Surprises up the energy ladder

Andrew Pascale,[1] Shoibal Chakravarty,[2] Paul Lant,[3] Simon Smart,[4] Chris Greig[5]

Working paper

16 March 2017

Abstract

Traditional discussions of the relationships between energy, CO2 emissions and human development capture between-country differences, but fail to expose within-country energy and CO2 emissions inequality. Household survey data offers researchers a window through which to better understand the unequal distribution of energy use and the Human Development Index (HDI) at a sub-national level. This study uses India Human Development Survey (IHDS) data [1, 2] to generate household consumption and emissions distributions for India in both 2005 and 2012, and consults the EORA global multi-regional input output database [3, 4] for sectoral intensities of India's economy. The analysis uses HDI 2015 methodology [5].

Results indicate that non-solid fuel use patterns have changed little across India's income deciles between 2005 and 2012; that total direct household energy use emissions (including non-commercial biomass but not including direct transport emissions) are surprisingly flat across both deciles and years analysed; and that indirect emissions represent the largest CO_2 emissions growth area across deciles and study years. While emissions inequality has clearly increased between top and bottom deciles in the seven years between IHDS surveys, overall trends in HDI inequality between deciles are harder to identify.

[1] Energy & Poverty Research Group, UQ Energy Initiative; School of Chemical Engineering, The University of Queensland, St. Lucia, Australia. Email: andrew.pascale@uqconnect.edu.au (corresponding author)
[2] National Institute of Advanced Studies, IISc Campus, Bangalore 560012, Email: shoibalc@nias.iisc.ernet.in
[3] School of Chemical Engineering, The University of Queensland, St. Lucia, Australia. Email: paul.lant@uq.edu.au
[4] Dow Centre for Sustainable Engineering Innovation, School of Chemical Engineering, The University of Queensland, St. Lucia, Australia. Email: s.smart@uq.edu.au
[5] UQ Energy Initiative, The University of Queensland, St. Lucia, Australia. Email: chris.greig@uq.edu.au

Results suggest two main areas for consideration. Addressing energy poverty and pressing welfare issues connected to energy use in India, such as household air pollution from solid fuels [6], can be aided by an apparent emissions neutral transition to modern energy carriers. However, the wealth creation needed to sustain a transition out of energy poverty appears to be accompanied by indirect CO_2 emissions growth, especially in the richest deciles. Addressing both of these challenges at the same time requires a coherent strategy that targets energy poverty and wealth creation in the poorest deciles while reducing the emissions intensity of the sectors – notably transportation – of the Indian and global economies supporting increasing household consumption.

Introduction

A recent publication from Chancel and Piketty [7] clearly shows that in recent years, within-country greenhouse gas (GHG) emissions inequality has increased at the same time that between-country GHG emissions inequality has decreased. Traditional discussions of energy development, national emissions and human development have failed to address this trend. Even seminal GHG focused academic work with a clear interest in sub-national populations and poverty alleviation [8] has fallen back on Figure 1's traditional representation of the relationship between the Human Development Index (HDI) and national emissions (with the addition of a 1 t CO_2 threshold marked roughly in green) to support its poverty agenda.

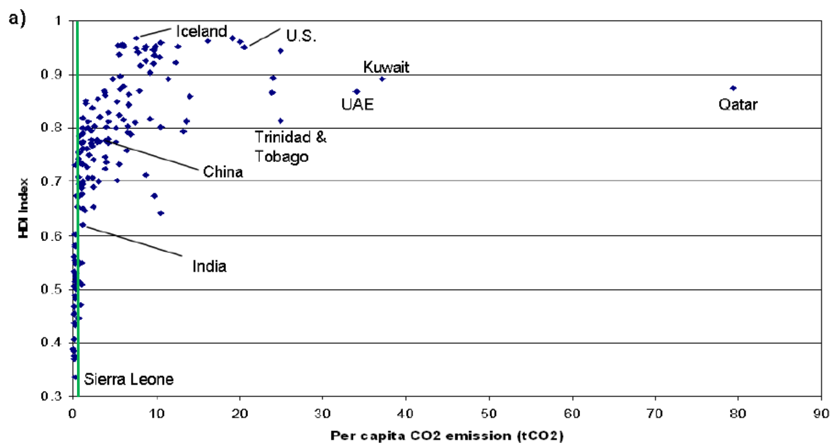


Figure 1 HDI rank (2005) vs per capita CO_2 emissions (2004) [supporting material for 8].

Figure 1 shows CO_2 emissions growing slowly while HDI increases rapidly until roughly 1 tCO_2 per capita is reached, at which point HDI scores start to show slower growth and CO_2 emissions tend to increase more rapidly. While depicting inequality between nations, the increasing importance of inequality within nations [7, 8] is not acknowledged by such representations. This study arises out of the need for poverty focused discussions of human development to account for inequality at sub-national levels in the context of energy use and GHG emission discussions.

India, with the largest populations in the world lacking access to electricity and clean cooking fuels in 2012 [9], and an HDI ranking of 130[6] in 2014 [5], provides an ideal country on which to focus such a study. This study is pressing in that India is home to an estimated one million premature deaths a year due to household air pollution arising from solid fuel use in households [6]. This study is timely in that India, the fourth largest GHG emitter in the world after China, the United States, and Europe (EU-28) [10] also recently discussed GHG emissions related commitments at the 2015 COP22 conference in Marrakech. India's submission to the COP21 in 2015 specifically refers to the need to ensure a reasonable HDI for the country and notes that "no country in the world has been able to achieve a Human Development Index of 0.9 or more without an annual energy availability of at least 4 toe [167 GJ] per capita" [11]. In 2013, India's per capita energy use was 0.6 toe (25 GJ) [12].

[6] 188 countries total. India's Inequality adjusted HDI ranking was also 130 out of 188 countries.

The Indian government's interest in the HDI is expected to increase the accessibility of this paper's findings to policy makers. Presented results are largely as one might expect and show total energy requirements and CO_2 emissions rising with incomes in India in both 2005 and 2012. Suggested policies are also fairly predictable, with the Indian government being urged to continue prioritization of modern energy access efforts alongside efforts to reduce the energy and emissions intensity of the sectors of its economy. However, both surprises and important puzzles that arise when looking closely at different aspects of household energy use and resulting emissions across deciles and the study years require acknowledgement and discussion.

Background

Presentations of the relationship between aspects of energy use (electricity consumption, GHG emissions) and human development show up widely in literature [8, 13-16] and traditionally take Figure 1's form. Examples of more advanced HDI and energy/emissions analyses can be found in the literature as well. Steinberg and Roberts [17], use their findings on the decoupling of energy, CO_2 emissions and human development over time to challenge the assumption underlying mainstream energy development indicators focused on poor countries, "that a high level of energy and carbon are a prerequisite for high living standards." Lamb et al. [18] identify and group nations with life expectancies greater than 70 years and carbon emissions less than 1 t CO_2 per capita in order to explore the drivers supporting examples of low-carbon human development along with potential transition pathways for countries sharing similar drivers.

Similarly, analyses of household energy use and/or emissions based on household survey data are also widely available in literature for both richer [19-25] and poorer countries [26-31]. In the case of India, such analyses are showcased in the work of Pachauri and Spreng [29] and Pachauri [28], who estimate the direct and indirect use of energy by Indian households for the years 1983 to 1999; Grunewald et al. [26], who estimate emissions footprints of households in 2005 and 2010; and Khandker et al. [27] who calculate direct household energy use in order to discuss measurement of energy poverty. Results from these works are not discussed in the context of the HDI. These works also reference guiding literature exemplifying, explaining or making such studies possible such as the input-output (IO) table focused work of Leontief [32], Bullard and Herendeen [33], Herendeen and Tanaka [34], Lenzen [35] and Miller and Blair [36], as well as the basic energy needs work of Goldemberg et al. [37].

Work on sub-national HDI analyses have been ongoing in India since 1995 [38]. Between 1995 and 2007, at least 22 Indian states and territories released human development reports featuring state and/or district level HDI estimates [39]. In 2002, India released a national human development report which estimated HDI values for 1981, 1991 and 2001 using a slightly modified index thought to better fit the Indian context[7] [40]. Reports focus on the geographical rather than socio-economic distribution of HDI scores in India.

Analysis of the HDI scores of economic quintiles in India in 1997/1998 and deciles in 2005, can be found in studies of a wider panel of countries in the work Grimm et al. [41] and Harttgen and Klasen [42] respectively[8]. In recent years, providers of the HDI have also recognized the need to account for within country inequality as part of national human development measures [43-45] and have released an inequality-adjusted HDI [5]. However, while acknowledging inequality within countries, annual reporting of the index and sub-indices remains at the national level and the distribution of inequality within countries is not addressed. The limits of the HDI in presenting the complex nature of well-being in a single index having three dimensions are widely recognized [46-49].[9] However, the HDI remains a simple but powerful metric accessible to both a wide range of policy makers and to readers familiar with energy literature.

No surveyed literature combines an analysis of both HDI scores and energy and emissions data in India at the sub-national level. Results from this analysis are expected to compliment global

[7] This study's results will not be comparable with either state or national reports as both used older (and in some cases modified) HDI methodology.
[8] For the same reason as the last footnote, this study's results will not be comparable.
[9] Additionally, the interplay between energy choices and other inequalities within India such as intrahousehold inequality [117], gender and caste form important considerations not explored by this study.

literature on the lack of energy access [50] to modern energy services [51] – better known as energy poverty [52-54], along with literature arising from India Human Development Survey (IHDS) data. This analysis is one of the first energy focused papers to cover both 2005 and 2012 IHDS years.

Selected findings from earlier energy related IHDS works include a higher likelihood that median households located in urban slums will have electricity than median rural households [55]; a much higher share of energy poor households in rural over urban locations despite a similar share of income poor households in both locations [27]; a likely increase in household non-farm enterprise incomes from improved electricity access and availability [56]; a finding that water supply and educational attainment are major determinants of the uptake of modern fuels alongside more obvious ones such as income, fuel pricing and access [57]; findings for well-being associations that highlight the need for electricity access prioritization in rural areas and electricity availability across all of India [58]; a finding that uptake of modern fuels is impeded by large family size [59]; findings that led the author to recommend renewed Indian government focus on improved stoves and kitchen ventilation [60]; and findings for the potential for social and economic benefits for rural women from the use of improved cookstoves in Indian households [61].

