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Assessing the extent and intensity of energy poverty using Multidimensional Energy Poverty Index: Empirical evidence from households in India☆

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ABSTRACT

In this paper, we have made a comprehensive assessment of the extent and various socio-economic implications of energy poverty in India. Amartya Sens's capability approach to development underpins the analysis of household-level data taken from the India Human Development Survey-II (IHDS-II), 2011-12 using the Multidimensional Energy Poverty Index (MEPI). The overall results show that energy poverty is widespread in India and the existence of energy poverty also coincides with the other forms of deprivations such as income poverty and social backwardness. For example, Dalits (Lower Caste) and Adivasis (Tribal) are found to be extremely energy poor compared to the other social groups in India. The results also reveal that it is the responsibility of women to manage the domestic chores such as collection of firewood and making of dung cake in traditional Indian households. Inefficient use of such biomass fuels is found to cause health hazards.

1. Introduction and background

The concept of energy poverty has received enormous attention not only in the literature but also in public policy, as energy in general (and cleaner energy in particular) is necessary to achieve systemic welfare of society (Birol, 2007). The declaration of the year 2012 as the "International Year for Sustainable Energy for All" by the United Nations (UN) General Assembly is a testimony to the overriding importance of energy accessibility and affordability in the promotion of socio-economic welfare. This is on account of the realization that welfare of society is closely intertwined with the use of modern technology and energy services. For instance, the use of LPG for cooking instead of biomass such as firewood or dung cake, protects women from health hazards like chronic respiratory problems; and access to electricity at home creates a conducive learning environment for children, and better healthcare environment at hospitals. (See, for example, Roberts et al. (2015) and Savacool (2012)).

The literature shows that there is no universally acceptable definition of energy poverty or fuel poverty.[1] However, the existing tradition is to capture domestic energy deprivation in developed countries with the concept of fuel poverty and that of developing countries with energy poverty. Accordingly, lack of heating fuel in developed countries and lack of access to electricity in developing countries symbolize the domestic energy deprivation with similar consequences for the socio-economic well-being of the society.

In this study, therefore, we adopt the definition of energy poverty by Day et al. (2016), who conceptualized energy poverty as a "situation of inability to realize the essential capabilities as a result of insufficient access to affordable, reliable and safe energy services, and taking into account the alternative means of realizing these capabilities in a reasonable manner". Energy poverty is thus perceived in a rather comprehensive multidimensional way along the line of Amartya Sen's capability approach to development. This is in sharp contrast to reducing energy poverty to some monetary metrics, such as, the quantity of energy consumed or expenditure incurred on energy resources. Likewise, the multidimensional nature of energy poverty is reiterated by Pereira et al. (2011), arguing that it extends beyond income and can be measured with a greater degree of accuracy with a multidimensional framework.

In this era of climate change with the unusual climatic conditions such as global warming, persistent drought, and unprecedented snowfall, energy poverty should be paid at least as much attention given to the other traditional, fundamental challenges faced by the world such as income poverty. This is in spite of the fact that the distinction between energy poverty and income poverty is blurring. Unlike the challenges like income poverty, any attempt to address energy poverty

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[1] See, for example, Pachuri et al. (2004), Pachauri and Spreng (2011), Wang et al. (2015) and Day et al. (2016) for various definitions and approaches to the measurement of energy poverty.

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through the expansion of the access and consumption of the energy resources such as fossil fuels would cause an increase in carbon emission. Therefore, use of energy without paying adequate attention to the efficiency of the use would warrant an associated flip side, environmental degradation and the resultant threat to the sustainable development. For instance, countries like the USA and Saudi Arabia with higher per-capita energy consumption also top the list of countries with higher per-capita CO_2 emission (see González-Eguino (2015), for relevant statistics). Urge-Vorsatz and Herrero (2012), for example, have documented the implicit trade-off between climate change mitigation and energy poverty alleviation and have suggested that the only option to align these two conflicting goals is to ensure high standards of efficiency. Malla (2012) has found empirical evidence of increasing carbon emission as a result of an increase in the use of fossil fuels in Nepal (Also see Kaygusuz (2011) and Chakravarty and Tavoni (2013)). This simultaneous tradeoff between tackling energy poverty and maintaining environmental sustainability will be more pressing in the case of developing countries like India, since India cannot adequately meet the energy challenges in the foreseeable future simply with the renewable energy resources.

The attempt to deal with energy poverty will be relatively more demanding than dealing with the income poverty through affirmative state actions such as taxation, social security schemes, and other public expenditure programs. This is because of, among other things, the lack of methodological and conceptual consensus regarding what constitutes energy poverty, implying that differentiated treatment of the issue should be adopted depending on the context involved (Barnes et al., 2011). For example, Kandkher et al. (2012) and Wang et al. (2015) have shown that the income non-poor need not necessarily be the energy non-poor especially in the rural areas in India, and therefore, energy poverty calls for a different remediation approach (Also see Spagnoletti and O'Callaghan (2013)). This is relevant in countries like India with varying cultural, geographical, and climatic conditions compared to the relatively small countries with similar cultural, geographical, and climatic features.

Further, eradication of energy poverty is a highly complex issue, (see, for example, Walker and Day (2012)), so it requires planned programs and strategies involving the development of huge infrastructure with a large amount of resources. Therefore, tackling energy poverty is different from dealing with the income poverty using traditional fiscal means.[2] For example, according to the India Energy Outlook (2015), a special report released by the International Energy Agency (IEA), India requires $2.8 trillion to develop its energy infrastructure to ensure better energy access by 2040.

In light of the above-cited factors, one can discern that the problem of energy poverty with associated complexities and nuances, can only be tackled with carefully calibrated measures and policies for which a proper understanding and assessment of the energy poverty situation is inevitable (Nussabaumer et al., 2012). A comprehensive assessment of energy poverty in India will also be useful to deal with its socio-economic consequences (González-Eguino, 2015). Therefore, in this paper, we undertake a comprehensive assessment of India's energy poverty scenario using the household data obtained from the India Human Development Survey-II (IHDS-II), 2011-12.

According to the India Energy Outlook (2015), India uses only about 6% of the world's primary energy resources, despite the fact that India accounts for 18% of world population. Specifically, portraying the enormity of the problem of energy poverty in India, the report indicates about 240 million people in India still do not have access to electricity and about 840 million people use firewood as the primary cooking fuel in traditional stoves, which cause indoor pollution and consequent health problems. These statistics justify the relevance of this study based on India; the findings of this study can guide the policy makers to adopt appropriate strategies to address the issue of energy poverty. Also, this study contributes to the literature as it is the first research attempt to evaluate India's energy poverty situation using the Multidimensional Energy Poverty Index (MEPI) based on Amartya Sen's capability approach to development as an underlying theoretical framework.

The empirical results obtained using the MEPI show that energy poverty is widespread in India and the existence of energy poverty also coincides with other forms of deprivations such as income poverty and social backwardness. For example, Dalits and Adivasis are found to be extremely energy poor compared to the other social groups in India. Results, which are similar to the findings of similar studies around the globe also reveal that in traditional Indian households, women are explicitly tasked with the management of domestic chores like the collection of firewood and making of dung cake, and the inefficient use of such biomass fuels is found to cause health hazards.

