A REPORT ON

TECHNO-ECONOMIC ASSESSMENT OF COOKING TECHNOLOGIES IN INDIA

TOWARDS DECARBONISING THE COOKING SECTOR

SED FUND

VASUDHA FOUNDATION
Green ways for a good earth!

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Vasudha Foundation is a non-profit organisation set up in 2010. We believe in the conservation of Vasudha, which in Sanskrit means the Earth, the giver of wealth, with the objective of promoting sustainable consumption of its bounties. Our mission is to promote environment-friendly, socially just and sustainable models of energy by focusing on renewable energy and energy-efficient technologies as well as sustainable lifestyle solutions. Through an innovative approach and data- driven analysis, creation of data repositories with cross-sectoral analysis, along with outreach to ensure resource conservation, we aim to help create a sustainable and inclusive future for India and Mother Earth.

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1 INTRODUCTION

Deep electrification refers to the process of replacing any non-electric energy source using fossil fuels with technologies that use electricity as a fuel source by either direct or indirect means. The idea is that 'deep electrification' will help improve the air quality index and reduce India's dependence on oil and gas imports while ensuring reduced greenhouse gas emissions.

The cooking sector in India is one of the sectors where primary fuels used are mostly LPG, PNG, and biomass. Providing energy for cooking purposes is crucial for improving public health, protecting the environment, promoting economic development, and advancing gender equality. Hence, it has been a priority of developmental programs to ensure food and energy security. In view of this, the Ministry of Power launched the Go Electric Campaign in February 2021 to spread awareness on the benefits of electric cooking. Further, the recently launched Lifestyle for Environment initiative looks at nudging individual behavioural choices and decisions for promoting energy efficiency and resource conservation.

In India, subsidised LPG has been a key policy intervention in transitioning from polluting fuels such as firewood, charcoal, and cow dung. It is important to note that although LPG is a convenient cooking fuel, its combustion contributes to indoor household air pollution (IHAP) with pollutants including carbon monoxide (CO), nitrogen dioxide (NO2), and formaldehyde (HCHO), which can have adverse effects on respiratory and cardiovascular health[1]. Furthermore, the sustainability of LPG as a primary cooking fuel is questionable due to its heavy reliance on imports. The share of LPG imports of its total consumption has risen from 50 percent to 60 percent from 2016-17 to 2021-22. Further, the anticipated risks of switching back to harmful and polluting solid fuels remains high with the gradual withdrawal of the subsidies for LPG in India[2]. This poses energy security risks and cost inflation, making it challenging to achieve SDGs and NDCs.

Electric cooking is often excluded from broader electrification strategies and forecasts in energy policy, while clean cooking advocates tend to overlook electrification in their initiatives. As a result, there is a significant lack of progress in meeting cooking needs through electrification. Although universal access to electricity and clean cooking fuels and technologies are interconnected goals of SDG7, and provide overlapping health, environmental, and economic benefits, the energy policy related to these goals remains disjointed. As renewable electricity capacity and generation continue to grow, it is important to consider exploring the potential of utilising this energy source for large-scale direct electric cooking or indirect electric to thermal conversion cooking technologies such as indirect solar cookers.

Research and real-world trials have demonstrated that electric cooking technologies such as induction and electric pressure cookers can be effectively used to prepare most Indian culinary dishes[3]. The significant advantages of using these cooking technologies include improved household air quality and enhanced safety. To facilitate a sustainable switch to electricity as the primary cooking fuel in India, several significant obstacles must be overcome, including the high upfront cost of electric cookstoves, the availability of affordable and reliable renewable electricity, and the need for behavioural change to adapt to a cultural shift.

We feel electric cooking can be explored as a key vector in transitioning to clean cooking and accordingly this study aims to provide a techno-economic comparison between current primary cooking energy technologies used and the potential switch to electric cooking technologies.

1 https://www.aqi.in/blog/gas-stove-emissions-iaq
2 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1848343
3 https://mecs.org.uk/wp-content/uploads/2022/03/India-eCookbook-21-compressed.pdf

2 NEED FOR ELECTRIC COOKING IN INDIA

The Multi-Tier Framework (MTF) in Figure 1 developed by ESMAP offers a definition for the adoption of clean cooking, where a household is deemed to have access to modern energy cooking services only if it achieves a score of Tier 4 or above for all six attributes outlined in the MTF for Cooking.[4]

Electric cookstoves, particularly induction cookstoves and electric pressure cookers (EPC), have been shown to be more efficient, less polluting, and safer compared to gas and biomass cookstoves, in terms of exposure, efficiency, and safety[5]. Additionally, electric cookstoves are more convenient due to the increased access to electricity and the strengthened electricity distribution system as part of the SAUBHAGYA programme[6]. However, challenges related to ensuring round-the-clock reliable supply must be addressed to ensure availability. The adoption of electric cookstoves also faces barriers due to the higher upfront costs of purchasing the stove and cookware. The average cost of purchasing a two burner LPG stove is around INR 1500 whereas the cost of purchasing two induction cooktops would vary from INR 3000 and upwards depending on power rating, efficiency and features.