Methods

Household survey selection

This study is based on publically available IHDS household survey data. The IHDS data set represents the result of a joint effort by the University of Maryland and the National Council of Applied Economic Research (NCAER), New Delhi. The 2005 data set covers 41,554 households containing 215,754 individuals. Data collection took place between November 2004 and October 2005, and accessed 1503 villages and 971 urban neighbourhoods across all but two Indian states and territories [2]. The 2012 data set covers 42,152 households containing

204,568 individuals[10,i]. Data collection took place between January 2011 and August 2013[ii], and accessed 1420 villages and 1042 urban neighbourhoods across all but two Indian states and territories. The 2012 data set includes 40,018 of the households visited during the 2005 survey. [1] Application of IHDS supplied weighting allows each survey sample to be nationally representative[iii].

The IHDS was chosen for this analysis due to the study's collection of household income data as well as consumption and detailed energy data. The income component of the IHDS study marks a departure from other India household surveys which focus on consumption or asset data as a measure of economic standing [46]. Based on an interest in calculating HDI scores by income deciles in India and comparing survey year results easily, per capita income given in constant 2011 international dollars at purchasing power parity ($PPP) is the selected metric of household economic status used in this study. Appendix A provides further information on the estimation and use of per capita income to separate India's population into deciles.

HDI calculation

HDI scores are estimated for each decile using the 2015 Human Development Report [5] methodology. The HDI is made up of three sub-indices covering income, education, and health. The estimation of those sub-indices builds from the estimation of characteristics of each decile population being analysed, such as mean income, life expectancy at birth (LEB) for a child born in the year of study, mean years of schooling (MYS) of the adult population, and expected years of schooling (EYS) for a child entering the base level of the school system in the year of study. Appendix B details the estimation of sub-indices and lists the IHDS variables used in HDI and HDI sub-index estimations.

Final estimation of the HDI involves the mathematical combination (geometric mean) of the three sub-indices. Sub-index formulas and HDI 2015 goalposts[iv], as well as an example calculation of the HDI are provided in the Technical Notes supplied with the 2015 HDR [5]. The

[10] For the methods section, this paper will switch from footnotes to appendices and endnotes as many of the methodological notes are quite lengthy and involved. Footnotes resume in the results section.

use of 2015 HDI methodology allows the HDI scores estimated by this study to be compared with HDI scores from prior years published in the UNDP's [5] 2015 HDR report. A discussion of the differences between current and older HDI methodologies can be found in Klugman et al. [62].

Energy definitions

In this study, household *modern energy* carriers include electricity, LPG and kerosene[v]. Household *solid fuels* include firewood, dung, crop residues and coal/charcoal. *Commercial* energy carriers are those purchased by a household. *Non-commercial* energy carriers are those self-collected by a household.[vi] Unless otherwise specified, all energy and emissions reported in this paper are given in MJ[vii] and tonnes carbon dioxide (t CO_2) per capita respectively. When results are reported for all of India or by quantiles, energy and emissions calculations have used IHDS supplied household weights to ensure results are representative of respective populations[viii].

This study estimates a variety of useful household energy measures. *Household boundary energy* use is defined as the amount of direct energy use within the boundaries of a household[ix]. *End-use energy* is defined as the actual useful energy delivered by an energy service after efficiency losses[x]. *Total direct primary energy use*[xi] represents household boundary energy plus the non-solar energy involved in its production[xii]. A household's *total energy requirement* is found by adding its total direct primary energy use and the *indirect energy use* arising from a household's consumption of goods and services[xiii]. *Indirect CO_2 emissions* cover the CO_2 emitted in the production of a good or service created for household consumption – also referred to interchangeably as embodied emissions in this study. *Total CO_2 emissions* cover the CO_2 emissions arising from a household's indirect CO_2 emissions as well as its *direct CO_2 emissions* arising from total direct primary energy use. To ease comparison of this studies results with national statistics and analyses that do not include non-commercial biomass energy, the study also estimates *total indirect and commercial energy carrier CO_2 emissions*.

Household boundary energy, end-use energy and total direct primary energy use and emissions for energy carriers used by households

In order to estimate the household boundary and end-use energy for a household, IHDS household consumption data and village level energy carrier data are combined with relevant energy and emissions data from literature [27, 28, 63-66] as well as government [67-74] and international [75-80] agencies. Smith et al. [63] provides the central text for India specific fuel energy content values, overall stove thermal efficiencies, and CO_2 emissions from fuel-stove combinations.[xiv]

Household boundary energy use is calculated by summing the energy content of all reported direct commercial and non-commercial energy carrier use.[xv] In the case of kerosene, IHDS provides a household's reported kerosene consumption in physical units.[xvi] In others, the IHDS reported household expenditure for a surveyed energy carrier must be divided by the reported[xvii] or estimated[xviii] price of the carrier.[xix] In the case of reported non-commercial energy use[xx], this analysis imputes[xxi] non-commercial fuel savings (avoided expenditure) for each house responding that it self-collected an energy carrier or both[xxii] self-collected and purchased an energy carrier. For each energy carrier, an imputation considers the overall energy use mix for all energy carriers in households, along with the household's urban or rural location, state, number of occupants, and IHDS provided weight. Following imputation, non-commercial energy consumption figures are estimated using the same methods as commercial energy sources.

Total direct primary energy use can now be estimated for each household. For both commercial and non-commercial firewood, dung[xxiii] and crop waste as well as non-commercial coal/charcoal, this analysis assumes that primary energy use for each energy carrier equals the household boundary fuel use. For commercial coal/charcoal, kerosene and LPG, the household boundary energy use is added to the indirect energy embodied in the energy carrier[xxiv] in order to arrive at the total direct primary energy use. In the case of electricity, this analysis chose to first account for transmission and distribution (T&D) losses [67, 68] and then account for generation efficiency as calculated from the IEA's [75, 79] energy balances for India for the appropriate year.[xxv]

CO_2 emissions arising from total direct primary energy use are estimated using the similar methods which require the addition of embodied emissions to the household based emissions for coal/charcoal, kerosene and LPG. Electricity CO_2 emissions data is calculated using the Central Electricity Agency's [69, 74] average emissions per kWh figure for each unit of net electricity generated across India's five regional grids.[xxvi]

Transportation fuels are not included in the 2005 IHDS survey and not disaggregated in the 2012 IHDs survey. Neither they, nor their impacts are included in this study's estimation of total direct primary energy use or CO_2 emissions. Similar limits on energy analyses of India household data are noted by Khandker et al. [27] and Pachauri [28]. However, as the purchase and use of personal transportation appliances is linked to income in India and represents a rapidly rising share of household energy requirement as overall household expenditures grow [30], the missing direct primary energy use and CO_2 emissions from private transportation in households can only be inferred from the indirect energy use and emissions associated with consumption of IHDS transportation categories that are included in this study's results.

Indirect energy use and CO_2 emissions from consumption of commodities other than energy carriers

In general, indirect energy and CO_2 emissions arising from the consumption of commodities other than energy carriers are calculated by multiplying adjusted expenditure[xxvii] in rupees for each of the IHDS consumption categories[xxviii] by an appropriate sectoral energy intensity value given in MJ/Rs and an appropriate emission intensity value given in kg CO_2/Rs respectively[xxix].

Although Pachauri [28] serves as the overall guide in the construction of methods used in the estimation of a household's indirect energy use, the study chose not to calculate sectoral energy and emissions intensities from scratch using a combination of government supplied IO tables and all available national energy and emissions data. This study diverges with works like

Pachauri [28], Pachauri and Spreng [29] and Parikh et al. [81] and emulates Grunewald et al. [26], by taking advantage of the growing availability of multiple region input-output (MRIO) tables that consistently cover the Indian economy over a large number of sectors, multiple years and are linked to national and global trade flows in energy and GHG emissions[xxx]. Appendix C provides relevant information on the process of determining indirect energy use and CO_2 emissions from consumption of commodities other than energy carriers.

Rural/urban energy and CO_2 emissions comparisons

Prior studies of household energy use in India indicate a large difference between urban and rural energy use patterns [27, 28]. Along with the combined all-India results that are the focus of this study, rural and urban results[xxxi] are also presented separately in Appendix E and Appendix G for comparison.

Results

Unless otherwise noted, results are presented by income decile. Decile based plots show the population with the lowest average annual per capita household incomes at the left of the horizontal axis in the decile labelled "1" and the population with the highest average annual per capita household incomes on the right of that axis in the decile labelled "10". Table 1 presents the annual per capita decile income boundaries in both scaled 2011 $PPP (and unscaled current INR) for each study year. The vertical axis of each plot corresponds to what is being presented.

Table 1 Decile annual per capita income boundaries in scaled 2011 $PPP (unscaled current INR)

Income decile	Annual per capita income boundaries in scaled 2011 $PPP			
	2005		2012	
	Lower boundary (unscaled 2005 INR)	Upper boundary (unscaled 2005 INR)	Lower boundary (unscaled 2012 INR)	Upper boundary (unscaled 2012 INR)
1	31 (91)	628 (1,857)	36 (184)	896 (4,543)
2	628 (1,857)	912 (2,697)	896 (4,544)	1,341 (6,800)
3	913 (2,698)	1,170 (3,460)	1,341 (6,800)	1,775 (9,000)
4	1,170 (3,460)	1,488 (4,399)	1,775 (9,000)	2,239 (11,356)
5	1,488 (4,400)	1,861 (5,500)	2,239 (11,356)	2,792 (14,160)
6	1,861 (5,500)	2,374 (7,018)	2,792 (14,160)	3,549 (18,000)
7	2,374 (7,018)	3,095 (9,148)	3,549 (18,000)	4,625 (23,455)
8	3,095 (9,148)	4,269 (12,621)	4,626 (23,460)	6,310 (32,000)
9	4,271 (12,625)	6,726 (19,882)	6,310 (32,000)	10,115 (51,300)
10	6,729 (19,892)	444,863 (1,315,050)	10,115 (51,300)	820,467 (4,161,000)

Welfare inequality

Figure 2 presents the result of estimations for the overall 2005 and 2012 HDI for each income decile. UNDP [5] development thresholds have been included in the graph using horizontal green lines in order to provide a reference for this study's findings. India's national HDI scores, interpolated from the scores given for the closest available years in the 2015 report, have also been indicated on the graph using appropriately coloured lines.