2. Theoretical underpinnings of the study: energy poverty and capability approach

Each and every individual on the face of the planet yearns for a contented life. However, what constitutes a contented life remains elusive, as it may vary from individual to individual and situation to situation. Therefore, what is pragmatic is to fix the bottom line as to what is necessary regarding goods and services to lead a dignified and contented life in society. It is here, the access and the affordability to modern, clean energy resources such as electricity and LPG emerge as the essential elements for a contended life. For example, access to modern cooking fuel will provide the leeway to girls to go to school because collecting firewood is treated as the responsibility of women and girls in the traditional Indian households. Thus, the relationship between energy use and well-being is at the core of the debate in the field of energy poverty. In other words, the lack of access and affordability of modern, clean energy resources and technology is to be treated as one of the forms of deprivations in the society (Day et al., 2016). Moreover, the issue of access to modern energy resources like electricity is more pressing, as it is impossible to address them from a household's point of view without the collective social endeavor, such as the intervention of the state.

As the idea of energy poverty is multidimensional, so are its consequences (Roberts et al., 2015). Cooking with biofuel causes indoor pollution and ill-health of women. The lack of electricity and proper lighting will affect the prospects of better education for children and it also affects the health of the people in both summer and winter as electricity provides cooling or heating services. Access to electricity will encourage the use of modern technologies and thereby improve productivity. As the prices of energy resources rise, households are forced even to reduce the consumption of essentials such as food and clothing to make up for the loss of purchasing power (Papada and Kaliampakos, 2016). In short, energy resources have a key multi-dimensional role in the promotion of the overall socio-economic welfare of the society. The overarching importance of energy resources in the promotion of social welfare implies that the idea of energy poverty should be conceptualized in a comprehensive manner without reducing it into certain simple metrics such as the amount of money spent on energy resources or quantity of a particular energy resource used. The 'capability approach' proposed by Amartya Sen is particularly useful for understanding what constitutes energy poverty and how to tackle the problem.

The effort to look at the access to energy resources through the lens of capability approach is justified by the findings of previous studies such as Kandkher et al. (2012) and Wang et al. (2015) who have established that freedom from income poverty need not necessarily imply freedom from energy poverty. Their finding also corroborates Sens's suspicion about the effectiveness of focusing on a particular

[2] Also see Boardman (2010) and Hills (2011) for a detailed discussion how fuel (energy poverty) is distinct from income poverty

parameter such as income as the measure of development as he viewed that the capacity to convert income, for instance, to desired outcomes will vary depending on the individual features, situation, gender, environment, etc. The capability approach focuses on the outcome, well-being rather than means to achieve well-being. Sen (2000) observed '*If freedom is what development advances, then there is a major argument for concentrating on that overarching objective, rather than on some particular means, or some specially chosen list of instruments.*' Additionally, access to clean, modern energy resources is directly linked to Amartya Sen's capability approach to development, exclusively by way of *economic facilities* — one of the five instrumental freedoms suggested by Amartya Sen, which helps to advance the general capability of a person (Sen, 2000, page no. 10). Access to energy resources, for example, electricity and LPG are crucial economic facilities that households yearn for, and therefore its absence constitutes deprivation. Hence, traditional approaches to conceptualizing and measuring the access to and affordability of modern energy resources through income or expenditure metrics on energy resources are essentially narrow and misleading.

Amartya Sen perceives the capabilities as real opportunities to choose the kind of life one values, and that is why Amartya Sen argued for the development paradigms that expand the capabilities and thereby the freedom to choose a life one values. Thus, if an individual is denied the freedom to choose, she/he is deprived of a particular capability, and this constitutes an instance of underdevelopment. As we look at the energy poverty through this perspective, it is evident that the lack of access and affordability to use modern energy resources reduces quality life for hundreds of millions. As mentioned above, energy poverty results in the premature mortality of women, denial of education to children and denial of freedom to lead a healthy and comfortable life during winter or summer. The empirical evidence in Szakonyi and Urpelainen (2015) proves this fact that the street vendors in Patna, India, unanimously believe that better lighting facilities would increase their trade and thereby the well-being of their family. In other words, access to better lighting facilities would increase their capabilities and open up new opportunities to have a life that they regard valuable. Hence, the issue of energy poverty is a question of deprivation of capability and therefore, should be viewed with a holistic perspective.

To sum up, we propose to look at the issue of energy poverty through the Amartya Sen's Capability approach because energy poverty— one of the unfreedoms as per Sen's idea of development— leads to other unfreedoms namely, ill-health and illiteracy (Walker and Day, 2012). For instance, according to the WHO, 2016 statistical updates, 4.3 million people die prematurely in a year due to illness attributable to the household air pollution caused by the inefficient use of solid fuels, for example, firewood, charcoal, and dung cake for cooking. Given the enormity of suffering caused by energy poverty, Sen (2014) recently observed that *"making it easier to produce energy with better environmental correlates (and greater efficiency of energy use) may be a contribution not just to environmental planning, but also to making it possible for a great many deprived people to lead a fuller and freer life."* From this, it is clear that energy poverty is to be looked at holistically using capability approach to the development proposed by Amartya Sen. Hence, in this study, we analyze the problem of energy poverty in India with a comprehensive approach using the MEPI to unearth the extent of socio-economic deprivation and the resultant denial of real freedom and opportunities to people.

3. Literature survey

Here we attempt to review briefly a few empirical studies exclusively on energy poverty, its measurement, and implications. A pioneering study by Pachuri et al. (2004) based on the NSSO data found evidence of a decrease in energy poverty among the very energy poor in India. An increase in access to electricity and LPG, will lead to significant economic and social benefits for those who are most deprived. Pereira et al. (2011) reported similar results from Brazil through a concerted effort by the government to expand reliable electrification, and by Andadari et al. (2014) from Indonesia through the expansion of subsidized LPG program to households. Kandkher et al. (2012) found that, while energy poverty and income poverty correlate to each other in the urban areas in India, they are not so in the rural areas, indicating that many of the income non-poor are energy poor in rural India. While 57% of households are energy poor and 22% are income poor in the rural areas, corresponding figures for the urban areas are 28% and 20% respectively. Further, India as a whole still depends on traditional means like firewood for meeting about 90% of its energy requirements and the study has reiterated the role of the expansion of electrification and penetration of LPG in ameliorating the energy poverty in India. A similar study in Bangladesh by Barnes et al. (2011) have found that the percentage of households in rural Bangladesh who are energy poor is 58%, whereas 45% are income poor showing again that income non-poor could be energy poor.