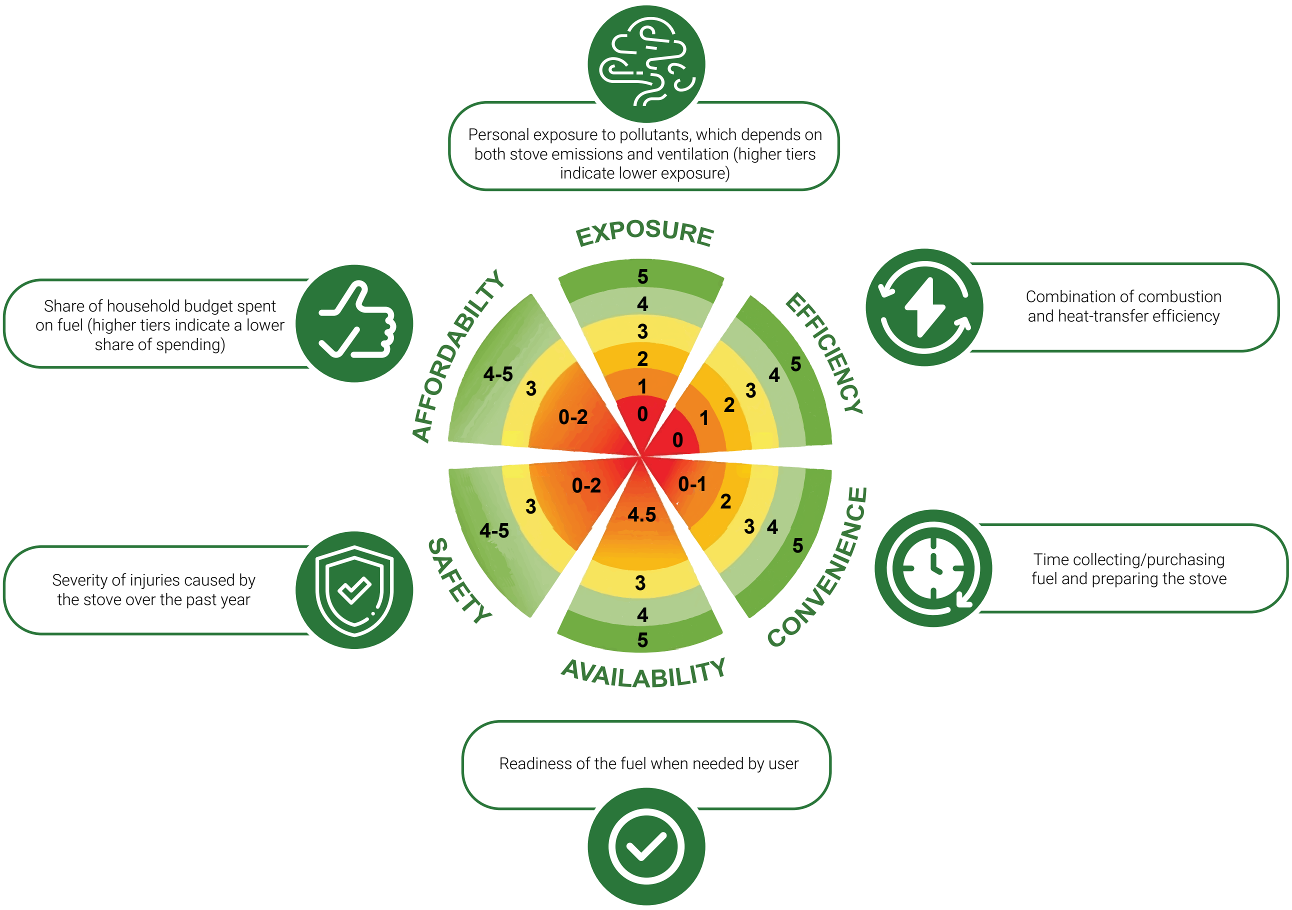


Figure 1: Attributes of the Multi-Tier Framework to assess clean cooking adoption[7]

4 https://www.worldbank.org/en/topic/energy/brief/fact-sheet-multi-tier-framework-for-cooking
5 https://sustainablereview.com/electric-stoves-are-better-for-the-planet-and-human-health/
6 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1897040
7 https://www.worldbank.org/en/topic/energy/brief/fact-sheet-multi-tier-framework-for-cooking

3

APPROACH AND METHODOLOGY

The cooking sector has undergone many changes in terms of fuel choice, programme design and business models. While no one size fits all, the cooking stove and its fuel choice are the most critical part of the equation. Hence, we developed a user-friendly tool that provides a techno-economic assessment of various cooking technologies and its respective fuels commercially available in India. Not just the technical aspects, it provides the social and environment impacts of the chosen cooking technologies. This tool is particularly useful for stakeholders involved in making decisions on clean cooking in India. The primary objective is to empower the user to make informed and efficient energy choices. The following provides a detailed break-up of the tool and its approach:

1. **Understanding the household and demographic profile**
   - Household size – The tool includes the count of adults and children in households, with a maximum limit of 10 individuals per household, including a maximum of five adults and five children.
   - Monthly income – entered by the tool user so that they can get to know the share of cooking fuel cost in their monthly income.
   - Area type – rural or urban, since the type of fuels used, and its usage usually vary.
   - State – Due to variations in cooking patterns and electricity costs (refer Annexure - Energy Demand & Cost)
   - Electricity tariff (INR/kWh) – Submitted by the user based on their residential electricity bills.
   - Eligibility for an LPG subsidy – To determine subsidy requirements.

2. **Meal & hot water profile**
   - The user has an option to select the usual dishes cooked by the households for breakfast, lunch, dinner, tea, and snacks. Additionally, the heating water demand is given by selecting the heat source and quantity of hot water required.

Based on the above selections, the tool provides a techno-economic assessment, in addition to the social and environmental impact assessment done for the different cooking solutions majorly used in India (traditional chulhas, improved chulhas, biogas, LPG, PNG, e-cooking solutions including solar based solutions).

Cookstove Characteristics

In this section, important variables to determine significant characteristics that a household preliminarily reviews before making an investment decision have been provided. Life, thermal efficiency, capital cost, overheads, and total cost are the variables.

Energy Demand & Cost

This component covers the energy attributes of using cookstoves. The variables included are daily cooking duration, hourly consumption, daily consumption and annual consumption.

Environment & Social Impact

The aspects covered in this section include unit carbon emission, annual carbon emission, the unit cost of energy, operational cost, overheads for energy services, total cost, and the social carbon cost.

Health Impact

The health part focuses mainly on indoor household air pollution (IHAP) caused by fuel emissions due to incomplete burning of fuelwood. The overall IHAP caused by cooking is influenced by the cooking fuel used and ventilation.

Financial Impact

This component covers the annual income of the household (HH), its potential savings and the payback period if the household shifts to the preferred mode of cooking.

The flowchart of the methodology to assess the socio-economic indicators of transitioning to electric cooking is based on Figure 2. A review of national and state policies has also been incorporated to understand the dissemination strategy, especially for LPG and alternatives to traditional cookstoves. At the moment, the tool does not assess the financing options for the end-user to transition to electric cooking solutions and subsidy-related information.

The following datasets were used to build background assumptions and research on the cooking situation in India:

1. National Family Health Survey (NFHS) dataset on household cooking fuels used in India from 1992 to 2021 to understand the transition in the usage of primary cooking fuels, especially LPG.
2. LPG usage to understand the imports, residential cooking consumption and Pradhan Mantri Ujjwala Yojana (PMUY) distribution.
3. India Residential Energy Survey (IRES) 2020 to understand the household-level granular data on the use of clean cooking fuels and other household aspects such as family size, and annual income.
4. Domestic electricity tariff data is taken from each DISCOMS tariff order to assess the cost of electric cooking for a particular household in India.

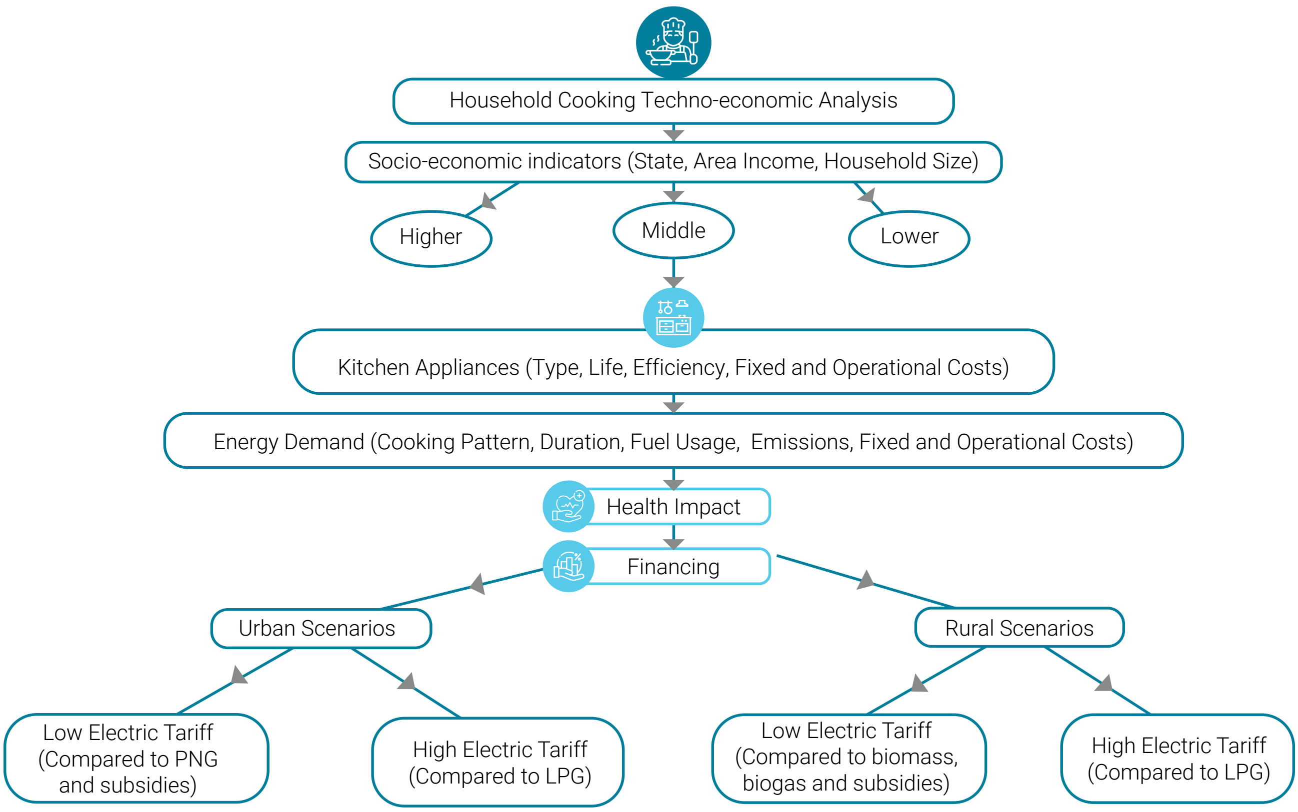


Figure 2 : Flow chart of the methodology used to conduct the techno-economic analysis