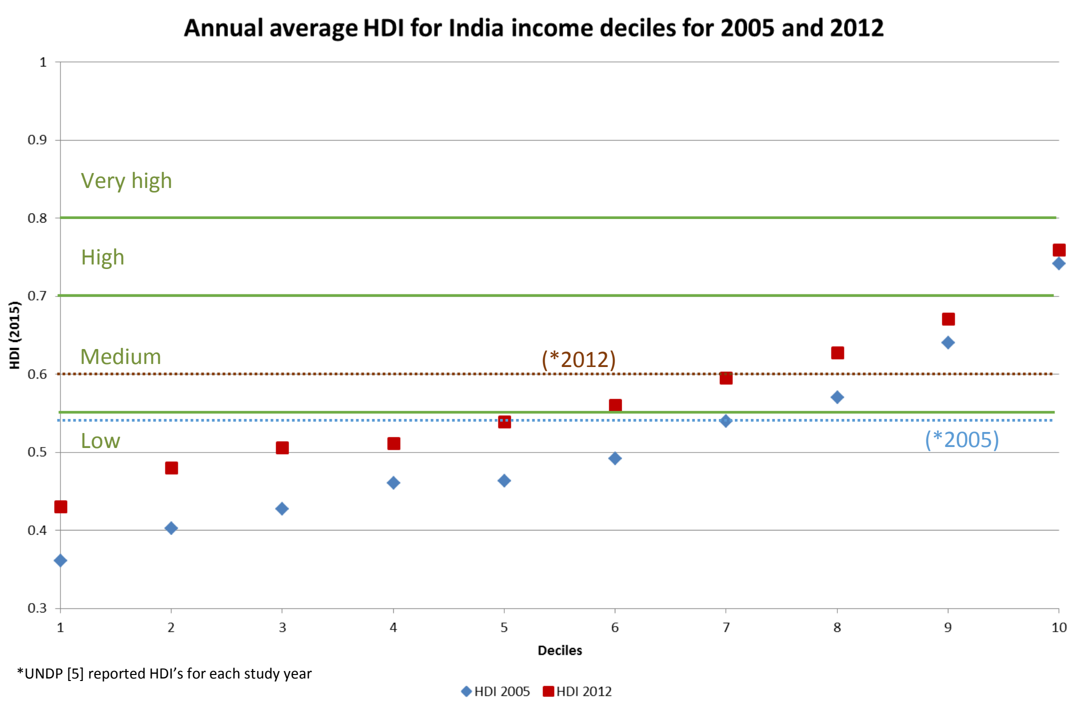


Figure 2 Average HDI for India income deciles for 2005 and 2012

Figure 2 shows a fairly large HDI inequality between top and bottom deciles for both 2005 and 2012. Although Figure 2 shows HDI gains for all deciles over the seven years separating IHDS surveys, half of India's population (~600,000 million people) is estimated to remain in low HDI territory in 2012. This is an improvement from the ~700,000 million people estimated to be in low HDI territory in 2005. For both years, the UNDP's national HDI score overestimates the average HDI of the Indian population, more closely matching the HDI score of the seventh income decile in each IHDs survey year.[11] Appendix D presents sub-indices results.

The gains of all deciles between 2005 and 2012 can be strongly attributed to education and income gains. Health gains across seven of eight deciles also help explain overall HDI improvements for those deciles. Gradually decreasing overall HDI gains of upper deciles between study years are due to the decreasing education index gains – especially for the top decile – and decreasing health index scores for the top two deciles. Uncertainties in the 2012 decile health results (see Appendix D) make it hard to conclusively determine whether HDI inequality in India is increasing, stayed roughly the same, or whether it is decreasing as Figure 2 appears to show. Welfare results separated into rural and urban locations can be found in Appendix E.

Energy & emissions inequality

Appendix F presents aggregate energy and emissions results for India. Figure 3 presents the average annual per capita direct and indirect energy requirement for India income deciles in 2005 and 2012. The income deciles presented in Figure 3 contain the same households for each year as those presented in the all-India results connected with welfare inequality.

[11] In recent years the HDR has started providing an inequality adjusted HDI along with the traditional national HDI score. It is expected that the UNDP's national inequality adjusted HDI would more closely match the mean of the distribution for each study year in this analysis. The additional work required in order to compare this study's results with the UNDP's inequality adjusted HDI for each study year is scheduled for a future revision of this paper.

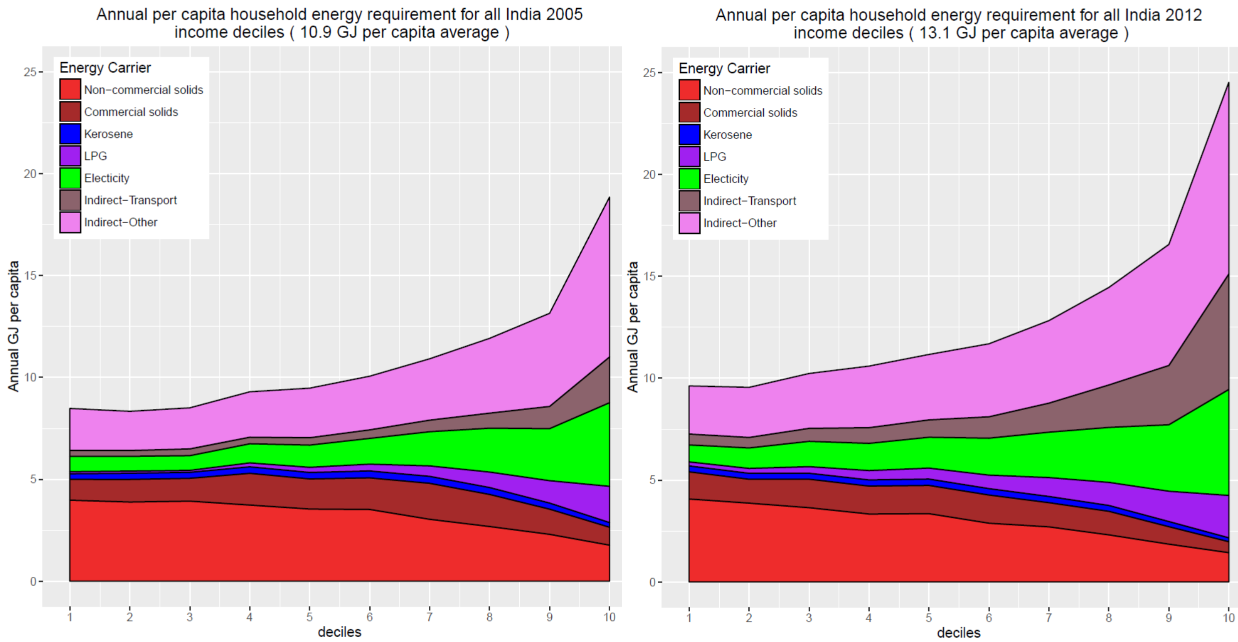


Figure 3a (left) Annual per capita household based energy requirement for all India 2005 income deciles
Figure 3b (right) Annual per capita household based energy requirement for all India 2012 income deciles

Surprisingly, both Figure 3a and Figure 3b show that total primary energy use (does not include direct emissions from transportation) sees small but fairly constant growth over deciles both *within* study years *and between* study years[12]. Results indicate that solid fuel use patterns have changed little across India's income deciles between 2005 and 2012 and that both electricity and LPG have seen growth in all deciles. As in 2005, poorer deciles in 2012 continue to rely on self-collected solid fuels for their majority of their direct household energy needs. Furthermore, results also indicate that while middle deciles in 2005 may have mixed replacement of self-collected fuels with both commercial solid and modern energy carriers before showing a clear preference for modern energy carriers in upper deciles, nearly all deciles in 2012 show a preference for modern fuels when deciding to transition from collected fuels to purchased fuels.

With respect to indirect decile energy requirements arising from household consumption, both Figure 3a and Figure 3b show a growing total requirement with income both in and between study years before a final larger jump between the ninth and tenth deciles.

[12] Due to the exclusion of some households from deciles results, average per capita emissions and energy values presented for all India results may differ slightly from those presented in decile results.

Figure 4 presents the average annual per capita CO_2 emissions from direct and indirect energy requirement for India income deciles in survey years and contain the same households for each year as those presented in Figure 3.

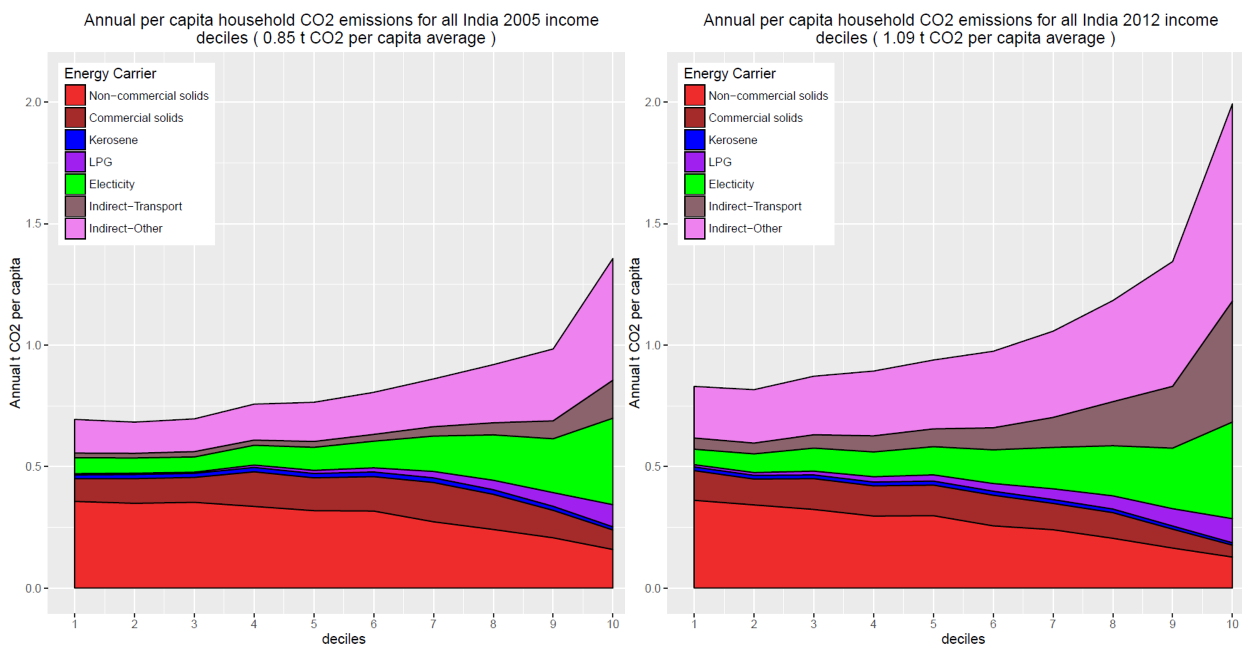


Figure 4a (left) Annual per capita household based CO_2 emissions for all India 2005 income deciles
Figure 4b (right) Annual per capita household based CO_2 emissions for all India 2012 income deciles

Figure 4 and Figure 4b show direct CO_2 emissions (not including direct transport emissions) increasing minimally but steadily across deciles within 2005, but staying nearly flat across the first nine deciles in 2012, before seeing a real increase. Indirect emissions (including from transport) represent the largest CO_2 emissions growth area across deciles and study years. The largest increase in CO_2 emissions both within each study year and across study years occurs for the richest decile.