Bhinde and Monroy (2011) reiterated the necessity of exploring the potential of renewable, clean energy in India since whatever programs initiated by the government of India so far are insufficient to reduce energy poverty. A similar view about the greater role of the renewable energy sources in reducing global energy poverty is documented by González-Eguino (2015). In an interesting study highlighting the larger socio-economic implications of energy poverty, Szakonyi and Urpelainen (2015) have reported the prevalence of extensive energy poverty among the street vendors in the city of Patna, the capital of Bihar state in India. Addressing the energy poverty with adequate lighting facilities has a huge potential to improve their business and thereby their standard of living. The results of a similar study conducted in Barabanki district of Uttar Pradesh in India by Urpelainen (2016) also highlight the dissatisfaction among the households on account of lack of electricity and consequent condition of poor lighting with kerosene which leads to not only health problems but also insecurity for women.

Based on a comprehensive study, Wang et al. (2015) have found evidence of a decrease in energy poverty in China, mainly due to the improvement in energy service availability, energy affordability, and energy efficiency. However, their results also reveal that some of the well-developed regions in China experience acute energy poverty compared to less economically developed regions substantiating the view that the freedom from income poverty does not necessarily imply the freedom from energy poverty, which calls for different approaches to deal with energy poverty. Another study related to China by Tang and Liao (2014) have observed that, despite the popularity of massive electrification and a marginal decrease in the energy poverty, the dependence of China's rural households on solid fuels remains relatively high, with marked regional differences. Specifically, over three-fourths of the rural households use biomass for cooking because they are constrained by the price of modern energy services.

Regarding the environmental implications of energy poverty alleviation, Chakravarty and Tayoni (2013) have estimated a rise in global warming by 0.13 °C by 2030, as it will entail an increase in energy demand by 7%. In the same vein, Kaygusuz (2011) has documented the evident tradeoff between reducing energy poverty and achieving environmental sustainability and called for an integrated approach to energy policies and general welfare programs of the government taking into consideration the specific nature and needs of the region. Likewise, stressing the importance of an integrated collaborative approach between various stakeholders namely, government, MNCs, NGOs, national and international institutions in fighting energy poverty in Asia, Spagnoletti and O'Callaghan (2013) have proposed the formation of the Multilateral Alliance to Alleviate Energy Poverty in Asia (MAAEPA) comprising all these stakeholders. The MAAEPA members can pool their diverse knowledge and resources to provide targeted support to energy poverty alleviation by performing coordination, monitoring, evaluation, and reporting functions. Along similar lines, Sovacool (2013) has opined that coordinated public and private efforts are necessary to alleviate energy poverty in Myanmar, where, only 13% of households have access to electricity. It includes the programs like financing for woodlots, nurseries, and renewable energy equipment, promoting public-private partnerships for larger grid-connected wind farms, large-scale hydroelectric dams, geothermal power plants, biomass power plants, waste-to-energy facilities, and liquid biofuel manufacturing facilities.

Outlining the recipe for the successful implementation of electrification from countries like China and Vietnam, Barnes (2007) has showed certain uniform pattern across various countries in the way national plans are executed to meet the challenge. Prominent ingredients of these success stories are as follows: (i) rolling out a master plan with the mission of taking electricity to all households, for example, the National Plan for Thailand Accelerated Rural Electrification (NPTARE) in Thailand and National Primary Rural Electrification County Program (NPRECP) in China. (ii) The commitment of the respective governments by providing adequate financial and technical support and weeding out unnecessary political interference. (iii) Prioritization of electrification in the initial stage in the form of electrifying rice producing areas in Vietnam based on its advantage in the rice production and electrifying economically backward regions in Thailand exemplify the clear planning in the implementation of the program and (iv) making full potential of the region with massive local support and expertise. For example, China through the Small Hydro Power (SHP) projects made use of its indigenous water resources and local expertise, whereas, in Mexico, local participation was promoted to inject a sense of ownership among rural people. Similarly, the creation of regulatory mechanisms, rationalization of subsidies, charging the fair price, removal of supply barrier, and adoption of cost-saving practices are other prominent measures adopted by these countries to achieve universal access to electricity.

Overall findings of previous studies are in line with our proposition that energy poverty is a multidimensional issue. Therefore, integrated affirmative actions are required to deal with the challenge where this comprehensive and multidimensional analysis will be instructive.

4. Data

The India Human Development Survey-II (IHDS-II), 2011-12 is the source of data used in this study. It covers 42,152 households from across India with a national representation. It includes 33 states and union territories, 384 districts, 1420 villages and 1042 urban areas. The rural sample is drawn based on the stratified random sampling, whereas urban sample through a stratified sample of towns and cities based on the Probability Proportional to Population (PPP).

The IHDS-II survey has collected information on 52 dimensions of human development, and is broadly classified under two heads with 26 dimensions each—first, income and social capital; second, education and health. Under income and social capital, information is collected on ownership of the farm, animals, business, sources of income, education, social and political networking, debt, and ownership of assets. In the second category of education and health, information is collected on education, family, health, gender relations, fuel, and energy use.

In this study, we make use of the information on fuel and energy use, income and health. The survey has information on whether the household has access to LPG, and also the purpose of LPG use, namely cooking, heating, and lighting purposes. It has information on the type of Chula (stove) used and whether it is with or without a chimney. Apart from LPG, information on the use of other fuels namely firewood, dung cake, crop residue, kerosene and coal/charcoal for cooking, heating, and lighting purposes are collected. Information on households having access to electricity is also collected.

5. Methodology

Bazilian et al. (2010), while examining the measurement of energy access, identified three types of metrics viz. the uni-dimensional indicators, composite indices, and hybrid indicators. Further, the IAEA (2005) report on the energy indicators for sustainable development provides the guidelines and methodologies for measuring energy indicators. Uni-dimensional indicators such as the international poverty line of $1 a day are simple, easy to interpret and yet convey a strong message. A similar indicator can be devised based on the amount required for the energy consumption for a decent standard of living. However, it is very narrow and may not be suitable for measuring energy poverty considering that it does not take into account the availability of energy resources and wide variation across regions as to what constitutes the amount of energy resources required for a decent living. Issues like energy poverty are very complex and require capturing various dimensions such as affordability, accessibility, and their consequences. As explained in the theoretical underpinning of the study, energy poverty is related to the income poverty, health, and other socio-economic variables. Therefore, the multidimensional composite indices which result in a single numeral value are better suited. Composite indices are easy to interpret the trends over time compared to a set of single variables individually. However, composite indices may suffer from the methodological drawback and can be too simplistic if the index is poorly constructed. A hybrid indicator comprising of several uni-dimensional indicators and a composite index can combine the best of both methods.

Practical Action (2010) – an international Non-Governmental Organization (NGO) has devised an energy access index[3] based on household fuel, electricity, and mechanical power. Each of the three components has five sub-dimensions; 1 represents the lowest level of access and 5 represents the highest level. The index can be used to assess the energy access at the household level as well as regional and national level.

Being multidimensional in nature, energy poverty should be measured based on a composite index to capture the various dimensions of energy deprivation. The multidimensional poverty index approach is popularized by the Oxford Poverty and Human Development Initiative (OPHI) (see Alkire and Foster (2007, 2011), Alkire and Santos (2010)), which is in turn inspired by Amartya Sen's capabilities approach.