4 PRIMARY COOKING FUEL CHARACTERISTICS

The use of cooking fuel in Indian HHs has been surveyed through NFHS carried out in five rounds from 1992-93 till 2019-21.[8] National Sample Survey Office (NSSO) also released a percentage distribution of households with different types of fuel used for cooking in 2018[9] and is like the value reported in the recent NFHS survey. Significant difference in cooking fuel characteristics is observed between urban and rural consumers as seen in Figure 3. Henceforth, the trends have been classified separately in 4.1 and 4.2 respectively:

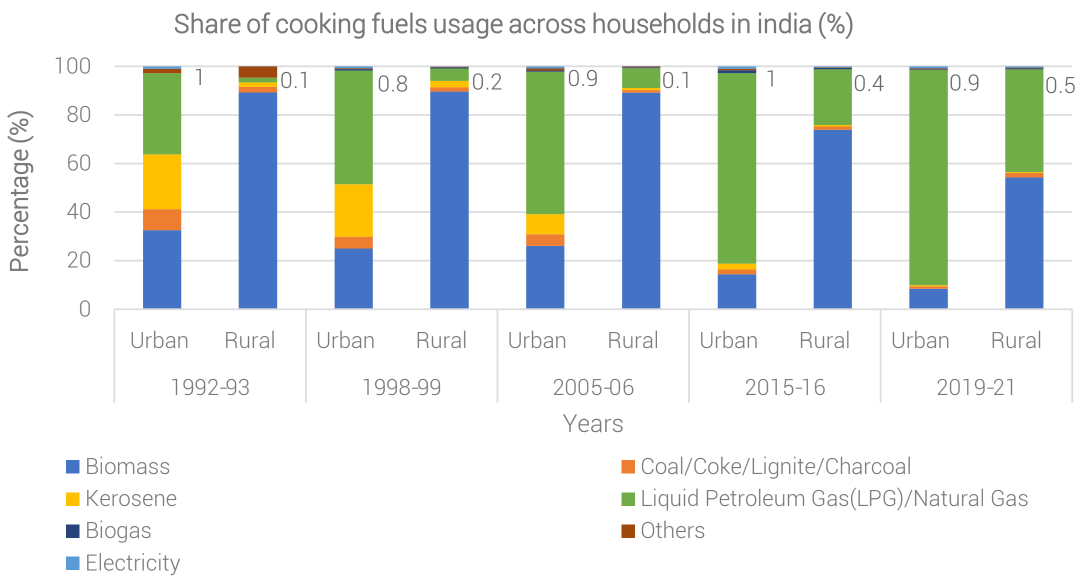


Figure 3 : Percent distribution of households by primary cooking fuel usage characteristics at the national level

Source: National Family Health Survey, India

4.1 Urban Households

- A substantial shift has occurred from the use of wood, kerosene, and coal to LPG/Natural Gas.
- The use of kerosene in 2019-21 is almost nil. This has been mainly due to restricted sales through public distribution systems (PDS) and the prohibition on the use of kerosene as a cooking fuel in major cities such as Delhi.
- Biomass[10] which is the major indoor air-polluting cooking fuel still being used has decreased to 8.4 percent in 2019-21 from almost 33 percent in 1992-93.

4.2 Rural Households

- Biomass is the major source of cooking fuel. However, the percentage distribution has reduced to 54.3 percent in 2019-21 from 89.2 percent in 1992-93.
- The percentage distribution of households using LPG in the same period has exponentially increased to 42.3 percent from 1.9 percent. This is a result of expanded efforts by the Government of India to increase LPG penetration in India and mainstream cleaner cooking options for rural households.

8 http://rchiips.org/nfhs/factsheet_NFHS-5.shtml
9 https://mospi.gov.in/documents/213904/0/nsc_AR_2018_19.pdf/fc8f7a95-86b0-8dec-ad45-5e4aa6c8fb5c?t=1613721187086
10 Biomass includes firewood, agriculture crop residue, cow dung cakes and straw/shrubs/crop waste

4.3 Use of LPG in India

As seen in Figure 4, the use of LPG has been steadily increasing from 2016-17 to 2021-22 with the overall domestic consumption in 2021-22 around 25,502 MT. At the same time, the percentage of domestic consumption (cooking) to the total consumption of LPG has increased to 90 percent from 87 percent. It is evident that the usage of LPG is import dependent which has associated risks of energy security and cost inflation. Hence, the Government of India on February 19, 2021 launched the 'Go Electric' campaign focusing on electrifying cooking and transport sectors through the adoption of electric cooking and electric vehicles. This is expected to help India achieve its Nationally Determined Contribution (NDC) targets and low carbon economic growth in the future.[11]

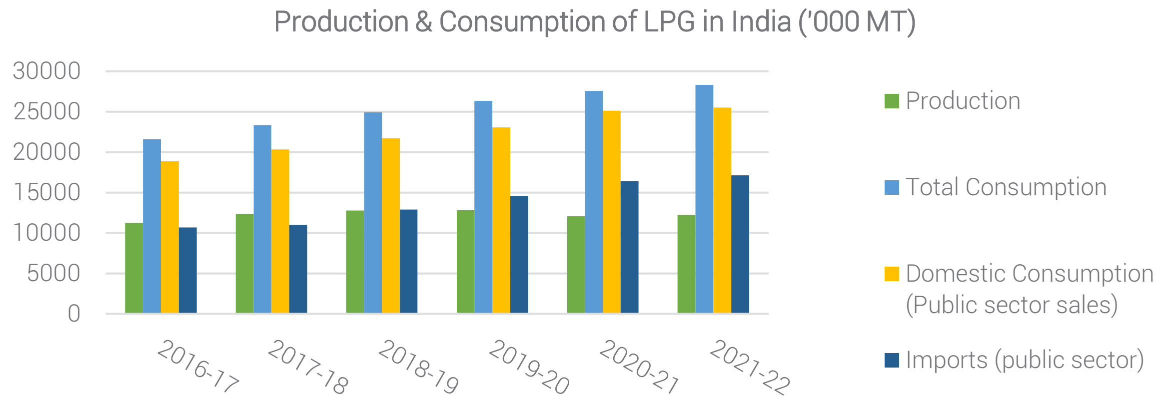


Figure 4 : Production and consumption of LPG in India

*Source: Oil companies & Directorate General of Commercial Intelligence and Statistics (DGCIS); *PSU OMCs*

However, till consumer confidence and scale-up mechanisms of electric cooking markets are in place, LPG & PNG would remain the preferable cleaner and affordable source of cooking fuel choice. As of January 1, 2023 almost 31.4 crores of active LPG connections exist in the country[12]. The share of total PMUY subscribers (~9.5 crores)[13] to the total number of active connections is approximately 30 percent and the state-wise distribution can be seen in Figure 5. The total number of PMUY connections from Uttar Pradesh, Bihar and West