Energy and CO_2 emission results separated into rural and urban deciles can be found in Appendix G. Decile based results showing the relationship between household boundary energy, end-use energy and CO_2 emissions from total direct primary energy use for India in both 2005 and 2012 can be found in Appendix H. Appendix I presents decile based results for total indirect and commercial energy carrier CO_2 emissions.

Combined welfare and energy inequality

Figure 5 presents HDI results for 2005 and 2012 varying with the household CO_2 emissions for each decile. HDI 2015 thresholds and results have been included in Figure 5 in the same manner that they were included in Figure 2.

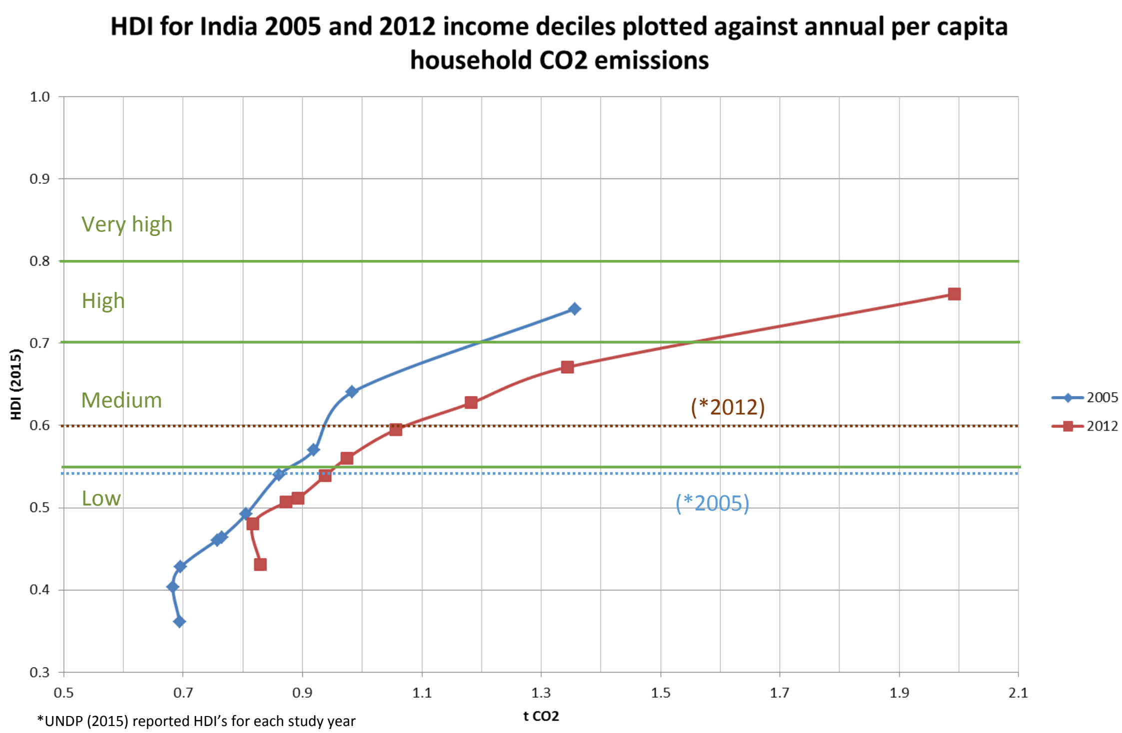


Figure 5 HDI for India 2005 and 2012 income deciles plotted against annual per capita household CO2 emissions

In general, Figure 5 shows that between 2005 and 2012, both HDI scores and CO_2 emissions grew for all decile groups in India. With the exception of move from the first to second decile group, Figure 5 also clearly suggests that increases in emissions accompany decile HDI score increases both within and between study years. Additionally, for the richest three deciles, emissions appear to be growing more quickly than gains in HDI between study years. Figure 5 also shows a small unexpected CO_2 emissions increase for the poorest population in each study year. Presentation of combined HDI, household boundary energy, and end-use energy can be found in Appendix J.

Findings/Discussion

Presented results are largely as one might expect and show HDI, total energy requirements and emissions rising with incomes in both 2005 and 2012. However, a few surprises and important puzzles arise when looking more closely at different aspects of household energy use. A brief discussion of how this study's results compare with relevant recent studies of disaggregated HDIs and the energy requirements and CO_2 emissions of Indian households can be found in Appendix K. A brief discussion of end-use energy findings can be found in Appendix L.

Drawing conclusions cautiously from combined welfare and energy inequality

Insights into energy, emissions, human development and welfare relationships arise naturally from results – and some directionality will be discussed – but causality is not demonstrated by this analysis and caution is required when drawing conclusions. For example, the results presented in Figure 5 can be interpreted to suggest that household energy use, and the resulting CO_2 emission increases of lower deciles between 2005 and 2012 have driven fairly sizable gains in HDI for those deciles over that time span. That is a possibility. However, when Figure 4 is included in the analysis, compelling alternative interpretations arise.

Figure 4 shows the total emissions connected to direct use household energy changing little in lower deciles despite the replacement of solid fuels with modern fuels. While the health benefits from lowered household air pollution (HAP) and greater efficiency of modern fuel use in households may be directly or indirectly supporting the increased incomes which result in HDI increases of lower deciles, evidence demonstrating such a relationship is not provided by this study. What is clear is that the increasing CO_2 emissions of lower (and all) deciles between study years can be attributed largely to higher emissions from household consumption.

A study such as Rao [56], which draws on IHDS 2005 data, and finds a likely increase in household non-farm enterprise incomes from improved electricity access, might be used to argue that energy directly supports wealth creation. However, even if electricity is available at a village, neighbourhood or household level, poor households must also be able to afford the energy services provided by electricity. Although Ahmad and Puppim de Oliveira [57] find education[13] to be one of a few major determinants of the uptake of modern fuels in Indian households, it is increased wealth which eventually allows households to sustain the transition from self-collected solid fuels that do not have a direct monetary cost attached to them, to modern energy carriers that require income to purchase. Increased income also supports the consumption of goods and services – with their own energy and CO_2 emissions requirements – that the growth of most national economic systems relies on. Increased wealth, regardless of the source and support system, appears to be central driver for both HDI gains and increasing household emissions between deciles both across and within study years.

Moving from solid but renewable and locally accessible energy carriers to modern but non-renewably produced and market dependent fuels

Firewood and other local biomass energy carriers (dung, crop residue, charcoal) represent renewable[14] energy sources and, as study results show in Figure 3, are generally accessible to poorer households who can self-collect these resources. The modern alternatives in India are largely non-renewable produced electricity, kerosene and LPG, none of which can be self-collected and all of which come with financial cost. Commonly stated motivations for making the transition to modern energy carriers include reductions in deforestation and the time and drudgery penalties associated with self-collection of energy carriers and use of inefficient energy services – especially for women and children [82].

The improvements in HAP that come with lowered in-home emissions from more efficiently

[13] Modern energy's critical role in supporting public infrastructure (schools, hospitals, water, sanitation) that directly supports development [110], does not show up in household consumption surveys and is not captured by the results shown in any of the figures in this paper. If it did, it would result in increased emissions attributed to India's poorer populations benefitting from that development (as might be indicated by HDI increases).

[14] "Renewable" is used with this definition - sustainably harvested and arising from natural processes [118]. The FAO [119] reported that India, with a national forest cover of 22% and 2% of the world's forest area in 2015, was one of the ten top countries in the world that gained forest area between 2010 and 2015. More research is needed to determine what the relationship between forests area gains and domestic firewood use (if there is any at all), in order to discuss whether biomass use in India is sustainable.

used and less locally emission intensive energy carriers are also a critical component in improving the human welfare of household residents. The World Health Organization (WHO) [83] estimates that deaths from HAP related to the combustion of solid fuels for cooking reached 4.3 million globally in 2012. The health benefits of a transition away from household solid fuel use in India are surveyed by Kankaria et al. [84] and are most evident in the case of a transition involving a household's cooking solution [85]. Although the scope of the cooking solution challenge in 2012 remained large with less than 400 million people living in households able to access and afford modern cooking solutions and only 86 million people living in households using improved biomass stoves with chimneys, there are some hopeful indications of beneficial change occurring between 2005 and 2012. IHDS data indicates that between 2005 and 2012, the number of people living in households using biomass stoves with chimneys nearly doubled (44m in 2005) and the number of people living in households using modern cooking solutions also nearly doubled (209m in 2005). However, IHDS data also indicates that the number of people living in households cooking in unventilated areas only reduced from 248 million to 241 million people.

The connection of the challenge with poverty is clear. In 2012, the percentage of the population living in households cooking in unventilated areas drops from over 29% (31.4% in 2005) of the poorest decile's population to under 9% (10.9% in 2005) of the richest income decile's population, and modern cooking solution usage moves from under 9% (4.4% in 2005) of the poorest decile's population to over 74% (59.5% in 2005) of the richest deciles population. Taken together the poor remain much more likely in 2012 to be living in households that cook in unventilated areas using solid fuels.