MEPI captures a set of energy deprivation which may affect a person. It is composed of eight dimensions of energy use, which are grouped into three broad categories viz. lighting, cooking and additional measures. All three categories are given an equal weight of 33.33% and subcategories within the broad three categories are further given equal weight. Fig. 1 shows the details of the indicators, weight, and its construction.

Each category is assigned a value of 0 or 1 depending on whether the presence of an attribute is a sign of energy poverty or not. For example, under lighting, a household not having access to electricity is coded as 1, whereas having electricity as zero. In the same manner, under cooking, a household using traditional Chula without a chimney is coded as 1 and a household not having access to LPG is coded as 1. Finally, under additional measures, a household using firewood, dung cake, crop residue, kerosene and coal/charcoal for cooking, lighting, and heating purposes are assigned a value of 1. Multidimensional Energy Poverty is measured by multiplying the weight of the individual component with the assigned value. Finally, we obtain the index by summing up values across all components.[4]

MEPI provides a flexible framework to set the dimensions based on

[3] Practical Action (2010), Poor People's Energy Outlook 2010. Rugby, UK.

[4] For a detailed account on the construction of index, refer HDR 2015 – Technical Notes, page number 8.

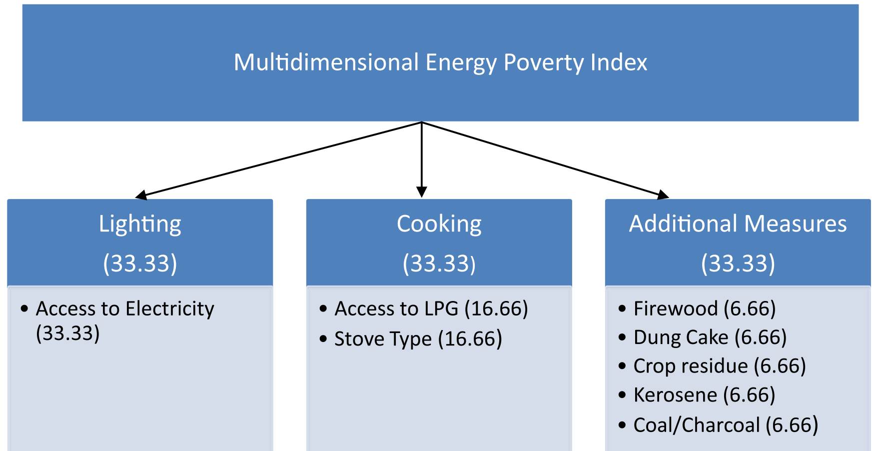

Fig. 1. Dimensions and Corresponding Variables of Energy Poverty. Note: Each indicator weight is multiplied by the deprivation code assigned and the sum of these values represents the multi-dimensional energy poverty index. For example, a household does not have access to LPG and uses a Chula with chimney, has access to electricity, uses firewood, dung cake, crop residue, kerosene and coal/charcoal for lighting, heating or cooking purposes. The energy poverty score of the household will be {[(16.66*1+(16.66*0)]+[(33.33*0)]+[(6.66*1)+(6.66*1)+(6.66*1)+(6.66*1)+(6.66*1)]}=50%.

its relative importance and it defines energy poverty. However, MEPI may be vulnerable to the weight assigned to different dimensions. Therefore, to test the sensitivity of the proposed index to the weights used, we conduct a sensitivity analysis using different weights and the ranking of the dimensions.

For the purpose of sensitivity analysis, we use the rank sum method of assigning weights. Three dimensions of energy poverty viz. cooking, lighting and additional measures are ordered based on the relative importance of the individual measures. The following formula is applied to arrive at the weight:

$$Wt_i = \frac{K - r_i + 1}{\sum_{j=1}^{K} K - r_i + 1} \quad (1)$$

Table 1
State wise energy poverty.

State	1	2	3	4	5	6	7	8	9	10
Jammu & Kashmir	46.39	11.53	12.22	12.50	11.11	4.17	1.94	0.00	0.14	0.00
Himachal Pradesh	24.20	8.54	18.37	18.03	26.85	3.53	0.20	0.14	0.14	0.00
Punjab	37.29	7.59	10.47	19.59	14.59	7.76	1.76	0.24	0.71	0.00
Chandigarh	92.94	0.00	2.35	1.18	3.53	0.00	0.00	0.00	0.00	0.00
Uttarakhand	24.79	8.76	5.34	14.53	23.93	15.38	2.56	1.71	2.99	0.00
Haryana	17.70	6.99	6.88	24.97	24.97	14.15	1.75	0.17	2.25	0.17
Delhi	90.29	3.57	1.90	2.46	1.23	0.45	0.00	0.11	0.00	0.00
Rajasthan	18.69	4.56	5.23	10.09	14.95	13.39	19.18	2.08	4.93	6.90
Uttar Pradesh	15.03	3.33	4.85	6.61	8.65	11.43	12.88	6.45	17.23	13.53
Bihar	12.66	3.74	3.08	4.66	6.69	14.49	18.49	0.92	16.79	18.49
Sikkim	83.96	1.89	2.83	4.72	4.72	1.89	0.00	0.00	0.00	0.00
Arunachal Pradesh	55.48	2.58	9.03	0.00	31.61	0.00	0.00	1.29	0.00	0.00
Nagaland	81.90	8.57	8.57	0.00	0.00	0.00	0.00	0.00	0.95	0.00
Manipur	89.77	4.55	2.27	3.41	0.00	0.00	0.00	0.00	0.00	0.00
Mizoram	54.67	24.00	6.67	14.67	0.00	0.00	0.00	0.00	0.00	0.00
Tripura	17.89	11.93	1.38	5.50	50.92	0.46	0.00	0.00	11.93	0.00
Meghalaya	22.56	0.75	8.27	12.03	49.62	6.02	0.00	0.00	0.75	0.00
Assam	19.41	24.72	0.82	7.87	16.14	0.61	3.47	2.76	22.06	2.15
West Bengal	25.95	1.69	4.34	7.52	10.99	17.40	13.80	0.79	9.17	8.35
Jharkhand	12.71	7.18	5.29	14.94	15.53	19.06	12.24	2.47	8.47	2.12
Orissa	12.79	2.14	1.80	3.16	29.36	16.09	8.65	1.22	22.85	1.94
Chhattisgarh	12.79	0.83	2.50	3.18	22.03	40.05	9.08	0.23	9.16	0.15
Madhya Pradesh	12.40	1.57	2.37	8.33	8.62	33.63	14.70	1.12	12.62	4.64
Gujarat	35.29	4.88	5.19	9.54	16.27	15.10	10.60	0.53	2.28	0.32
Daman & Diu	23.73	27.12	10.17	20.34	15.25	3.39	0.00	0.00	0.00	0.00
Dadra, Nagar Haveli	35.59	15.25	0.00	8.47	35.59	5.08	0.00	0.00	0.00	0.00
Maharashtra	30.76	9.74	5.87	6.66	14.06	14.21	13.48	0.37	2.89	1.98
Andhra Pradesh	31.87	18.13	3.84	8.97	30.85	3.98	0.51	0.14	1.71	0.00
Karnataka	19.17	16.12	3.70	21.16	26.70	7.14	1.97	0.24	3.78	0.03
Goa	96.28	0.00	2.13	0.00	1.06	0.00	0.00	0.53	0.00	0.00
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kerala	12.69	39.77	11.33	25.78	8.23	1.17	0.26	0.06	0.71	0.00
Tamil Nadu	50.10	9.51	4.27	6.00	26.09	1.83	0.20	0.66	1.32	0.00
Pondicherry	71.96	17.76	0.00	2.80	7.48	0.00	0.00	0.00	0.00	0.00
Anadman/Nicobar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall	25.52	8.64	5.28	10.88	17.23	12.52	8.00	1.23	7.15	3.55

Note: State wise percent of population having energy poverty index score at a frequency of 10%. 1 stands for up to 10% and 10 stands for 91–100%.