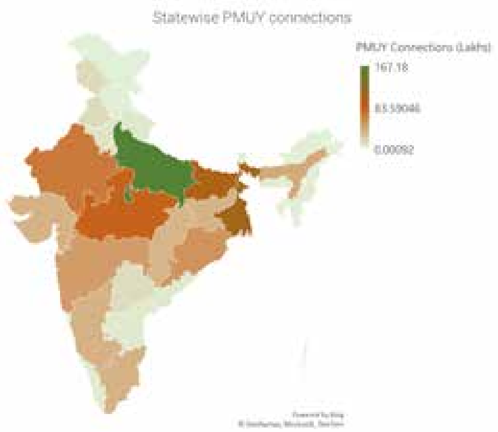


Figure 5 : State wise PMUY connections

Source: PSU OMCs (IOCL, BPCL and HPCL) "PMUY connections" refer to those households where subscription vouchers have been issued

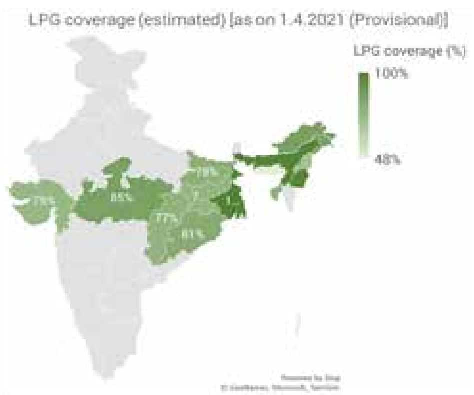


Figure 6 : Estimated state-wise LPG coverage in India as of 1st April 2021

Source: PSU OMCs (IOCL, BPCL and HPCL)

11 https://pib.gov.in/PressReleasePage.aspx?PRID=1705892
12 https://ppac.gov.in/consumption/active-domestic-customers
13 https://ppac.gov.in/uploads/rep_studies/1679987824_READY_RECKONE_Magazine.pdf

Bengal is almost 42 percent of the total number of PMUY connections in India. There are some states where LPG coverage lags the national average as can be seen in Figure 6. Some of the major states with less than 80 percent of households having LPG connections are Meghalaya, Nagaland, Gujarat, Jharkhand, Chhattisgarh, Tripura, and Bihar.

Some of the other key initiatives by the Government of India are PMUY, PAHAL (Pratyaksh Hanstantrit Labh) and PMGKY (Pradhan Mantri Garib Kalyan Package). The Direct Benefit Transfer of LPG (DBTL) scheme named PAHAL was launched for the whole country in 2015[14]. The applicable subsidy is directly transferred into the bank accounts of the beneficiaries. More than 26.29 Crore LPG consumers have joined the scheme, and more than INR 1,31,814 Crore has been transferred into the bank account of the consumers till 31st March 2020[15]. Under PMGKY, two LPG cylinder refills to PMUY beneficiaries were provided between April 2020 to September 2020 in response to the hardships faced by the economically weaker section during the COVID-19 pandemic. Oil Marketing Companies (OMCs) have transferred INR 9670.41 crore to the account of PMUY beneficiaries for buying LPG refills and have delivered 14.17 Crore LPG refills to PMUY beneficiaries under this scheme as on September 2020[16]. However, the challenges persist.

Recent insights from India Residential Energy Survey (IRES) based on the information provided by 14,850 households from 152 districts in the 21 most populous states which accounts for 97 percent of India's population show similar trends in fuel stacking and the rural-urban gap in the usage of clean cooking fuels. According to the findings, it has been observed that approximately 85 percent of Indian households employ clean cooking fuels. However, it is noteworthy that merely 47 percent of these households exclusively rely on such fuels. This implies that nearly half of the LPG users in India continue to supplement their usage with polluting solid fuels.[17]

4.4 Electric Cooking in India

Some of the key trends seen from recent studies are as follows:

- According to a primary survey conducted in 2015 with a thousand rural Indian HHs using induction stoves, 84 percent of the households replaced LPG as the secondary fuel and 5 percent of the HHs replaced firewood as the primary cooking fuel.[18]
- Till 2017-18, almost 7.05 lakh solar cookers have been distributed/sold through government schemes.[19]
- The study based on the India Residential Energy Survey (IRES) 2020 indicates that 5 percent of the total households have shifted to electric cooking with 93 percent of them still relying on LPG as primary fuel and using electric cooking as a backup.[20]
- As of July 2021, 5 percent of India's population (~70 million) is using electricity as fuel in their cooking stack. Also, 33 percent of the population (~ 460 million) uses clean fuels for cooking, including LPG, PNG, etc.[21]

14 https://pib.gov.in/newsite/printrelease.aspx?relid=114245
15 https://mopng.gov.in/en/marketing/pahal
16 https://mopng.gov.in/en/marketing/pmgky
17 https://www.ceew.in/publications/state-of-clean-cooking-energy-access-in-india-ires-2020-report
18 https://www.sciencedirect.com/science/article/abs/pii/S030142151530149X?via%3Dihub
19 https://pib.gov.in/Pressreleaseshare.aspx?PRID=1525934
20 https://economictimes.indiatimes.com/news/india/delhi-tamil-nadu-lead-indias-transition-to-electric-cooking-with-17-adoption-ceew-study/articleshow/87107173.cms
21 https://mecs.org.uk/resources/factsheets/factsheets-bangladesh-india-nepal-srilanka/

4.4.1 Standards & Testing Available

Under the voluntary scheme by the Bureau of Energy Efficiency guidelines (BEE) for labelling of energy appliances[22], the rating for induction hob cookstoves is mentioned in Table 1, domestic LPG cookstoves is applicable as per Table 2 and microwave ovens as per Table 3. However, electric pressure cookers are yet to be included.

Table 1 : BEE Voluntary Scheme for rating the energy efficiency of induction hob cookstoves

Star Rating Band for Induction Hob (Valid till 31st December, 2024)	
Star rating	**Energy Consumption, Ehob (Wh)**
1 star	200 >= Ehob > 194
2 star	194 >= Ehob > 188
3 star	188 >= Ehob > 182
4 star	182 >= Ehob > 175
5 star	Ehob <= 175