Interestingly, IHDS data suggests that between 2005 and 2012, improved chulhas with chimneys appear to have reached poorer households in large enough numbers to invert the observed distribution between deciles in 2005. In 2005, improved chulha usage reached as few as 3.1% the population living in poorer deciles and increased to up to 6.6% of the population living in the richest deciles. However, in 2012 this trend reversed, with up to 9.1% of the population living in poorer deciles reporting improved chulha usage and only 4.7% of the population living in the richest deciles reporting the same.

The reason for this reduction in the richest deciles can probably be attributed to the transition from solid to modern cooking solutions found in the results of this analysis. The reasoning and mechanisms supporting the transition to improved chulhas in poorer deciles cannot be guessed at using IHDS data, but is an area with human welfare and policy implications [60, 61, 83-85] deserving of further research. Similarly, the impacts of such transitions on human welfare measures such as LEB are part of a complex puzzle that will not be solved as part of this analysis. One might reason after consulting relevant literature that LEB (and HDI) in India, especially in poorer deciles, will be positively impacted as HAP decreases, but the results of the LEB analyses in this study extend do not extend to causality.

Growth of total household emissions in 2012 despite a decrease in average household emissions from total direct primary energy use from 2005 to 2012

This study finds that average emissions from total direct primary energy use in Indian households in 2012 actually returned a small decrease (2%) from 2005 emission levels. However, as can be observed in Figure 4, India's average total household emissions per capita grew from 0.85 to 1.09 t CO_2 between 2005 and 2012. A growth in India's per capita indirect emissions from an average of 0.26 to 0.51 t CO_2 over the same time span provides an explanation as to this change. While indirect CO_2 emissions increased by more than 63% for each decile between 2005 and 2012, for the richest four deciles it more than doubled. The growth in incomes observed for all deciles between 2005 and 2012 in Figure 10 are not only aiding the achievement of higher HDI scores shown in Figure 2 but also appear to be driving the relationship between growing HDI scores and total household emissions shown in Figure 5. This relationship suggests that unless the emissions intensity of goods and services consumed in India are reduced, higher incomes resulting in higher HDI scores and greater household consumption in India will come with a growth in indirect emissions.

In the case of emissions intensive services such as transportation, Figure 4 indicates agreement with Pachauri's [30] finding that high incomes have facilitated a rapid growth in CO_2 emissions from that sector. As only the indirect emissions from transportation (private and public) can be included in this study, it is critical that the direct emissions arising from private transportation be included in further research. A complete understanding of total household CO_2 emissions and energy use is hindered by their omission.

Constancy of household emissions despite small increase in total direct primary energy use and large increase in modern energy carrier use

Figure 4 suggests that despite only a small increase in total direct primary energy use and a much larger transition to modern energy carriers as incomes increase in 2012, per capita household emissions from total direct primary energy use do not decrease, but stay generally constant across the deciles. In theory, the move to more efficient modern energy carriers should overshadow the small increase in total primary energy use and result in reduced total CO_2 emissions.

The major factor operating against the expected reduction in household emissions in richer deciles in 2012 India is the fairly high emissions intensity and low T&D efficiency of India's largely coal powered electricity grid. In 2012, coal fired generation represented nearly 72% of India's electricity generation capacity [80] and T&D losses were estimated at 25.7%. Emission reductions from the use of increasingly efficient and modern energy powered services as incomes rise are unlikely unless the emissions intensity of India's grid is reduced and T&D losses are minimized. Although India has taken steps to reduce T&D losses from 30.4% in 2005, to 25.7% in 2012, and 23.04% in 2013-2014 [68], the last figure was still roughly three times the 2013 global average for grid T&D losses of 8.16% [86].

Decreases in India's grid CO_2 emissions intensity are expected to arise from both a product of continued improvements in T&D losses and proposed expansion of solar PV and wind generation facilities in the next decade [87]. However, India's need to improve grid reliability and meet rapidly growing electricity demand may also provide drivers for higher grid CO_2 emissions intensities. Bhattacharyya's [88] scenario of grid expansion through expansion of coal generation infrastructure offers one pathway to the realization of that possibility.

If India can continue with critical reductions in the CO_2 emissions intensity of its grid, this will aid India's population in minimizing the CO_2 emissions of households as they make the transition to modern energy carriers and higher HDI scores. For example, the 0.2 improvement in HDI score (0.43 to 0.63) observed in the transition from decile one to eight in 2012 in Figure 5 corresponds only to a 2.5% increase in CO_2 emissions (0.572 to 0.585 t CO_2 per capita) from direct total primary energy use (not including transportation) in households. The eighth decile uses more than three times the electricity, nearly six times the LPG, self-collects only 57% of the fuel of the first decile, and has reduced solid fuel by 36%. However, it should be observed that the eighth income decile in India in 2012 has still not reached 'high' or 'very high' human development categories according to UNDP [5] scoring. In fact a high human development score is not reached in the either IHDS survey year until incomes reach the tenth decile.

Discussing household energy and CO_2 emission results in an energy poverty context

Results of this study suggest that addressing energy poverty in India, strictly defined as a lack of access to modern energy services, might be pursued with little to no impact on total direct per capita household CO_2 emissions[15], by extending an inefficient and carbon intensive electricity grid to all households in India. However, unless the wealth creation required to maintain a sustained energy carrier transition at the household level can be decoupled from the increased CO_2 emissions arising from household consumption underpinned by the Indian electricity grid – especially lifestyle rather than basic needs related consumption as wealth grows – then the carbon lock-in [89] created by this extension will ensure a high base emissions intensity[16] of Indian goods and services until carbon intensive plants are retrofitted or replaced. If wealth creation and household consumption trends observed in the results of this analysis hold during the period of grid expansion and subsequent years of carbon lock-in, then India's one billion strong population will represent an ever increasing share of global CO_2 emissions for years to

[15] This argument assumes that CO2 emissions from biomass fuels cannot be viewed 'carbon neutral', even if there may be some grounds for treating dung and crop and forest residues in this fashion [111].

[16] Reductions up to a base level dictated by the primary fuel type are possible through efficiency gains and reductions in T&D losses.

come. In short, growing incomes and the extension of a carbon intensive grid in India can address energy poverty, but both provide inertia for the central drivers for consumption based CO_2 emissions of richer Indians.

Although exploring options to address this tension are beyond the current scope of this study, a few broad options can be put forth. Changing individual behaviour as wealth grows represents one option, but is unlikely given global views on consumption's relationship to modern lifestyles. Distributed generation systems aimed at separating potentially carbon intensive energy poverty alleviation and wealth creation efforts from those aimed at reducing the carbon intensity of Indian goods and services, represents a more likely option that may already be occurring in some areas of India. A third option involves extending the grid rapidly to address energy poverty and create wealth, but doing so using only generation options that lower the emissions intensity of India's grid. Under current global energy and emissions related pressures, reducing energy poverty at the same time as lowering the emissions intensity of India's grid represents not just a national, but a global imperative. Discussions of financing for the energy transitions India requires in order to develop and reduce poverty among its people, while also considering global GHG emission requirements, should be referred to Chancel and Piketty [7], whose arguments regarding responsibilities for funding climate related adaptation, also seem applicable here.

Discussing household CO_2 emission results in a global context

The difference between the total household CO_2 emissions presented in this study and national emissions for India put forth in global discussions of climate change and social justice requires unpacking. Critically, the results of this study do not include direct CO_2 emissions from a household's private means of transportation. Less obvious, but also important is that the study's focus on CO_2 leaves out a sizeable portion of the GHG's arising from household energy use and consumption of goods and services in India. For example, Chakravarty et al.'s [8] CO_2 focused paper would need to be extended to other GHGs in order to capture the roughly 25% of global GHG emissions missing from their analysis. Studies such as Pathak et al. [90], which estimates that CO_2 represents only 16% of GHG arising from the life cycle of a panel of common

Indian food items, provide further illustration of the need to include other GHGs in household energy and emissions analyses.

Global discussions of human induced climate change regularly refer to CO_2-equivalent (CO_2e) emissions from India, which move beyond just CO_2 to cover a wider range of GHGs. This study's finding of an average household emissions level of 1.09 t CO_2 per capita for India in 2012 (0.83 t CO_2 per capita if only commercial and indirect sources of emissions are considered) must be understood as a share of the 1.64 t CO_2 (excluding Land-use change and forestry[17]) and 2.39 t CO_2e (excluding LUCF) annual per capita emissions estimated to be attributed to India by combining World Resources Institute [91] and UN [92] data[18]. This study's CO_2 emissions finding also represents a share of the 2.1 t CO_2e annual per capita emissions attributed to India by recent compelling work from Chancel and Piketty [7], who demonstrate the use of CO_2e emission intensities available in MRIO databases in order to consider GHG emissions responsibility in an unequal world.[19] As part of their analysis they estimate that the average per capita GHG emissions needed from now until 2100 for the world's population to keep global warming below 2° C is 1.2 t CO_2e.[20]

Table 2 estimates the share of this study's annual average per capita emissions in each national figure discussed. Table 2 also estimates decile based results for each national figure by scaling it

---

[17] See Chapter 17 in Baumert et al. [110] for more on Land-use change and forestry (LUCF)

[18] These figures represent production-based accounting emissions. Chancel and Piketty [7] estimate a consumption-based accounting estimate of 2.1 t CO2e annual per capita emissions for India in 2013, which also excludes LUCF.

[19] Chancel and Piketty's [7] calculation of a global distribution of individual carbon emissions, notably moves beyond CO_2 to include other greenhouse gases and allows them to capture 88% of global CO_2e emission in 2013. Their ability to discuss responsibility also arises in part as a by-product of an emissions accounting method change from production to consumption that is made possible by the relatively recent emergence of comprehensive environmental IO data sets (GTAP, EORA, …) with the necessary breadth of coverage to complement chosen income data sets. The shift from production to consumption-based emission accounting allows the authors to attribute the indirect emissions embedded in traded goods and services to consumers rather than producers, and strengthens linkages between income and emissions and allows the authors to move away from discussion of the carbon intensity of national economies to the lifestyles of high emitting individuals.

[20] The authors arrive at this number by dividing IPCC estimates of an 88 year, 1000 GT CO_2e emissions allowance under scenario RCP 2.6 [120] by the sum of annual UN population estimates through 2100. The authors choose RCP 2.6 as it is the only modelled scenario in [120] that *likely* contains the global temperature rise range to below 2°C. In tables in the document, the number appears as 1.3 tCO_2e. Their estimate appears to average global emissions between estimates including and excluding land use change emissions.

proportionately to this study's decile based household CO_2 emission results.