Table 2
State wise cumulative energy poverty.

State	1	2	3	4	5	6	7	8	9	10
Jammu & Kashmir	100	53.61	42.08	29.86	17.36	6.25	2.08	0.14	0.14	0.00
Himachal Pradesh	100	75.80	67.25	48.88	30.85	4.00	0.47	0.27	0.14	0.00
Punjab	100	62.71	55.12	44.65	25.06	10.47	2.71	0.94	0.71	0.00
Chandigarh	100	7.06	7.06	4.71	3.53	0.00	0.00	0.00	0.00	0.00
Uttarakhand	100	75.21	66.45	61.11	46.58	22.65	7.26	4.70	2.99	0.00
Haryana	100	82.30	75.31	68.43	43.46	18.49	4.34	2.59	2.42	0.17
Delhi	100	9.71	6.14	4.24	1.79	0.56	0.11	0.11	0.00	0.00
Rajasthan	100	81.31	76.74	71.51	61.42	46.48	33.09	13.91	11.83	6.90
Uttar Pradesh	100	84.97	81.64	76.79	70.18	61.53	50.09	37.21	30.76	13.53
Bihar	100	87.34	83.61	80.52	75.87	69.18	54.69	36.20	35.28	18.49
Sikkim	100	16.04	14.15	11.32	6.60	1.89	0.00	0.00	0.00	0.00
Arunachal Pradesh	100	44.52	41.94	32.90	32.90	1.29	1.29	1.29	0.00	0.00
Nagaland	100	18.10	9.52	0.95	0.95	0.95	0.95	0.95	0.95	0.00
Manipur	100	10.23	5.68	3.41	0.00	0.00	0.00	0.00	0.00	0.00
Mizoram	100	45.33	21.33	14.67	0.00	0.00	0.00	0.00	0.00	0.00
Tripura	100	82.11	70.18	68.81	63.30	12.39	11.93	11.93	11.93	0.00
Meghalaya	100	77.44	76.69	68.42	56.39	6.77	0.75	0.75	0.75	0.00
Assam	100	80.59	55.87	55.06	47.19	31.05	30.44	26.97	24.21	2.15
West Bengal	100	74.05	72.36	68.02	60.50	49.50	32.11	18.31	17.52	8.35
Jharkhand	100	87.29	80.12	74.82	59.88	44.35	25.29	13.06	10.59	2.12
Orissa	100	87.21	85.08	83.28	80.12	50.75	34.66	26.01	24.79	1.94
Chhattisgarh	100	87.21	86.37	83.88	80.70	58.67	18.62	9.54	9.31	0.15
Madhya Pradesh	100	87.60	86.03	83.66	75.34	66.72	33.09	18.39	17.26	4.64
Gujarat	100	64.71	59.83	54.64	45.10	28.83	13.73	3.13	2.60	0.32
Daman & Diu	100	76.27	49.15	38.98	18.64	3.39	0.00	0.00	0.00	0.00
Dadra, Nagar Haveli	100	64.41	49.15	49.15	40.68	5.08	0.00	0.00	0.00	0.00
Maharashtra	100	69.24	59.51	53.64	46.97	32.92	18.71	5.23	4.87	1.98
Andhra Pradesh	100	68.13	50.00	46.16	37.19	6.34	2.36	1.85	1.71	0.00
Karnataka	100	80.83	64.72	61.01	39.85	13.15	6.01	4.04	3.81	0.03
Goa	100	3.72	3.72	1.60	1.60	0.53	0.53	0.53	0.00	0.00
Lakshadweep										
Kerala	100	87.31	47.54	36.20	10.43	2.20	1.04	0.78	0.71	0.00
Tamil Nadu	100	49.90	40.39	36.11	30.11	4.02	2.19	1.98	1.32	0.00
Pondicherry	100	28.04	10.28	10.28	7.48	0.00	0.00	0.00	0.00	0.00
Anadman/Nicobar										
Overall	100	74.48	65.84	60.56	49.68	32.45	19.93	11.94	10.71	3.55

Note: State wise cumulative percent of population having energy poverty index score at a frequency of 10%. Cumulative percent is calculated from 10 to 1 to show the extent of poverty.

where, r_i is the rank of the ith objective, and K is the total number of objectives. The energy poverty dimension ranked first will have a weight of 50%, second 33.33% and third 16.66%. We use two ordering schemes — the first, cooking, lighting and additional measures; the second, lighting, cooking and additional measures. If there is more than one indicator in a given dimension, it is equally divided among them. For example, based on the first ordering, cooking has the highest weight of 50%, and it is equally divided at 25% between two sub-dimensions. Lighting has a weight of 33.33% and additional measures have a weight of 16.66, and it is equally divided among the five sub-dimensions at 3.33% each. The same method is followed in the second ordering as well.

6. Empirical results

Tables 1 and 2 present the empirical results at the state level and overall energy poverty situation in India. We group the households into ten categories; each category represents 10% difference in the energy poverty score, 1 stands for the households having energy poverty score of up to 10% and in the same manner, each successive category represents 10% incremental energy poverty score. A low score in the energy poverty index is better compared to a higher score as higher score represents higher levels of deprivation. From Table 1, it is clear that in cities like Delhi and Chandigarh, more than 90% of the households have energy poverty scores of less than 10%. It is understandable because the former is the capital city of India and the latter is a well-planned city in India. In the same manner, in states like Goa, Mizoram, Manipur, Nagaland, Arunachal Pradesh and Sikkim, more than 50% of the households fall under category 1, representing lower energy poverty. Less energy poverty may be largely because only the capital city of the state is surveyed considering the small size of the states.

Table 2 presents the cumulative percent of the households having up to a certain percent of energy poverty score from category 10 to category 1. Considering an arbitrary criterion of energy poverty score of 33.33%,[5] nearly 60% of the households have energy poverty score of above 33.33%. In states such as Rajasthan, Bihar, Utter Pradesh, Jharkhand, Orissa, Chhattisgarh, and Madhya Pradesh, more than 70% of the households have energy poverty score of greater than 33.33%. States like Kerala, Tamil Nadu and Jammu & Kashmir have less than 40% of the households having energy poverty scores of more than 33.33%, which is well-below the national average.