Table 2 : BEE Rating for domestic LPG cookstoves

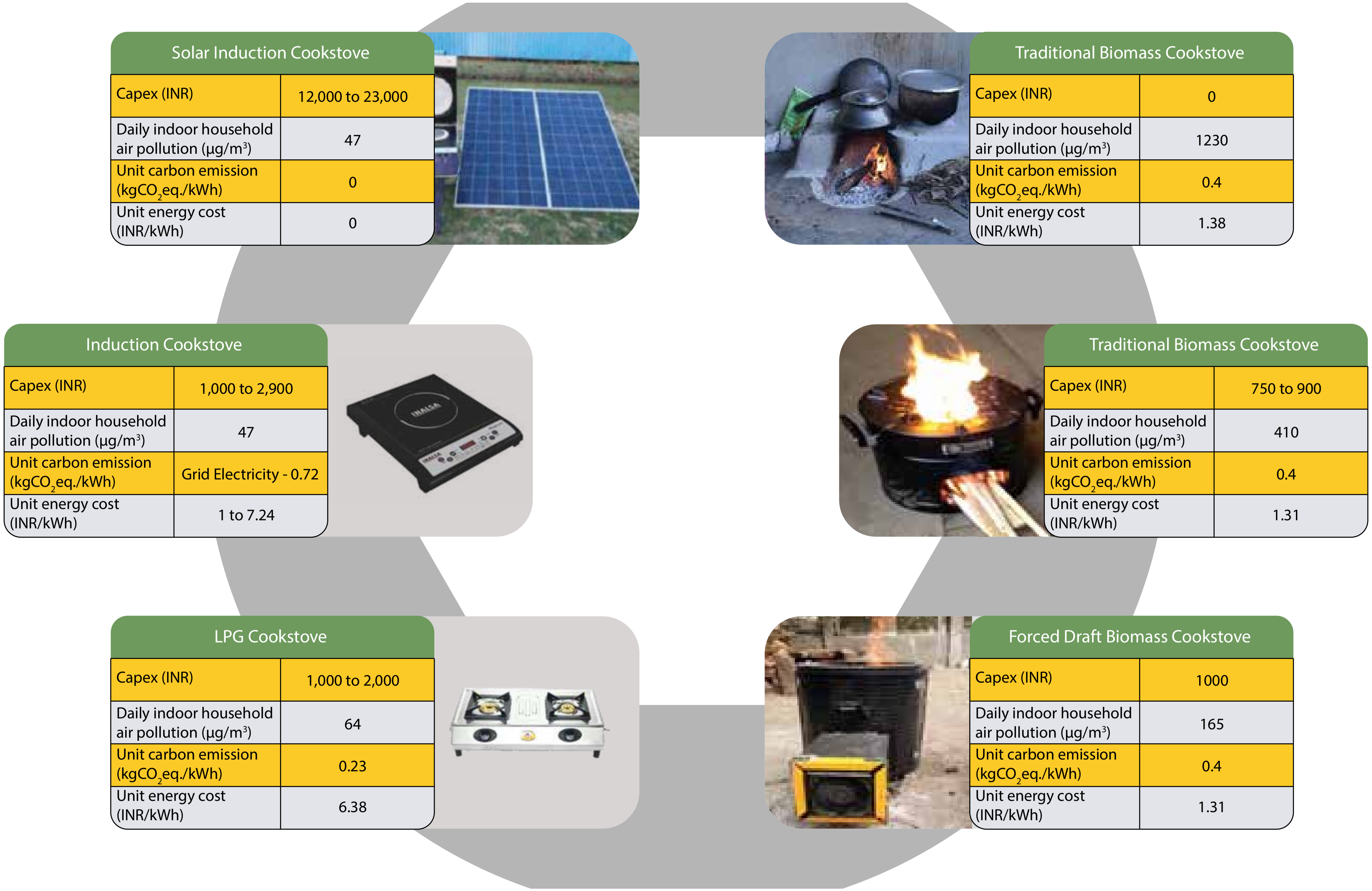
Star Rating	Thermal Efficiency (As per IS 4246: latest)
1 star	If Thermal efficiency >= 68% & <72%
2 star	If Thermal efficiency >= 72% & <75%
3 star	If Thermal efficiency >= 75% & <78%
4 star	If Thermal efficiency >= 78% & <81%
5 star	If Thermal efficiency >= 81%

Table 3 : BEE Rating for microwave ovens

Parameter	Minimum Requirement
Microwave function efficiency	≥ 54%
Power consumption in standby mode	≤ 0.6
Star rating	**Energy consumption per cooking cycle (E) Wh**
1 star	56 < E ≤ 60
2 star	52 < E ≤ 56
3 star	48 < E ≤ 52
4 star	44 < E ≤ 48
5 star	E ≤ 44

22 https://beestarlabel.com/Home/EquipmentSchemes?type=V

4.5 Technology Overview of Various Cooking Options in India



Solar Induction Cookstove	
Capex (INR)	12,000 to 23,000
Daily indoor household air pollution (µg/m³)	47
Unit carbon emission ($kgCO_2eq./kWh$)	0
Unit energy cost (INR/kWh)	0

Traditional Biomass Cookstove	
Capex (INR)	0
Daily indoor household air pollution (µg/m³)	1230
Unit carbon emission ($kgCO_2eq./kWh$)	0.4
Unit energy cost (INR/kWh)	1.38

Induction Cookstove	
Capex (INR)	1,000 to 2,900
Daily indoor household air pollution (µg/m³)	47
Unit carbon emission ($kgCO_2eq./kWh$)	Grid Electricity - 0.72
Unit energy cost (INR/kWh)	1 to 7.24

Traditional Biomass Cookstove	
Capex (INR)	750 to 900
Daily indoor household air pollution (µg/m³)	410
Unit carbon emission ($kgCO_2eq./kWh$)	0.4
Unit energy cost (INR/kWh)	1.31

LPG Cookstove	
Capex (INR)	1,000 to 2,000
Daily indoor household air pollution (µg/m³)	64
Unit carbon emission ($kgCO_2eq./kWh$)	0.23
Unit energy cost (INR/kWh)	6.38

Forced Draft Biomass Cookstove	
Capex (INR)	1000
Daily indoor household air pollution (µg/m³)	165
Unit carbon emission ($kgCO_2eq./kWh$)	0.4
Unit energy cost (INR/kWh)	1.31

Figure 7 : Comparison of different cookstoves In India

4.5.1 EESL's & IOCL's Program for Large-scale Adoption of Solar-based Induction Cookers in India

In March 2023, EESL floated an Expression of Interest (EoI) for large-scale adoption of induction cooking solutions powered by solar PV for rural and urban Indian households with the upfront cookware cost almost completely financially supported by carbon financing. The objective is to promote clean cooking, reduction in drudgery, improved health and access to clean energy and address gender aspects.

EESL, with this program, can begin a new wave of demand aggregation for solar induction cooking solutions and further provide a 'technology push' to the supply side of the market. Moreover, the first cost barrier for the consumer is bridged by accessing carbon financing. The solution providers shall maintain the equipment installed at individual households for seven to ten years based on stakeholder comments for ensuring verification and validation of the carbon credits during the project's entire lifetime.

Several trials conducted at Indian Oil's Faridabad Lab to compare the energy consumption and cost for residential cooking also confirm the fact that cooking with electricity is much cheaper compared to cooking with LPG. The trials were conducted for a family of four, each meal consisting of 12 rotis, 230 grams of dal, 430 grams of vegetables, and 125 grams of rice. Table 4 further provides a range of induction cookstoves available in the Indian market.

Surya Nutan is indigenously designed, developed, and patented by Indian Oil R&D Centre.[23] It is suitable for an Indian household, with a family of four, requiring boiling, steaming, frying and 'roti' making. The solar collector converts incoming radiation into heat. This thermal energy is then re-utilised for cooking/heating purposes.

Field demonstrations have been carried out in different cities of India with varying solar radiation intensity and cooking habits. It's been observed that the time taken is comparable to cooking with an LPG cylinder. The different models available are – Single Burner Solar, Double Burner Solar, and Double Burner Hybrid. The first two models can work independently as well as on solar & grid electricity simultaneously. In the Double Burner Hybrid, one cooktop works only on grid electricity while the other can work independently or simultaneously using grid electricity and solar.