Table 2 Global Indian emission attributions for 2012 (unless marked otherwise) scaled proportionately to this study's decile based household emission results from household consumption and all energy carriers

Category	India Avg	Study share	1	2	3	4	5	6	7	8	9	10	World Avg
CO_2 household 2012, (all), p	1.09	100%	0.83	0.82	0.87	0.89	0.94	0.97	1.06	1.18	1.34	1.99	
CO_2 national 2012, p [91, 92]	1.64	66%	1.25	1.23	1.31	1.35	1.41	1.47	1.59	1.78	2.02	3.00	4.77
CO_2e national 2012, p, ex. LUCF [91, 92]	2.39	46%	1.82	1.79	1.91	1.95	2.05	2.13	2.31	2.59	2.94	4.36	6.31
CO_2e national 2013, c, [7]	2.10	52%	1.60	1.57	1.68	1.72	1.81	1.88	2.04	2.28	2.59	3.84	6.20

* p = production-based accounting, c = consumption-based accounting

This study's household emissions which include those arising from total direct primary energy use and indirectly from household consumption, but do not include direct household emissions from transportation represent 66%, 46% and 52% of the various national GHG emissions figures attributed to India in 2012. The scaled decile CO_2e emission results (choose a flavour) shown in Table 2 suggest that even the poorest decile in India in 2012 had CO_2e emissions above Chancel and Piketty's [7] sustainable average emission threshold to keep global warming to under 2° C. Scaled CO_2 emissions results for India also suggest that the poorest decile in India is already above Chakravarty et al.'s [8] proposed 1 t CO_2 emissions floor to be reached by 2030.

However, caution should be exercised as national and global emissions may only account for emissions from commercial sources[21]. Using emission results that include non-commercial energy carriers to attribute shares of national emissions to income deciles may result in the under-attribution of emissions to richer deciles, and over attribution to poorer deciles. Table 3 mirrors Table 2, but presents results using only emissions from household consumption and commercial sources.

---

[21] Handling of emissions from energy carriers considered renewable also requires close scrutiny. Depending on one's view of how emissions from renewable energy carriers should be accounted for, and which of India's energy carriers should be considered renewable, an argument might be made for a different accounting method from the one used in this study. Direct emissions from all energy carriers are included in national and deciles results. No indirect emissions are attributed to non-commercial energy carriers, or commercial dung, firewood or crop residue.

Table 3 Global Indian emission attributions for 2012 (unless marked otherwise) scaled proportionately to this study's decile based household emission results from household consumption and only commercial energy carriers

Category	India Avg	Study share	1	2	3	4	5	6	7	8	9	10	World Avg
CO_2 household 2012, (all), p	0.83	100%	0.47	0.47	0.55	0.60	0.64	0.72	0.82	0.98	1.18	1.86	
CO_2 national 2012, p [91, 92]	1.64	50%	0.93	0.94	1.09	1.18	1.27	1.42	1.62	1.94	2.34	3.70	4.77
CO_2e national 2012, p, ex. LUCF [91, 92]	2.39	35%	1.35	1.36	1.58	1.72	1.84	2.07	2.35	2.82	3.39	5.37	6.31
CO_2e national 2013, c, [7]	2.10	39%	1.19	1.20	1.39	1.51	1.62	1.82	2.07	2.48	2.99	4.73	6.20

* p = production-based accounting, c = consumption-based accounting

Table 3 provides estimates that the household CO_2 emissions arising from only commercial sources that this study captures, represent lower shares (50%, 35%, and 39%) of India's national GHG emissions in 2012. Table 3 further indicates that if household emissions from commercially purchased energy and consumption were used for scaling national figures, then the poorest 20% of India had yet to reach a 1 t CO_2 emissions floor in 2012, and Chancel and Piketty's [7] consumption based 2013 emissions accounting figure represented the only Indian CO_2e emissions attribution under which a few deciles (1.19 and 1.20 t CO_2e for first and second deciles respectively) had not yet crossed a threshold of 1.2 t CO_2e. Table 3 also suggests that the CO2 and CO2e emissions for India's richest decile have yet to reach world average emissions in those categories. However, it is expected that national emissions attributed to the top decile in Table 3 would near or exceed the world average and GHG emissions of bottom deciles would decrease further, if this study was able to fully include direct emissions from transportation in decile results. Wider GHG coverage, an exploration of national and global GHG accounting of non-commercial and renewable energy carriers, and direct transportation emissions all arise as important areas for inclusion in future analyses similar to this one.

Conclusion: Wealth, HDI and emissions: no longer a puzzle but the challenge

This study's results suggest that one option for supporting the move to modern fuels, an improved HDI score and a reduction in household emissions is supporting the improved wealth and economic productivity of India's poor. However, our results also show that increasing wealth inevitably coincides with increased consumption – consumption supplied via a carbon intensive grid and carbon dependent materials such as plastic [93] and steel [94]. In fact, for the richest 10% of Indians, 61% of all energy consumed and 66% of CO_2 emissions arise from the consumption of non-energy carrier goods and services. At the same time, the richest 10% of Indian's only emit 20% more emissions from total direct primary energy use than the poorest 10% (not including direct emissions from private transportation).

Until wealth creation and human development is decoupled from consumption or zero carbon intensity energy and household products are introduced at large scale into the Indian economy to support livelihood growth, households with rising incomes will see consumption form an increasingly dominant share of household energy use and CO_2 emissions. Given that there is a pressing need to reduce greenhouse gas emissions in order to minimize the degree to which global climates change, the time India has to make such transitions is an open and unresolved question. A large part of the answer to that question depends on the resolve of the world's top emitters [8] to make needed changes or at least take responsibility for funding adaptation [7] for the world's most vulnerable populations.

Table 2 provides an estimate of 3 t CO_2 for the annual average per capita CO_2 emissions of India's top decile in 2012. That represents 63% of the global average in that year. Per capita CO_2 emissions for the rest of India's deciles in 2012 were significantly lower, decreasing from the ninth decile's estimated 2 t CO_2 emissions which were only 43% of the world average that year. From this perspective India appears to have the time to engineer needed energy and emissions transitions. However, when considering that only an estimated 20% of India's population in 2013 was emitting levels of CO_2e lower than the amount required to keep global warming below 2° C [7], and that 20% represents the least developed population in India, time appears to be less on India's side.

With respect to making lasting improvements in the lives of its poorer populations as might be indicated by higher HDI scores, India faces two conflicting and resource intensive tasks. The first involves leveraging the roll out of modern energy carriers to increase incomes and improve public health, its education system and the living environments of its poorest households. Enabling access that allows for affordability as well as availability to those energy carriers is a key part of laying the groundwork to accomplish well-being improvements for India's poorest populations [57, 58]. The second involves reducing the emissions intensity of the modern energy carriers India uses to carry out that task and which, along with carbon intensive consumption items, play an increasing part in the Indian population's CO_2 emissions as their incomes rise. Key aspects of the second task include reducing the carbon intensity of India's grid, finding or creating replacement for high emissions goods and services currently imported into India, finding carbon neutral [bio-derived] replacement feedstocks used in the production of the plastic, steel and other carbon intensive materials that comprise many modern goods, and implementing the low carbon intensity recycling of such materials.

References

1. Desai, S. and R. Vanneman, *India Human Development Survey-II (IHDS-II), 2011-12*. 2016, Inter-university Consortium for Political and Social Research (ICPSR) [distributor].
2. Desai, S., R. Vanneman, and N.D. National Council of Applied Economic Research, *India Human Development Survey (IHDS), 2005*. 2016, Inter-university Consortium for Political and Social Research (ICPSR) [distributor].
3. Lenzen, M., et al., *Mapping the structure of the world economy.* Environmental science & technology, 2012. **46**(15): p. 8374-8381.
4. Lenzen, M., et al., *Building Eora: a global multi-region input–output database at high country and sector resolution.* Economic Systems Research, 2013. **25**(1): p. 20-49.
5. UNDP, *Human Development Report 2015: Work for Human Development*. 2015, New York, NY: United Nations Development Programme.
6. Smith, K.R. and A. Sagar, *Making the clean available: Escaping India's chulha trap.* Energy Policy, 2014. **75**: p. 410-414.
7. Chancel, L. and T. Piketty, *Carbon and inequality: from Kyoto to Paris*. 2015, Paris School of Economics.
8. Chakravarty, S., et al., *Sharing global CO2 emission reductions among one billion high emitters.* Proceedings of the National Academy of Sciences, 2009. **106**(29): p. 11884-11888.
9. International Energy Agency (IEA) and the World Bank, *Sustainable Energy for All 2015—Progress Toward Sustainable Energy*. Global Tracking Framework Report. 2015, Washington DC: World Bank.