Table 3 shows the comparison of energy poverty scores based on equal weight and two weighing schemes based on the rank sum weight method. The average energy poverty index scores are very close to each other in all three methods. Further, the correlation among the three energy poverty measures, highest correlation of 0.99 and lowest of 0.97 is recorded. Therefore, it confirms that the energy poverty index is robust to the weights used in the index construction.

Energy poverty situation can vary not only across states but also

[5] See Nussabaumer et al. (2012). It implies that a household is considered as energy poor if the household do not have access to electricity or do not have access to LPG and uses traditional Chula without chimney.

Table 3
Average energy poverty index value based on equal weighted and rank sum weighted method.

Frequency	Energy Poverty (Equally Weighed)	Energy Poverty (Rank Sum Weighed)-1	Energy Poverty (Rank Sum Weighed)-2
1	2.98	3.17	3.17
2	13.47	13.37	18.40
3	22.42	27.93	25.26
4	32.48	33.77	39.52
5	45.45	43.55	44.61
6	53.34	57.91	55.00
7	60.24	63.70	67.81
8	73.46	71.67	76.89
9	83.78	89.71	89.71
10	93.33	94.92	94.92

Note: Energy Poverty is calculated based on equal weight for all three factors, Energy Poverty (Rank Sum Weighed)-1 is based on the cooking, lighting and additional measures ordering of dimensions and Energy Poverty (Rank Sum Weighed)-2 is based on lighting, cooking and additional measures. The correlation between Energy Poverty (Equally Weighed) and Energy Poverty (Rank Sum Weighed)-1 is 0.99, Energy Poverty (Equally Weighed) and Energy Poverty (Rank Sum Weighed)-2 is 0.98 and Energy Poverty (Rank Sum Weighed)-1 and Energy Poverty (Rank Sum Weighed)-2 is 0.97.

across districts in a state as well. To document the disparity across districts, we present the analysis of the districts. However, for the sake of brevity, we present the districts with more than 90% of the households having energy poverty scores of greater than 40%. As seen from Table 4, 90% of the households in 19 districts in Utter Pradesh, 17 in Madhya Pradesh, 13 in Orissa, 11 in Chhattisgarh, 8 in Bihar, 6 in Rajasthan, 5 in West Bengal and 3 in Maharashtra have energy poverty scores above 40%. Similarly, States like Assam, Jharkhand, Gujarat and Karnataka have one district each with a higher energy poverty score.

6.1. Energy poverty and socio-economic variables

We attempt to compare the energy poverty situation with socio-economic variables such as caste/religion, occupation, and distribution of household activities among the male and female members. The results given in Table 5 show that the energy poverty situation across castes/religion varies considerably. Adivasis and Dalits have highest energy poverty figures. However, Other Backward Classes (OBCs) and Muslims have energy poverty scores which resemble the national average. Communities like Brahmin and other forward castes, Christian, Sikh, and Jain have recorded energy poverty figures substantially lower than the national average.

Table 6 presents the distribution of energy poverty across different occupations. People practicing agriculture and allied activities, agricultural and non-agricultural laborers are the most energy poor, more than 70% of the households have energy poverty scores of more than 33.33%. Salaried employees and people in organized business have least energy poverty scores. These results are also along the expected lines given by the socio-economic profile of India like any other developing nation.

Table 7 presents the information about the fuel collection frequency and details of family members collecting the fuel. It appears that fuel

Table 4
Names of the districts with more than 90% of the households having energy poverty index score of 40% and more.

State	District	State	District	State	District
Uttar Pradesh	Rampur	Madhya Pradesh	Dewas	Chhattisgarh	Kanker
Uttar Pradesh	JyotivaPhule Nagar	Madhya Pradesh	Barwani	Chhattisgarh	Bastar
Uttar Pradesh	Kheri	Madhya Pradesh	Betul	Bihar	PurbiChamparan
Uttar Pradesh	Farrukabad	Madhya Pradesh	Hoshangabad	Bihar	Madhubani
Uttar Pradesh	Kannauj	Madhya Pradesh	Dindori	Bihar	Supaul
Uttar Pradesh	Kanpur Dehat	Madhya Pradesh	Mandla	Bihar	Saharsa
Uttar Pradesh	Banda	Madhya Pradesh	Seoni	Bihar	MuzaffarPur
Uttar Pradesh	Chitrakoot	Orissa	Bargarh	Bihar	Siwan
Uttar Pradesh	Fatehpur	Orissa	Kendujhar	Bihar	Banka
Uttar Pradesh	Kaushambi	Orissa	Mayurbhanj	Bihar	Kaimur (Bhabua)
Uttar Pradesh	Allahabad	Orissa	Bhadrak	Rajasthan	Churu
Uttar Pradesh	Ambedkar Nagar	Orissa	Dhenkanal	Rajasthan	Bharatpur
Uttar Pradesh	Sultanpur	Orissa	Puri	Rajasthan	Dhaulpur
Uttar Pradesh	Bahraich	Orissa	Kandhamal	Rajasthan	Karauli
Uttar Pradesh	Sharawasti	Orissa	Baudh	Rajasthan	SawaiMadhopur
Uttar Pradesh	Siddharathnagar	Orissa	Sonapur	Rajasthan	Dausa
Uttar Pradesh	Kushinagar	Orissa	Balangir	West Bengal	Darjiling
Uttar Pradesh	Deoria	Orissa	Nabarangapur	West Bengal	Jalapiguri
Uttar Pradesh	Chandauli	Orissa	Koraput	West Bengal	Maldah
Madhya Pradesh	Sheopur	Orissa	Malkangiri	West Bengal	Murshidabad
Madhya Pradesh	Datia	Chhattisgarh	Koriya	West Bengal	Birbhum
Madhya Pradesh	Tikamgarh	Chhattisgarh	Jashpur	Maharashtra	Washim
Madhya Pradesh	Chhatarpur	Chhattisgarh	Korba	Maharashtra	Bhandara
Madhya Pradesh	Panna	Chhattisgarh	Janjgir	Maharashtra	Hingoli
Madhya Pradesh	Damoh	Chhattisgarh	BilasPur	Gujarat	Narmada
Madhya Pradesh	Satna	Chhattisgarh	Kawardha	Karnataka	Bidar
Madhya Pradesh	Umaria	Chhattisgarh	Rajnandgaon	Jharkhand	Dhanbad
Madhya Pradesh	Sidhi	Chhattisgarh	Mahasamund	Assam	Dhubri
Madhya Pradesh	Ratlam	Chhattisgarh	Dhamtari		

Table 5
Cumulative energy poverty based on caste and religion.

Caste/Religion	1	2	3	4	5	6	7	8	9	10
Brahmin	100	53.30	45.87	38.35	27.13	19.01	11.49	5.49	4.43	1.66
Forward caste excluding Brahmin	100	59.34	48.53	40.42	29.58	17.58	9.46	4.52	4.14	1.55
Other Backward Castes	100	76.92	67.94	63.53	52.02	35.22	21.24	12.34	10.65	4.20
Dalit	100	82.82	77.06	72.93	62.72	38.87	24.46	14.94	13.57	5.17
Adivasi	100	88.62	84.33	81.75	73.80	48.57	31.27	20.96	19.63	2.63
Muslim	100	77.39	67.11	61.93	50.10	35.51	22.98	14.97	13.91	4.00
Christian, Sikh, Jain	100	56.95	34.71	22.41	9.35	2.44	1.01	0.51	0.25	0.00

Note: Caste and Religion wise cumulative percent of population having energy poverty index score at a frequency of 10%. Cumulative percent is calculated from 10 to 1 to show the extent of poverty.