Table 4 : Electric cooking technologies available in India

Brand	Model Name	Solar	MRP (INR)	Selling Price (INR)	Watt (W)	No. of burner	Solar Panel (Wp)	Backup
Philips	Philips Viva Collection HD4928/01	No	5,595	3,199	2100	1		
Usha	Cookjoy (Cj1600Wpc)	No	4,000	2,499	1600	1		
Prestige	Prestige Iris 1.0	No	3,280	1,699	1200	1		
Philips	Prestige PIC 20	No	2,895	2,115	1600	1		

23 https://iocl.com/pages/SolarCooker

Brand	Model Name	Solar	MRP (INR)	Selling Price (INR)	Watt (W)	No. of burner	Solar Panel (Wp)	Backup
Pigeon	Pigeon by Stovekraft Cruise 12303	No	3,193	1,599	1800	1		
Maharaja Whiteline	Superion 12DX Neo Plus	No	3,500	1,799	1200	1		
V-Guard	VIC 1.8 EL	No	4,450	2,199	1800	1		
Crompton	ACGIC-INSTSERV1200	No	3,250	2,890	1200	1		
Havells	Cooktop TC 18-GHCICDQK180	No	5,695	3,850	1800	1		
Wipro	Vc061160	No	4,999	1,999	1600	1		
Surya	GEINDSTOV09	Yes	12,500	12,500	-	1		
Exalta	Exalta	Yes	44,990	44,990	650	1	330*2	100Ah*2, lead acid
Greenmax Technology	Greenmax	Yes	25,000	25,000	700	1	250	1hr, LiFePO4 30ah 25.6v
Indian Oil	Surya Nutan	Yes	12,000-23,000	12,000-23,000	-	2	1000	50-70Ah, 48V
Channing Copper company	Charlie	No	4,72,000	4,72,000	4000/ 3200/ 1800/ 1800	4		4 kWh Lithium Iron Phos-phate LiFePO4

Source: Secondary research of available e-cooking stoves by Vasudha Foundation – Power Sector Team

5

USING THE TOOL – CASE STUDIES

Based on the tool results, a sample result for Uttar Pradesh has been provided below.

5.1 Rural (Traditional Cookstove vs Electric Induction)

For a family size of three adults and two children from lower socio-economic strata, who use firewood as fuel with a traditional cookstove. Following are the results of replacing with a two-burner electric induction stove.

5.1.1 Cookstove Characteristics

Table 5 : Cookstove characteristics comparison of leapfrogging from traditional cookstove to induction cookstove

Variable	Units	Baseline	e-Cooking	Delta
Type	**-**	**Traditional cook stove (TCS)**	**Electric Induction (2 burner)**	**-**
Total Cost	INR	0	2200.0	2200.0
Thermal Efficiency	percent	15.0	80.0	65.0
Overheads	INR/year	0	200.0	200.0
Life	Years	1	10.0	9.0
Capex	INR	0	2000.0	2000.0

A household needs to replace a traditional cookstove every year and requires zero to very low costs of fuelwood which needs to be procured once or twice a week. Hence, the upfront high cost for an electric induction becomes the major obstacle. From Table 5, we also see that life and thermal efficiency improve with an electric induction cookstove.

5.1.2 Energy Demand & Cost

Table 6 : Fuel characteristics comparison of leapfrogging from traditional cookstove to induction cookstove

Variable	Units	Baseline	e-Cooking	Delta
Results - Operating specifics				
Daily cooking duration	hours/day	3.61	2.6	-1.01
Hourly consumption	kWh/hour	4.43	1.8	-2.63
Daily consumption	kWh/day	15.99	11.52	-4.47
Annual consumption	kWh/year	5253.47	3783.66	-1469.81

Variable	Units	Baseline	e-Cooking	Delta
Results - Cost Specifics				
Unit cost	INR/kWh	1.41	3	1.59
Opex	INR/year	7407.39	11350.99	3943.6
Overheads	INR/year	500	500	0
Total operating cost	INR/year	7907.39	11850.99	3943.6
Results - Social & Environmental Aspects				
Unit carbon emission	$kgCO_2eq./kWh$	0.4	0.72	0.31
Annual carbon emission	$kgCO_2eq./year$	2101.39	2705.32	603.93
Social carbon cost	INR/year	14860555	19131421	4270866

From Table 6, it is evident that the major benefit as a result of using an electric cookstove is the substantial reduction in time and fuel consumption. The operational cost of electric cooking is 50 percent higher compared to cooking using a traditional stove which is mainly because the unit electricity cost is 113 percent compared to the unit cost of firewood fuel. Currently, the associated carbon emission with the use of electric cooking is significantly higher due to the use of coal for grid-based electricity generation. With increasing capacity and generation of solar and wind resources, the emission factor will reduce in order to achieve India's net-zero targets as well. In line with our NDC and 450 GW of RE capacity addition, the grid emission factor for India is expected to decline from 0.72 kgCO2/kWh in 2021-22 to 0.52 by 2026-27 and further to 0.44 by 2031-32[24]. Further improvement of the grid emission factor is expected with rising penetration of clean energy sources. Hence, there is a need to leapfrog to clean cooking solutions in rural areas, going forward.

5.1.3 Health Impacts

Table 7 : Health impacts comparison of leapfrogging from traditional cookstove to induction cookstove

Variable	Units	Baseline	e-Cooking	Delta
Daily IHAP (PM 2.5)	µg/m3	1230.0	47.0	-1183.0
Annual IHAP (PM 2.5)	mg/m3	404.06	15.44	-388.62

The use of induction cookstove reduces the exposure to some major health hazards. Respiratory problems such as chronic bronchitis, pneumonia, and asthma; eye problems such as eye irritation, dryness, and even blindness in severe cases; cardiovascular diseases like stroke and heart disease; lung cancer, burns and injuries and carbon monoxide poisoning can be avoided. [25]

24 CEA, CO2 Baseline Database for the Indian Power Sector, December 2022

25 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4221659/

Some of the health hazards that the user needs to be aware and cautious of in electric cooking are electromagnetic radiation, burns and injuries, electric shock and carbon monoxide poisoning (indirectly, due to poor ventilation).

5.1.4 Financing

As there are no cost savings associated with the capex and operation of the stoves, payback is not possible when a traditional cookstove would be replaced with an electric stove. On the contrary, the annual operational cost exceeds by almost INR 4000.

The payback including social carbon cost is not possible as well because of the higher carbon emission intensity of grid-based electricity.

Hence, the case for replacing traditional cookstoves needs to be addressed more from the perspective of health benefits, time savings, biodiversity degradation and adaptation to climate change.

5.2 Urban (LPG vs Electric Induction)

For a family size of three adults and two children from lower socio-economic strata, who uses a two-burner cookstove with LPG as a primary cooking fuel. Following are the results of replacing with a two-burner electric induction stove.

5.2.1 Cookstove Characteristics

Table 8 : Cookstove characteristics comparison of shifting from LPG cookstove to induction cookstove

Variable	Units	Baseline	e-Cooking	Delta
Type	**-**	**LPG (2 burner)**	**Electric Induction (2 burner)**	**-**
Total Cost	INR	1100	2500.0	1400.0
Thermal Efficiency	percent	70.0	80.0	10.0
Overheads	INR/ year	100	300.0	200.0
Life	Years	10	10.0	0.0
Capex	INR	1000	2200.0	1200.0

From Table 8, we see that efficiency improves with the use of an electric induction cookstove. However, the major challenge is the cookstove cost being higher by about 100 percent.

5.2.2 Energy Demand & Cost

Table 9 : Fuel characteristics comparison of shifting from LPG cookstove to induction cookstove

Variable	Units	Baseline	e-Cooking	Delta
Results - Operating Specifics				
Daily cooking duration	hours/day	2.71	2.6	-0.11
Hourly consumption	kWh/hour	2	1.8	-0.2
Daily consumption	kWh/day	5.42	5.2	-0.22
Annual consumption	kWh/year	1780.47	1708.2	-72.27
Results - Cost Specifics				
Unit cost	INR/kWh	6.38	3	-3.38
Opex	INR/year	11359.4	5124.6	-6234.8
Overheads	INR/year	1000	600	-400
Total operating cost	INR/year	12359.4	5724.6	-6634.8
Results - Social & Environmental Aspects				
Unit carbon emission	$kgCO_2eq./kWh$	0.23	0.72	0.48
Annual carbon emission	$kgCO_2eq./year$	409.51	1221.36	811.85
Social Carbon Cost	INR/year	2895951	8637210	5741259

From Table 9, it is evident that the major benefit as a result of using an electric cookstove is the substantial reduction in time and fuel consumption. The total annual operational cost of electric cooking is estimated to reduce by almost 50 percent. Electric cooking currently results in significantly higher carbon emissions due to the use of coal for grid-based electricity generation. Nevertheless, with the growth in capacity and generation from solar and wind resources, the emission factor will further decrease and help India achieve its net-zero targets.