10. Olivier, J.G.J., et al., *Trends in global CO2 emissions: 2016 Report*. 2016, PBL Netherlands Environmental Assessment Agency: The Hague.
11. Government of India, *India's intended nationally determined contribution*. 2015, COP21: Paris.
12. World Bank, *Energy use (kg of oil equivalent per capita)*, in *World Development Indicators*. 2016: Washington DC.
13. IEA, *World Energy Outlook 2004*. 2004, Paris: OECD.
14. Suárez, C.E., *Energy Needs for Sustainable Human Development*, in *Energy as an Instrument for Socio-Economic Development*, T.B.J.a.J. Goldemberg, Editor. 1995, UNDP: New York.
15. Shyu, C.-W., *Ensuring access to electricity and minimum basic electricity needs as a goal for the post-MDG development agenda after 2015.* Energy for Sustainable Development, 2014. **19**(0): p. 29-38.
16. Gaye, A., *Access to energy and human development*, in *Human Development Report 2007/2008*. 2007, UNDP.
17. Steinberger, J.K. and J.T. Roberts, *From constraint to sufficiency: The decoupling of energy and carbon from human needs, 1975–2005.* Ecological Economics, 2010. **70**(2): p. 425-433.
18. Lamb, W.F., et al., *Transitions in pathways of human development and carbon emissions.* Environmental Research Letters, 2014. **9**(1): p. 014011.
19. Lenzen, M., *Energy and greenhouse gas cost of living for Australia during 1993/94.* Energy, 1998. **23**(6): p. 497-516.
20. Lenzen, M., et al., *A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan.* Energy, 2006. **31**(2): p. 181-207.
21. Roca, J. and M. Serrano, *Atmospheric Pollution and Consumption Patterns in Spain: An Input-Output Approach.* Nota di lavoro, 2007. **62**.
22. Wier, M., et al., *Effects of household consumption patterns on CO2 requirements.* Economic Systems Research, 2001. **13**(3): p. 259-274.
23. Kerkhof, A.C., S. Nonhebel, and H.C. Moll, *Relating the environmental impact of consumption to household expenditures: An input–output analysis.* Ecological Economics, 2009. **68**(4): p. 1160-1170.
24. Bin, S. and H. Dowlatabadi, *Consumer lifestyle approach to US energy use and the related CO 2 emissions.* Energy policy, 2005. **33**(2): p. 197-208.
25. Weber, C.L. and H.S. Matthews, *Quantifying the global and distributional aspects of American household carbon footprint.* Ecological Economics, 2008. **66**(2): p. 379-391.
26. Grunewald, N., et al., *The carbon footprint of Indian households*, in *32nd General Conference of The International Association for Research in Income and Wealth*. 2012: Boston. p. 5-11.
27. Khandker, S.R., D.F. Barnes, and H.A. Samad, *Are the energy poor also income poor? Evidence from India.* Energy Policy, 2012. **47**: p. 1-12.
28. Pachauri, S., *An energy analysis of household consumption: Changing patterns of direct and indirect use in India*. Springer Science & Business Media. Vol. 13. 2007.

29. Pachauri, S. and D. Spreng, *Direct and indirect energy requirements of households in India.* Energy policy, 2002. **30**(6): p. 511-523.
30. Pachauri, S., *An analysis of cross-sectional variations in total household energy requirements in India using micro survey data.* Energy Policy, 2004. **32**(15): p. 1723-1735.
31. Cohen, C., M. Lenzen, and R. Schaeffer, *Energy requirements of households in Brazil.* Energy Policy, 2005. **33**(4): p. 555-562.
32. Leontief, W.W., *Quantitative input and output relations in the economic systems of the United States.* The review of economic statistics, 1936: p. 105-125.
33. Bullard III, C.W. and R.A. Herendeen, *The energy cost of goods and services.* Energy policy, 1975. **3**(4): p. 268-278.
34. Herendeen, R. and J. Tanaka, *Energy cost of living.* Energy, 1976. **1**(2): p. 165-178.
35. Lenzen, M., *Primary energy and greenhouse gases embodied in Australian final consumption: an input–output analysis.* Energy Policy, 1998. **26**(6): p. 495-506.
36. Miller, R.E. and P.D. Blair, *Input-output analysis foundations and extensions / Ronald E. Miller and Peter D. Blair*. 2nd ed.. ed. 2009, Cambridge: Cambridge : Cambridge University Press.
37. Goldemberg, J., et al., *Basic Needs and Much More with One Kilowatt per Capita.* Ambio, 1985. **14**(4/5): p. 190-200.
38. Government of Madhya Pradesh, *The Madya Pradesh Human Development Report*. 1995: Bhopal.
39. Planning Commission. *State Human Development Reports*. 2013 18 September 2014 [cited 2016 27 September]; Available from: http://planningcommission.gov.in/plans/stateplan/index.php?state=b_shdrbody.htm.
40. Planning Commission. *National Human Development Report 2001*. 2002 [cited 2016 27 September]; Available from: http://planningcommission.gov.in/reports/genrep/nhdrep/nhd2001.zip.
41. Grimm, M., et al., *Inequality in human development: An empirical assessment of 32 countries.* Social Indicators Research, 2010. **97**(2): p. 191-211.
42. Harttgen, K. and S. Klasen, *A Household-Based Human Development Index.* World Development, 2012. **40**(5): p. 878-899.
43. Alkire, S. and J.E. Foster, *Designing the inequality-adjusted human development index.* 2010.
44. Kovacevic, M., *Measurement of inequality in Human Development–A review.* Measurement, 2010: p. 35.
45. UNDP, *Beyond scarcity: Power, poverty and the global water crisis*. Human Development Report 2006. 2006.
46. Desai, S.B., et al., *Human development in India.* 2010.
47. Alkire, S. and M.E. Santos, *Acute Multidimensional Poverty: A New Index for Developing Countries* 2010, Oxford Poverty & Human Development Initiative University of Oxford.
48. Anand, S. and A. Sen, *The Income Component of the Human Development Index.* Journal of Human Development, 2000. **1**(1): p. 83-106.
49. Nathan, H.S.K. and S. Mishra, *Progress in human development: Are we on the right path?* International Journal of Economic Policy in Emerging Economies, 2010. **3**(3): p. 199-221.

50. Pachauri, S., *Reaching an international consensus on defining modern energy access.* Current Opinion in Environmental Sustainability, 2011. **3**(4): p. 235-240.
51. Sovacool, B.K., *Conceptualizing urban household energy use: Climbing the "Energy Services Ladder".* Energy Policy, 2011. **39**(3): p. 1659-1668.
52. IEA, *Chapter 13: Energy and Poverty*, in *World Energy Outlook 2002*. 2002, OECD Publishing. p. 365-404.
53. Pachauri, S. and D. Spreng, *Measuring and monitoring energy poverty.* Energy Policy, 2011. **39**(12): p. 7497-7504.
54. Nussbaumer, P., M. Bazilian, and V. Modi, *Measuring energy poverty: Focusing on what matters.* Renewable and Sustainable Energy Reviews, 2012. **16**(1): p. 231-243.
55. Aklin, M., et al., *Quantifying slum electrification in India and explaining local variation.* Energy, 2015. **80**(1): p. 203-212.
56. Rao, N.D., *Does (better) electricity supply increase household enterprise income in India?* Energy Policy, 2013. **57**: p. 532-541.
57. Ahmad, S. and J.A. Puppim de Oliveira, *Fuel switching in slum and non-slum households in urban India.* Journal of Cleaner Production, 2015. **94**: p. 130-136.
58. Ahmad, S., M.V. Mathai, and G. Parayil, *Household electricity access, availability and human well-being: Evidence from India.* Energy Policy, 2014. **69**: p. 308-315.
59. Kumar, R., *Implications of 'Energy Poverty' of the Poor in India*. 2011, Duke University.
60. Zhang, Y., *Household Energy Use, Indoor Air Pollution, and Health Impacts in India: A Welfare Analysis*. 2009, University of Maryland.
61. Sheikh, R.I., *Energy and Women's Economic Empowerment: Rethinking the Benefits of Improved Cookstove Use in Rural India*. 2014, Georgetown University.
62. Klugman, J., F. Rodríguez, and H.-J. Choi, *The HDI 2010: new controversies, old critiques.* The Journal of Economic Inequality, 2011. **9**(2): p. 249-288.
63. Smith, K.R., et al., *Greenhouse gases from small-scale combustion devices in developing countries, Phase IIa: Household Stoves in India.* US Environmental Protection Agency, Research Triangle Park, NC, 2000: p. 98.
64. Reddy, B.S. and T. Srinivas, *Energy use in Indian household sector – An actor-oriented approach.* Energy, 2009. **34**(8): p. 992-1002.
65. Misra, J.B., S.K. Yadav, and S. Chauhan, *Inverse relationship between oil content and specific gravity of groundnut kernels.* Journal of the Science of Food and Agriculture, 1993. **61**(2): p. 231-234.
66. Singh, S., et al., *Comparative study of indoor air pollution using traditional and improved cooking stoves in rural households of Northern India.* Energy for Sustainable Development, 2014. **19**: p. 1-6.
67. Central Electricity Authority, *Transmission and Distribution Losses (T&D Losses)*.
68. Central Statistics Office, *Energy Statistics 2015*, M.o.S.a.P.I. National Statistical Organization, Editor. 2015, Government of India: New Delhi.
69. Central Electricity Authority, *CO2 Baseline Database*. 2007.
70. National Sample Survey Office, *Prices and Wages in Rural India, October 2011 to December 2011*, M.o.S.P. Implementation, Editor. 2012, Government of India.
71. Central Electricity Authority, *Statement showing estimated average rates of electricity (Updated up to 31.03.2009)*, F.S.A. Division, Editor. 2009.

72. Central Electricity Authority, *Tariff and Duty of Electricity Supply in India*. 2012, Ministry of Power, Government of India.
73. Central Electricity Authority, *Tariff and Duty of Electricity Supply in India*. 2013, Ministry of Power, Government of India.
74. Central Electricity Authority, *CO2 Baseline Database*. 2016.
75. IEA. *India: Balances for 2005*. 2016 [cited 2016 28 August]; Available from: http://www.iea.org/statistics/statisticssearch/report/?year=2005&country=INDIA&product=Balances.
76. Regional Wood Energy Development Programme in Asia (RWEDP), *Woodfuel Flows,* . 1996, FAO: Bangkok, Thailand.
77. World Bank. *Inflation, consumer prices (annual %)*. 2016 14 June 2016 [cited 2016 25 June]; Available from: http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG.
78. IEA. *India: Electricity and Heat for 2005*. 2016 [cited 2016 26 August]; Available from: http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=electricityandheat&year=2005.
79. IEA. *India: Balances for 2012*. 2016 [cited 2016 20 October]; Available from: http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=Balances&year=2012.
80. IEA. *India: Electricity and Heat for 2012*. 2016 [cited 2016 20 October]; Available from: http://www.iea.org/statistics/statisticssearch/report/?year=2012&country=INDIA&product=ElectricityandHeat.
81. Parikh, J., et al., *CO 2 emissions structure of Indian economy.* Energy, 2009. **34**(8): p. 1024-1031.
82. Practical Action, *Poor people's energy outlook 2014: Key messages on energy for poverty alleviation*. 2014, UK: Practical Action Publishing Ltd.
83. WHO. *Household air pollution and health*. 2016 February 2016 [cited 2016 16 September]; Available from: http://www.who.int/mediacentre/factsheets/fs292/en/.
84. Kankaria, A., B. Nongkynrih, and S.K. Gupta, *Indoor air pollution in India: Implications on health and its control.* Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine, 2014. **39**(4): p. 203.
85. Sambandam, S., et al., *Can Currently Available Advanced Combustion Biomass Cook-Stoves Provide Health Relevant Exposure Reductions? Results from Initial Assessment of Select Commercial Models in India.* EcoHealth, 2015. **12**(1): p. 25-41.
86. IEA. *Electric power transmission and distribution losses (% of output)*. 2014 [cited 2016 19 September]; Available from: http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.
87. IEA, *India Energy Outlook 2015*, in *World Energy Outlook Special Report*. 2015, OECD/IEA: Paris France.
88. Bhattacharyya, S.C., *Influence of India's transformation on residential energy demand.* Applied Energy, 2015. **143**: p. 228-237.
89. Unruh, G.C., *Understanding carbon lock-in.* Energy Policy, 2000. **28**(12): p. 817-830.
90. Pathak, H., et al., *Carbon footprints of Indian food items.* Agriculture, Ecosystems & Environment, 2010. **139**(1): p. 66-73.
91. WRI, *CAIT Climate Data Explorer*. 2015, World Resources Institute: Washington, DC.