Table 6
Cumulative energy poverty based on occupation.

Occupation	1	2	3	4	5	6	7	8	9	10
Cultivation	100	94.81	87.04	80.69	67.34	47.72	29.68	15.53	13.68	5.46
Allied ag	100	89.47	75.19	70.93	58.90	39.35	24.81	15.04	11.78	5.51
Ag wage labor	100	96.40	90.70	88.03	77.57	47.10	29.89	19.26	17.81	5.94
Non ag wage labor	100	86.98	80.19	76.21	65.16	42.62	26.63	18.04	16.32	4.77
Artisan/Indept	100	59.88	48.23	43.66	32.45	16.81	9.88	7.08	6.34	1.33
Petty shop	100	55.62	45.02	39.96	29.56	19.39	10.75	6.03	5.45	1.69
Organized Business	100	32.45	22.05	16.58	9.52	4.76	1.94	0.88	0.53	0.18
Salaried	100	43.81	33.05	26.69	17.95	9.35	4.74	2.33	2.00	0.49
Profession	100	48.97	42.80	39.09	27.57	17.70	11.11	5.76	4.53	0.82
Pension/Rent etc.	100	54.06	43.04	35.90	26.61	16.15	9.80	7.14	6.54	1.54
Others	100	71.70	60.79	54.16	44.16	29.89	20.40	12.51	11.42	3.69

Note: Occupation wise cumulative percent of population having energy poverty index score at a frequency of 10%. Cumulative percent is calculated from 10 to 1 to show the extent of poverty.

Table 7
Fuel collection frequency by different household members.

Fuel Collection Frequency				
Frequency	**Adult Women**	**Adult Men**	**Girls Under 15 Years Age**	**Boys Under 15 Years Age**
Daily	2724	843	353	279
Weekly	6825	3967	760	563
Monthly	1728	1624	347	258
Quarterly	584	514	121	90
Half yearly	326	282	73	73
Yearly	365	322	50	52
Total	12,552	7552	1704	1315

Note: Total number of adult women, men and girls and boys aged under 15 at different fuel collection frequency.

Table 8
Average fuel collection time in minutes.

Average Fuel Collection Time (Min)				
Frequency	**Adult Women**	**Adult Men**	**Girls Under 15**	**Boys Under 15**
1	100	93	109	95
2	115	129	132	126
3	143	146	109	119
4	155	166	122	113
5	155	154	127	128
6	172	176	138	128
7	161	171	128	118
8	160	167	151	132
9	154	157	143	133
10	145	153	127	127

Note: Average time spent by adult women, men and girls and boys aged under 15 for one time fuel collection in minutes.

Table 9
Average income of the households.

Frequency	Average Total Income	Average Per capita Income
1	215,912.63	53,239.96
2	165,505.34	37,170.19
3	166,834.88	34,932.55
4	133,571.41	27,081.24
5	84,053.38	19,112.37
6	71,196.78	15,370.93
7	71,298.82	14,455.51
8	56,311.61	12,733.84
9	49,145.87	12,044.66
10	53,133.64	11,817.58

Note: Average income of households at different frequencies of energy poverty index score.

collection is mainly the responsibility of female household members; nearly 62% of family members engaged in fuel collection are female, i.e. adult women and girls under the age of 15. Regarding the frequency of fuel collection, more than 50% of the sample collects fuel once in a week followed by a daily and monthly collection.

Table 8 presents the comparison of energy poverty scores and average time spent on a one-time collection of fuel by different household members. Adult women and men spend more or less similar amount of time in fuel collection. As energy poverty score increases, there is an increase in the amount of time spent on fuel collection up to 60% of energy poverty score and it starts decreasing after that. However, the amount of time spent by the extremely energy poor is substantially higher than the people having very low energy poverty scores. The results presented in Tables 7 and 8 have significant socio-economic implications. For example, women in predominantly energy-poor households in India could be forced out of the wage-earning labor market; they ought to spend a lot of time and effort to collect solid fuels. This could be one of the major reasons for the lowest labor

Table 10
Energy poverty, income contrasted with domicile classification.

Frequency	Energy Poverty		Cumulative Energy Poverty		Average Total Income		Average Per-capita Income	
	Village	Town	Village	Town	Village	Town	Village	Town
1	46.85%	74.52%	100.00%	100.00%	222,833.61	241,041.10	56,420.75	61,551.51
2	9.21%	8.26%	53.15%	25.48%	157,755.92	168,427.59	38,766.85	40,951.11
3	5.21%	3.57%	43.94%	17.22%	135,834.89	107,133.00	27,737.57	27,707.63
4	7.94%	4.60%	38.73%	13.65%	142,036.28	99,567.61	26,706.40	23,625.51
5	13.84%	4.70%	30.79%	9.05%	83,024.53	77,755.80	20,175.62	19,174.47
6	7.25%	2.16%	16.95%	4.36%	73,215.32	75,476.03	16,525.92	16,005.18
7	3.86%	0.69%	9.69%	2.19%	72,831.94	66,293.50	16,138.55	19,036.20
8	0.37%	0.38%	5.84%	1.51%	40,314.43	48,290.91	9449.38	14,334.37
9	4.20%	1.06%	5.47%	1.13%	62,987.43	55,377.10	14,265.65	14,022.32
10	1.27%	0.07%	1.27%	0.07%	54,782.87	58,750.00	13,968.30	9055.71

Note: Energy poverty, cumulative energy poverty and average income of households at different frequencies of energy poverty index score.

Table 11
Percentage of household members having health issues.

Frequency	TB	BP	Heart	Cancer	Asthma	Mental Illness
1	1.17	22.39	5.52	0.39	3.22	1.10
2	0.87	22.66	6.35	0.65	4.56	1.58
3	2.13	22.54	6.07	0.23	5.33	1.39
4	1.60	17.32	4.58	0.66	4.82	2.04
5	1.75	9.89	2.66	0.22	4.26	1.39
6	2.14	7.94	2.59	0.19	4.96	1.74
7	2.93	7.82	2.42	0.21	6.04	2.21
8	3.68	5.43	2.14	0.58	5.03	1.75
9	2.74	5.64	1.14	0.27	4.60	1.70
10	4.17	3.98	1.93	0.20	7.39	1.86

Note: Percentage population having Tuberculosis, Blood Pressure, Heart diseases, Cancer, Asthma and Mental illness at different frequencies of energy poverty. 1 stands for households having energy poverty index score of less than 10 and 10 for households having energy poverty index score of more than 90%.

market participation rate among females in India (Das et al., 2015). Undoubtedly, such unfreedoms affect the financial independence and empowerment of women.