5.2.3 Health Impacts

Table 10 : Health impacts of transitioning from LPG to Electric Induction

Variable	Units	Baseline	e-Cooking	Delta
Daily IHAP (PM 2.5)	µg/m3	64.0	47.0	-17.0
Annual IHAP (PM 2.5)	mg/m3	21.02	15.44	-5.58

A major health hazard associated with the use of LPG is the inhalation of toxic chemicals such as nitrogen dioxide and formaldehyde. This causes eye, nose and throat irritation as well as increased allergic sensitisation.[26]

5.2.4 Financing

With an annual saving of approximately INR 6000, if the household uses an electric induction cookstove instead of LPG, the payback expected is within three to four months of purchasing and using the stove.

The payback including social carbon cost is approximately three years. This is majorly due to the annual operational savings on fuel cost despite the higher carbon emission intensity of grid-based electricity.

The above-mentioned cost, health, and time benefits indicate that switching to grid-electricity based cooking using induction cookstoves would be beneficial for households that are accustomed to LPG for their primary cooking.

26 https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants

6

WAY FORWARD

6.1 Technology

The technology penetration in the clean cooking sector is a complex interwinding of various social, cultural, economic, environment and health aspects. Hence, any technology programme implementation should look at attributes like the ecosystem for sales and after-sales, demand aggregation potential and finance while not limiting it to product level sale.

- Induction cookstove are a safe and energy-efficient cooking option suitable for most Indian cooking applications, provided that magnetic cookware with a flat bottom is used. However, cookware made from aluminium, copper, or glass materials would not work directly with induction cooktops, limiting their access to some users.
- Electric pressure cookers are a convenient and energy-efficient option for cooking meals quickly. They can be used to prepare a variety of dishes, including rice, lentils, and vegetables.
- Solar-powered cookstoves are an environmentally friendly and cost-effective option for cooking in areas with limited access to electricity. They use solar panels to convert sunlight into electricity, which is then used to power the cookstove.
- Using electricity for thermal storage on a commercial basis needs to be further developed for use in areas with low sunlight irradiation or where it is difficult to provide reliable electricity infrastructure.

6.2 Policy

Over the years, the cooking sector has undergone tremendous change with changes in technology, fuel types and programme models. This spans from programmes on improved cookstoves (Unnat Chulha Abhiyaan) to Pradhan Mantri Ujjwala Yojana for LPG, promotion of piped natural gas (PNG), 'Go Electric' campaign for electric induction-based cooking and now the most recent IOCL Surya Nutan programme for solar based cooking. Time and again, the objectives of clean cooking have not been aligned with clean energy access and development initiatives. As a result, the sector has remained underrated amongst financial institutions, fund providers, development banks, etc. There is a need for a holistic integration of clean cooking with the electricity sector and further development of a cohesive policy energy outlook.

- To create demand, it is crucial to set targets for the percentage of households that should use electric cooking appliances. This can provide a clear goal for the industry to work towards and encourage investment in electric cooking technologies.
- Creating infrastructure needed to support electric cooking, such as electric grid upgrades and renewable electricity generation, is required to ensure sufficient electric capacity to support the industry's sustainable growth.
- To ensure consumer safety and accessibility, the following policy measures can be implemented: mandating energy efficiency standards for electric cooking appliances to promote informed purchase decisions and reduced energy consumption; regulating product pricing to ensure affordability for a wider range of households and commercial kitchens; developing training programs for appliance installers and repair technicians to ensure a skilled workforce is available to support the maintenance and after-sales of electric cooking appliances.
- To support manufacturers in producing high-quality and affordable electric cooking appliances, the following recommendations can be considered: providing subsidies to incentivise manufacturers to produce more affordable products; promoting public-private partnerships to develop and bring new electric cooking solutions to market; and investing in research and development of more efficient and affordable

electric cooking technologies to drive innovation in the industry and expand accessibility for a wider range of consumers.

6.3 Behavioural Change

Addressing gender and social inclusion: Efforts to scale up electric cooking should consider gender and social inclusion considerations. For example, women and marginalised groups should be involved in decision-making processes and should have access to the same opportunities as other groups. Moreover, electric cookstoves are convenient and safe for children, women, and the elderly in a household. The major convenient factors include availability, and efficiency. Safety aspects include reduced exposure to emissions and burn injuries. Hence, it is important to consider the co-benefits of transitioning to electric cooking for targeting the beneficiary groups in a better way.

Addressing cultural preferences: Cultural preferences should be considered when promoting electric cooking. For example, people may prefer certain cooking methods, such as using clay pots or open fires, for traditional dishes or standing or sitting while cooking. Efforts to promote electric cooking should be sensitive to cultural preferences and should focus on demonstrating how electric cooking can be used in combination with traditional cooking methods.

Conducting awareness campaigns: Awareness campaigns can be conducted to educate people about the benefits of electric cooking, including its environmental benefits and potential cost savings. These campaigns should be tailored to address different social groups' specific needs and concerns and should consider gender and social inclusion considerations.

Engaging with local communities: Engaging with local communities is key to promoting the adoption of electric cooking technologies. This can involve working with local panchayat groups, community groups, and women's organisations to ensure that everyone is aware of the benefits of electric cooking and has access to it.

Addressing affordability: Electric cooking appliances should be made affordable and accessible to all, including low-income households and marginalised communities. Market transformation programmes, financial incentives and better targeting of subsidies can help to make electric cooking appliances more affordable.

Finally, it is important to foster behaviour change among consumers to encourage the adoption of electric cooking technologies. This can involve providing information about the benefits of electric cooking, offering training and support to help people use electric cooking appliances effectively, and creating social norms that encourage the use of electric cooking.

7

ANNEXURES

7.1 Calculation Steps

7.1.1 Cookstove Characteristics

- Overheads (INR/year) = 10 percent * Capex (INR)
- Total Cost (INR) = Capex (INR) + Overheads (INR)

7.1.2 Energy Demand & Cost

- Daily cooking duration (hours) – For household sizes below 3, 75 percent of the daily cooking duration is considered. For households having more than 6 members, an additional 25 percent of cooking time is assumed compared to an average household size of 3 to 6 members.
- Daily consumption (kWh/day) = Daily cooking duration (hours/day) * Hourly Consumption (kWh/hour) * Stacking percentage
- Annual consumption (kWh/year) = Daily consumption (kWh/day) * 365 (days/year) * 90 percent
- Annual carbon emission (kgCO_2eq./year) = Annual consumption (kWh/year) * Unit carbon emission (kgCO_2eq./kWh)
- Opex (INR/year) = Unit cost (INR/kWh) * Annual consumption (kWh/year)
- Total operating cost (INR/year) = Opex (INR/year) + Overheads (INR/year)
- Social Carbon Cost (INR/year) = 86 (USD / MtCO_2eq.) * 0.001 * 82.23 (INR/USD) * Annual carbon emission (kgCO_2eq./year)

7.1.3 Health Impact

- Annual Indoor Household Air Pollution [IHAP] [PM 2.5] (mg/m^3) = [Daily Indoor Household Air Pollution (µg/m^3) * 365 (days/year) * 90 percent * Stacking percentage]/1000

7.1.4 Financing

- Payback period (years) = Cookstove Capex (INR) / [{Baseline total energy cost (INR/year) – Electric total energy cost (INR/year)} + {Baseline cookstove overheads (INR/year) – Electric cookstove overheads (INR/year)}]
- Payback period [including social carbon cost] (years) = Cookstove Capex (INR) / [{Baseline total energy cost (INR/year) – Electric total energy cost (INR/year)} + {Baseline cookstove overheads (INR/year) – Electric cookstove overheads (INR/year)} + {Baseline social cost of carbon (INR/year) – Electric social cost of carbon (INR/year)}]
- Annual Opex Savings (INR/year) = Baseline total energy cost (INR/year) – Electric total energy cost (INR/year)

