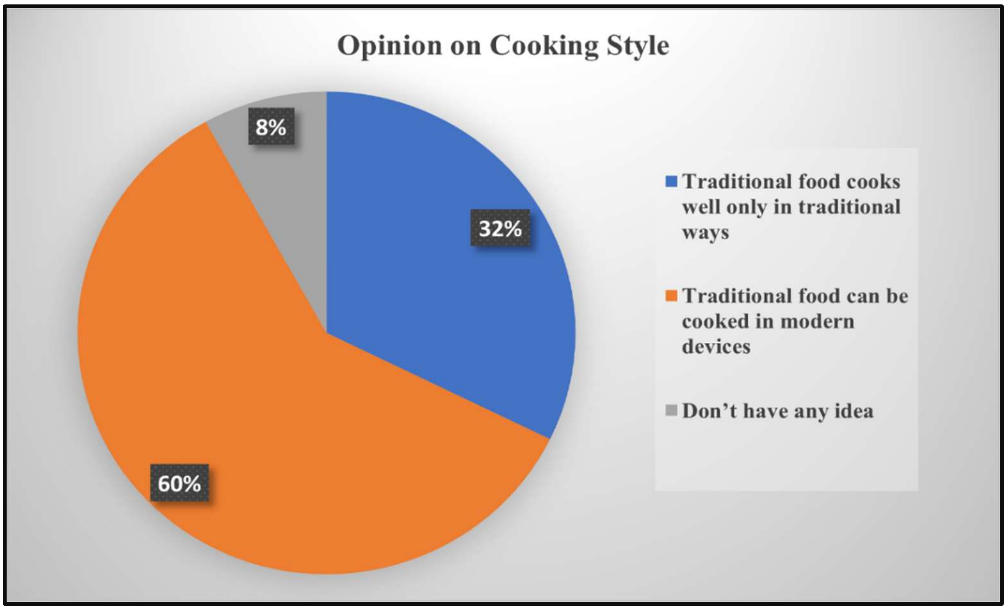

Figure 10. Opinion on cooking style in Population sample (Pilot Survey, n=62)

Figure 10 captures the respondents' views on whether traditional food items can be prepared in traditional ways (using traditional open chulhas like Oley) alone or can be prepared using modern cooking devices as well. About 60% of respondents opined that traditional food items can be cooked using modern devices, while about 32% believed that traditional food items can be prepared only in the traditional ways. The survey also brought forth that females play a major role in house chore activities such as the purchase of kitchen utensils, and meeting other small day-to-day requirements, whereas male participation is more prominent in deciding critical matters (e.g., major procurements/ expenses that have major financial implications). Further, important insights could be derived from the survey responses regarding the current status of access to reliable electricity. About 27% of the respondents mentioned experiencing power cuts every day. Only 20% of the sample population mentioned experiencing no power cut at all. From the responses, it was evident that the time of load shedding is spread over the whole day in different parts of the Bengaluru city. About 40% of the respondents indicated a load-shedding duration of more than one hour (quick restoration of power is considered as no load-shedding). More interestingly, about 42% of the respondents mentioned hearing the sound of a transformer bursting before the power cuts. This necessitates a relook into the sub-distribution infrastructure in the respective localities to examine the extent of overloading and assess the requirement for infrastructure augmentation.

7.2 Salient Insights from the Survey

The pilot survey brought forth important insights regarding the various socio-cultural facets that continue to deter the large-scale adoption of eCooking in India. The salient findings are enumerated below in a thematic manner.

a) Consumer Awareness:

The level of consumer awareness regarding the array of available eCooking devices was found to be a pivotal factor. For the energy transition to succeed it is necessary to make the consumers well-informed regarding the optimal usage of the new technological solution and the associated benefits.

b) Convenience as a Factor:

The perception regarding the convenience of using modern electric cooking appliances is important to ensure a mass-scale energy transition in residential cooking. The current usage of eCooking devices needs to be understood well to transform consumer behaviour through extensive interaction using community engagement channels.

c) Reliability of Electricity Access:

The envisaged success of the eCooking transition lies in access to reliable electricity. Especially, for the low-income household pockets within the city, daily availability of uninterrupted electricity for a significant duration (covering the meal preparation time) is a crucial factor.

d) Economic Concerns in Low-to-Medium Income Households:

In households with modest income levels, the apprehension attached to the electricity bills is a focal concern. Perceptions regarding the tangibility of LPG consumption make it a more comfortable choice among consumers. IOT-based metering built into the electric cooking appliances and the sensitization regarding such advanced solutions may result in better consumer and community-level awareness.

e) Household Electric Connections:

Electric load emanating from household cooking would require proper electrical wiring, and therefore, a registered connection. The policymakers at the highest level in the Government of India need to look beyond the administrative definition of 'electrified households' and strengthen the sub-distribution infrastructure to improve the quality and reliability of dispatched power.

8. Conclusion

The complex and interlinked dimensions of energy security, carbon footprint, and household air pollution in India call for a transformative shift in cooking practices. While the Pradhan Mantri Ujjwala Yojana has increased LPG access, the challenges associated with import dependence and rising LPG prices necessitate an evaluation of electricity-based cooking as a sustainable alternative. Bengaluru is used as a spatial anchor to assess the household-level readiness toward transitioning from LPG to electricity-based cooking, through a household survey. Such a transition also needs to account for broader socio-economic and cultural dimensions that require a nuanced understanding of regional variations in culinary habits and the ways of food preparation. Information regarding the level of income and education, family size and composition, affordability & accessibility of the cooking appliance and fuel, consumer awareness regarding various options, household level energy demand, access to reliable electricity, and familial aspirations are crucial since these attributes dictate a lot of the choices made by the different households. About 27% of the survey respondents mentioned experiencing power cuts every day, and 40% of the respondents indicated experiencing load-shedding durations of more than one hour quite often. Interestingly, about 42% of the respondents mentioned hearing the sound of a transformer bursting before the power cuts. This necessitates a relook into the sub-distribution infrastructure in the respective localities to examine the extent of overloading and assess the requirement for infrastructure augmentation. Electrical infrastructure would require strengthening to withstand the sudden rise in power demand, especially during the characteristic Indian evening peak hours, since the evening time household cooking coincides with this peak load period. A behavioral nudge may be required to shift (or distribute) this additional load attributable to residential electric cooking, which would be a daunting task given the regional cultural, behavioral, and culinary diversities in India. Therefore, to formulate a nationwide costed strategy for the energy transition in the residential cooking sector in India, a detailed ground-data-based analysis at the state as well as the regional levels, accompanied by realistic scenario-building would be required for contributing meaningfully to the larger energy security canvas at the national level.

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