6.2. Energy poverty, income, and health

We attempt to find the relationship between energy poverty, income and health issues of the households. Table 9 presents the comparison of energy poverty with the income of people, i.e. total as well as per-capita income. The result shows the close relationship between a low score of energy poverty and high levels of total as well as per-capita income. This result is consistent with the findings of Kandkher et al. (2012) who found a positive relationship between income and energy consumption in India. To discern the urban- rural difference in the energy poverty and income relationship, we categorized these figures for rural and urban groups. However, we have information on the place of dwelling of only 9136 households. It is clear from Table 10 that there is not much difference in the average total or per-capita income between village and town, but the extent of energy poverty is markedly greater in villages in comparison with the towns. This reinforces the findings of the extant studies that in rural areas a household may be income non-poor but they can be energy poor.

The use of different solid energy resources can have an influence on the health of the household members. Therefore, Table 11 presents the information on family members having specific diseases or had in the recent past concerning tuberculosis, blood pressure, heart-related diseases, cancer, asthma, and mental illness. As energy poverty increases, percent of family members having tuberculosis seem to be increasing, especially from energy poverty score of 50% and beyond. However, in the case of blood pressure and heart-related diseases, as energy poverty increases (it also means as income decreases as per results furnished above) there is a substantial decline in blood pressure and heart-related diseases. Since physical effort is required to meet the energy requirement of households, it makes individuals involved in such efforts physically fit and resilient which is one of the major means suggested by health experts to deal with health hazards such as blood pressure and heart-related diseases. Besides, results regarding the extent of energy poverty across occupation given above show that those who are suffering from severe energy poverty are mostly agricultural and non-agricultural laborers and they are not vulnerable to high blood pressure or heart diseases under normal conditions. But asthma shows a clear increasing trend as energy poverty increases. This could be due to the use of biofuels without proper ventilation and exhaust fans as reported from across the globe. Obviously, cancer and mental disorders do not seem to have any association with the energy poverty or income levels.

Considering the close relationship between income poverty and energy poverty, the apparent association between energy poverty and diseases like asthma could be because of income poverty and not necessarily due to energy poverty. To separate this, percent of household members having various health issues are compared vis-a-vis energy poverty and income poverty. For this purpose, we divided the households into deciles based on the total income of the households from the richest to the poorest and results are presented in Table 12. We compare this result with the similar result based on energy poverty. It is clear from the table that the percent of household members having tuberculosis and asthma are marginally higher in the case of energy poor than income poor. However, blood pressure figures are substantially higher in the case of income poor compared to energy poor.

Overall, the results obtained corroborate our initial proposition that energy poverty is multidimensional in nature with wider socio-economic implications in India and hence appropriate methodological apparatus should be used. Therefore, we assess energy poverty with a

Table 12
Relationship between income and diseases.

Frequency	TB	BP	Heart	Cancer	Asthma	Mental Illness
1	0.97	25.35	5.81	0.52	3.70	0.83
2	1.12	21.58	5.07	0.47	4.21	1.54
3	1.47	17.54	4.54	0.38	4.33	1.14
4	1.31	15.93	4.77	0.38	4.49	1.26
5	1.91	13.67	4.01	0.28	4.39	1.51
6	2.23	12.05	3.39	0.31	4.61	1.73
7	2.25	11.94	3.20	0.33	4.31	1.97
8	2.27	10.64	2.94	0.19	4.33	1.85
9	2.29	8.45	2.55	0.36	4.70	1.76
10	2.64	10.47	3.12	0.31	5.97	1.94

Note: Percentage population having Tuberculosis, Blood Pressure, Heart diseases, Cancer, Asthma and Mental illness at different frequencies of income. 1 stands for the richest and 10 poorest.

comprehensive method namely, MEPI based on Amartya Sens's capability approach to development. For example, the findings such as Adivasis and Dalits who are socially and economically poor are also energy poor essentially reveal that access to energy, among other factors, is to be considered as instrumental in promoting the welfare and thereby the real freedom of the people. Besides, the agency of women, as Sen put it, appears to be constrained in the face of energy poverty, as they are predominantly engaged in the collection and use of firewood in the traditional Indian society with consequences like health issues and inability to participate in the wage-earning labor markets.

7. Conclusion and policy implications

Access to affordable modern energy resources like electricity and LPG is essential in the face of growing opulence, climate change, health and socio-economic hazards of using traditional solid biofuel. Given this realization, we have attempted to assess the energy poverty situation in India as proper assessment of the extent and nature of the problem is inevitable in the process of addressing such challenges. Towards this, we have used household level primary data from the India Human Development Survey-II (IHDS-II), 2011-12 and analyzed it using multidimensional energy poverty index approach.

The empirical results indicate the prevalence of extensive energy poverty in India, especially in rural areas where households rely heavily on traditional biofuels such as firewood, dung cake, and agricultural residue. Dalits, Adivasis and socially marginalized sections are the worst victims of energy poverty. Similarly, the results reveal that women in the households spend a lot of time and energy in the collection and use of solid biofuel, a major energy resource used by Indian households in inefficient stoves. This kind of social convention will have far-reaching consequences regarding the decrease in the women's labor market participation and an increase in the illness caused by indoor pollution among women and children. This study finds that income poverty and energy poverty are commensurate with each other implying that in a predominantly agrarian society like India, access to modern energy services remains the dream for most of the energy poor laborers.

Thus, these results strongly substantiate the proposition that energy poverty is multidimensional in nature and hence it should be evaluated based on a comprehensive theoretical framework such as Amartya Sen's capability approach using MEPI.

The insights from this study can provide valuable inputs for policy makers. The existence of widespread energy poverty in India presents formidable challenges for policy makers. Apart from meeting the existing demand for energy resources, India's overall energy requirement is expected to increase manifold in the coming decades due to the growing population and the commensurate increase in urbanization as outlined in the IEO-2015. In addition to this, the success of governmental scheme to boost manufacturing heavily depends on guaranteeing round-the-clock electricity supply. Therefore, India has to embark on a comprehensive action plan to address its burgeoning energy concerns such as the expansion of access to electricity, especially in rural areas through capacity additions, which requires regulatory and tariff reforms along with ensuring ease of new project approvals and execution. Likewise, the provision for easy and affordable access to LPG in both urban and rural areas, promotion of the use of efficient stoves and LED bulbs can go a long way in curbing health issues and wastage of precious energy resources. Since India possesses the second largest coal reserve in the world, ensuring efficient and fair practices in the allocation of coal blocks and promotion of better technologies in its use can also help to ameliorate the problem of energy poverty in an eco-friendly manner. Finally, the government must explore all means to harness the potential of renewable, cleaner energy resources in India to address the problem of energy poverty.

Finally, recent programs and policies of the Government of India can have a far-reaching positive impact on the alleviation of energy poverty in India. For example, an amendment to the Electricity Act-2003 in 2014 to reform the electricity sector, and 'International solar alliance' launched by India on the sidelines of the Paris climate conference 2015 to harness the solar potential of the country and energy subsidy reform can go a long way in reducing energy poverty.

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