7.1 Assumptions

7.1.1 Cookstove Characteristics

Table 11 : Assumptions taken for cookstove characteristics

Stove Type	Life (years)	Thermal Efficiency (percent)	Capex (INR)
Traditional cook stove (TCS)	1	15%	0
Improved cook stove (ICS - Natural)	3	25%	INR 750 to INR 900
Improved cook stove (ICS - Forced)[27]	3	35%	INR 1000
Biogas (2 burner)[28]	10	70%	INR 40,000 to INR 60,000
PNG (2 burner)	10	70% to 80%	INR 1,100 to INR 2,500
LPG (2 burner)[29]	10	70% to 80%	INR 1,000 to INR 2,000
Electric Induction (1 burner)[30]	10	80% to 90%	INR 1,000 to INR 2,900
Electric Induction (2 burner)	10	80% to 90%	INR 2,000 to INR 5,800
Electric Pressure Cooker	10	80% to 90%	INR 5,000 to INR 10,000

Source: Capex cost assumed based on secondary research of cookstove options available in the market and through schemes

7.2.2 Energy Demand & Cost

7.2.2.1 Daily Cooking Duration

Table 12: Assumptions on the daily cooking time of each stove type

Stove Type	Daily Cooking Duration (hours)
Traditional cook stove (TCS)	3.6 to 4
Improved cook stove (ICS - Natural)	3.2 to 3.5
Improved cook stove (ICS - Forced)	2.9 to 3.3
Biogas (2 burner)	2.7 to 3
PNG (2 burner)	2.7 to 3
LPG (2 burner)	2.7 to 3
Electric Induction (1 burner)	3.9 to 4.1
Electric Induction (2 burner)	2.6 to 2.8
Electric Pressure Cooker	3.9 to 4.1

Note: Time is assumed based on the average household cooking patterns of an Indian family of 4 to 5 persons.

27 http://164.100.94.214/national-biomass-cookstoves-programme
28 https://mnre.gov.in/img/documents/uploads/77e0a45feb0c4ce4974a0429d1e39001.pdf
29 https://beestarlabel.com/Content/Files/Final_LPG_schedule.pdf
30 https://beestarlabel.com/Content/Files/Schedule_Induction_hobs.pdf

7.2.2.2 Unit Carbon Emission & Unit Cost

Table 13 : Assumptions on carbon emission factors and cost by fuel type

Fuel Type	Unit Carbon Emission (kgCO_2eq./kWh)	Unit Cost (INR/kWh)
Firewood[31]	0.4	1.27 to 1.41
Livestock Waste	0.4	1.21 to 1.35
Biogas	0.15	1.5
LPG[32]	0.23	6.38
PNG	0.2	5.86
Grid electricity[33]	0.72	1 to 7.24
Solar PV rooftop[34]	0	0

Table 14 : State wise grid electricity tariff of Indian States

State	BoP (INR/kWh)	Lower (INR/kWh)	Middle (INR/kWh)	Higher (INR/kWh)
Andaman and Nicobar Islands	2.10	2.10	2.50	6.63
Andhra Pradesh	1.45	1.45	3.00	7.24
Arunachal Pradesh	2.65	2.65	4.00	4.00
Assam	4.65	4.25	4.90	6.15
Bihar	6.10	6.10	6.25	6.70
Chandigarh		2.50	2.50	4.25
Chhattisgarh		3.60	3.60	4.50
Dadra and Nagar Haveli		1.40	1.75	2.35
Daman and Diu		1.40	1.40	2.25
Delhi		3.00	3.00	3.75
Goa		1.50	1.50	2.25
Gujarat	1.50	1.50	3.34	3.95
Haryana		2.00	2.25	5.25
Himachal Pradesh	3.30	3.30	3.95	4.85
Jammu and Kashmir	1.25	1.25	1.69	2.75

31 https://acp.copernicus.org/articles/18/15169/2018/acp-18-15169-2018.pdf
32 https://www.mdpi.com/2073-4433/10/12/729
33 https://cea.nic.in/cdm-co2-baseline-database
34 https://www.sciencedirect.com/science/article/abs/pii/S0301421513010719

State	BoP (INR/kWh)	Lower (INR/kWh)	Middle (INR/kWh)	Higher (INR/kWh)
Jharkhand		6.00	6.00	6.00
Karnataka		4.01	4.71	6.95
Kerala	1.50	1.50	3.85	5.83
Lakshadweep	1.00	1.00	1.35	4.15
Madhya Pradesh	3.25	3.25	4.59	5.98
Maharashtra	1.06	1.06	2.67	6.38
Manipur	2.00	2.00	4.20	5.50
Meghalaya	3.65	3.65	3.70	4.20
Mizoram	2.50	2.50	4.80	5.50
Nagaland		4.50	4.95	6.00
Odisha		3.00	3.90	4.80
Puducherry	1.00	1.00	1.55	2.60
Punjab		4.64	4.64	6.50
Rajasthan	3.50	3.50	5.63	7.17
Sikkim		1.00	1.50	3.33
Tamil Nadu		2.50	3.00	4.60
Telangana		1.45	3.30	6.67
Tripura	4.03	4.03	5.41	6.16
Uttar Pradesh	3.00	3.00	3.35	4.78
Uttarakhand	1.61	1.61	2.80	4.00
West Bengal	3.63	3.63	5.28	5.92

Source: DISCOMs Electricity Tariff Orders of 2021-22 and 2022-23

7.2.2.3 Social Carbon Cost

The Social Cost of Carbon (SCC) provides a monetary estimate of the economic damages that would result from the emission of an additional ton of carbon dioxide into the atmosphere. Its purpose is to express the effects of climate change in economic terms, aiding policymakers and decision-makers in understanding the financial impacts of decisions that could increase or decrease emissions.[35]

For one tonne of CO_2 emissions, the social cost for India assumed is USD 86.[36]

35 https://www.rff.org/publications/explainers/social-cost-carbon-101/

36 https://www.downtoearth.org.in/dte-infographics/social_cost_corbon/index.html

7.2.3 Health Impacts

7.2.3.1 Daily IHAP

Table 15: Assumptions on indoor household air pollution caused by different cookstove types

Stove Type	Daily IHAP - PM 2.5 (µg/m3)
Traditional cook stove (TCS)	1230
Improved cook stove (ICS - Natural)	410
Improved cook stove (ICS - Forced)[37]	165
Biogas (2 burner)[38]	60
PNG (2 burner)	47
LPG (2 burner)[39]	64
Electric Induction (1 burner)	47
Electric Induction (2 burner)	47
Electric Pressure Cooker[40]	35

7.2.4 Financing

7.2.4.1 The annual income of HH

Table 16 : Assumptions on annual income based on socio-economic status and area type

Area Type	Socio-economic status	Annual Income (INR)
Rural	Lower	₹ 2,00,000
Rural	Middle	₹ 5,70,000
Rural	Higher	₹ 9,00,000
Urban	Lower	₹ 2,50,000
Urban	Middle	₹ 7,12,500
Urban	Higher	₹ 11,25,000

Source: India Residential Energy Survey (IRES) 2020

37 https://www.sciencedirect.com/science/article/pii/S0160412018324772
38 https://www.researchgate.net/publication/337429023_In-Field_Emission_Measurements_from_Biogas_and_Liquified_Petroleum_Gas_LPG_Stoves
39 https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-020-09865-1
40 https://www.isid.ac.in/~epu/dispapers/dp22_04.pdf

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