92. United Nations Population Division, *World Population Prospects: The 2015 Revision*. 2015, Department of Economic and Social Affairs.
93. Mülhaupt, R., *Green Polymer Chemistry and Bio-based Plastics: Dreams and Reality.* Macromolecular Chemistry and Physics, 2013. **214**(2): p. 159-174.
94. Norgate, T., et al., *Biomass as a Source of Renewable Carbon for Iron and Steelmaking.* ISIJ International, 2012. **52**(8): p. 1472-1481.
95. World Bank. *PPP conversion factor, private consumption (LCU per international $)*. 2016 14 June 2016 [cited 2016 25 June]; Available from: http://data.worldbank.org/indicator/PA.NUS.PRVT.PP.
96. World Bank. *GNI per capita, PPP (constant 2011 international $)* 2016 14 June 2016 [cited 2016 28 June]; Available from: http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.KD.
97. UNESCO Institute for Statistics, *UIS Methodology for estimation of mean years of schooling*. 2013.
98. UNESCO Institute for Statistics, *India International Standard Classification of Education (ISCED) 2011 Mapping*. 2014.
99. Huebler, F., *Education indicators in the HDI: Expected years of schooling and mean years of schooling*, in *Workshop on Measuring Human Development*. 2013, UNESCO Institute for Statistics: Eschborn.
100. Toson, B. and A. Baker, *Life expectancy at birth: methodological options for small populations.* National statistics methodological series, 2003. **33**.
101. Shah, I. and V. Gosavi, *Human Development Index and Human Poverty Index for Indian states, 2005: Multivariate Statistical Analysis of basic indicators*, in *Department of Statistics*. 2010, Lund University.
102. London Health Observatory, *Calculating life expectancy and infant mortality rates*, in *Mapping health inequalities across London: technical supplement*. 2001.
103. Barik, D., S. Desai, and R. Vanneman, *Economic Status and Adult Mortality in India*. 2016.
104. Silcocks, P., D. Jenner, and R. Reza, *Life expectancy as a summary of mortality in a population: statistical considerations and suitability for use by health authorities.* Journal of Epidemiology and Community Health, 2001. **55**(1): p. 38-43.
105. World Health Organization, *Life tables by country India* in *Global Health Observatory data repository*. 2016.
106. UNDP, *Human Development Report 2010 The Real Wealth of Nations: Pathways to Human Development*. 2010: NY,NY.
107. IEA. *Balance Definitions*. [cited 2017 24 January]; Available from: https://www.iea.org/statistics/resources/balancedefinitions/#biofuelsandwaste.
108. Ministry of Statistics and Programme Implementation, *Energy Statistics*. 2014, Central Statistics Office, Government of India: New Delhi.
109. Chandrashekhar, V., *Up in Smoke*, in *The Caravan*. 2015.

110. Karekezi, Stephen, Susan McDade, Brenda Boardman, and John Kimani. 2012. "Chapter 2 - Energy, Poverty and Development." In Global Energy Assessment - Toward a Sustainable Future, 151-190. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.

111. Searchinger, Timothy D, Steven P Hamburg, Jerry Melillo, William Chameides, Petr Havlik, Daniel M Kammen, Gene E Likens, Ruben N Lubowski, Michael Obersteiner, and Michael Oppenheimer. 2009. "Fixing a critical climate accounting error." Science 326 (5952):527-528.
112. Baumert, Kevin A, Timothy Herzog, and Jonathan Pershing. 2005. Navigating the numbers: Greenhouse gas data and international climate policy: World Resources Institute.
113. Dikhanov, Y., Income Effect and Urban-Rural Price Differentials from the Household Survey Perspective. ICP Global Office, February, 2010.
114. UNSD. Exchange Rates and Population. http://unstats.un.org/unsd/snaama/dnllist.asp, 2015 (accessed 6 September 2016).
115. United Nations Statistics Division. GDP per capita. http://unstats.un.org/unsd/snaama/glossresults.asp?gID=9, 2015 (accessed 20 September 2016).
116. Gelman A, Hill J. Data analysis using regression and multilevel/hierarchical models: Cambridge University Press; 2006.
117. Coffey D, Khera R, Spears D. Intergenerational effects of women's status: Evidence from joint Indian households. Working Paper; 2015.
118. IEA. Renewables. https://www.iea.org/topics/renewables/, 2016 (accessed 16 September 2016).
119. Food and Agriculture Organization of the United Nations. Global Forest Resources Assessment 2015, How are the world's forests changing? Rome2015.
120. IPCC. Climate Change 2014, Mitigation of Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014.
121. Woodbridge, R, M Sharma, and D Fuente. 2005. "Atlas of Household Energy Consumption and Expenditure in India." Chennai, India: Institute for Financial and Management Research.
122. Budya, Hanung, and Muhammad Yasir Arofat. 2011. "Providing cleaner energy access in Indonesia through the megaproject of kerosene conversion to LPG." Energy Policy 39 (12):7575-7586.
123. Viswanathan, Brinda, and KS Kavi Kumar. 2005. "Cooking fuel use patterns in India: 1983–2000." Energy Policy 33 (8):1021-1036.
124. Barnes, Douglas F, and M Sen. 2002. "Energy Strategies for Rural India: Evidence from Six States." ESMAP, Washington, DC Available at http://imagebank. worldbank. org/servlet/WDS_IBank_Servlet.
125. Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. 2010. Energy Poverty in Rural and Urban India. In Policy Research Working Paper: World Bank.

Appendix A

So as not to skew results by including richer households reporting large income losses in the bottom decile, this study follows suit with IHDS 2005 methods [2] and removes all households with a reported annual income less than 1,000 rupees (Rs 2005) from consideration for the quantile based analyses[xxxii,xxxiii].

For decile based analyses, average per capita income is calculated by dividing total reported household income by the number of persons in the house[xxxiv]. Households are then sorted by average per capita income to get a distribution having the lowest per capita household income at one end and the highest per capita household income at the other end. Average per capita income for each household is then multiplied by the IHDS supplied weighting to arrive at the portion of Indian population that household is meant to represent. The total population represented by the survey is then divided by ten, and households are sorted into decile groups aligning as closely as possible with a decile share of the representative population[xxxv]. After finishing this procedure, the first decile contains households having the lowest per capita incomes in India while the tenth decile contains those with the highest per capita incomes.

Table 4 lists the IHDS variables used in sorting and placing households in income deciles.

Table 4 IHDS variables used in sorting and placing households in income deciles

IHDS variables used in sorting and placing households in income deciles	relevant 2005 IHDS variables	relevant 2012 IHDS variables
	idhh , income , incfarm , incbus , copc , hhassets , npersons , urban , sweight , income5	idhh , income , incag , incbus , copc , assets , npersons , urban2011 , wt

Appendix B

In order to calculate each sub-index for a decile, certain characteristics of the population being analysed must be estimated. For the income sub-index, the decile's mean per capita *income* in constant 2011 international dollars at purchasing power parity ($PPP) must be known. This is arrived at by finding the mean of a deciles household per capita incomes in current 2005 or 2012 rupees, transforming the figure to constant 2011 rupees using Indian consumer price inflation values from the World Bank [77] and then applying a 2011 rupee to 2011 $PPP conversion factor for private consumption, also supplied by the World Bank [95]. Before placing the resultant per capita income into the HDI income sub-index formula, each value is scaled using a factor calculated by dividing the World Bank Gross National Income for India in the appropriate year in constant 2011 $PPP [96] by the mean of the income distribution across all deciles for each year in the study[xxxvi].

For the education sub-index, *mean years of schooling* and *expected years of schooling* for each decile must be found[xxxvii]. Mean years of schooling is calculated, according to UNESCO [97] guidelines and referencing the India specific International Standard Classification of Education (ISCED) mapping[xxxviii] [98] shown in , by taking the mean of the highest year of schooling achieved by the 25 and older population in each decile[xxxix]. Expected years of schooling represents the number of years of schooling a child from a specific decile entering school in the year of the study, can expect to achieve before leaving school, and involves a more complicated calculation, the details of which can be found in Harttgen and Klasen [42] and a UNESCO Institute for Statistics [99] presentation.

Table 5 ISCED 2011 mapping to IHDS education years completed for use in HDI Mean Years of School calculations

IHDS 2005		IHDS 2012		UNESCO India Mapping		
Standard years completed	Highest degree/diploma completed	Standard years completed	Highest degree/diploma completed	ISCED 2011 Level	ISCED 2011 Theoretical duration	**Years used in analysis**
missing	N/A	missing	N/A	0	0	**0**
0	missing or None (0)	0	missing or Inc/None (1)	0	0	**0**
1	missing or None (0)	1	missing or Inc/None (1)	1	1	**1**
2	missing or None (0)	2	missing or Inc/None (1)	1	2	**2**
3	missing or None (0)	3	missing or Inc/None (1)	1	3	**3**
4	missing or None (0)	4	missing or Inc/None (1)	1	4	**4**
5	missing or None (0)	5	missing or Inc/None (1)	1	5	**5**
6	missing or None (0)	6	missing or Inc/None (1)	2	6	**6**
7	missing or None (0)	7	missing or Inc/None (1)	2	7	**7**
8	missing or None (0)	8	missing or Inc/None (1)	2	8	**8**
9	missing or None (0)	9	missing or Inc/None (1)	3	9	**9**
10	missing or None (0)	10	missing or Inc/None (1)	3	10	**10**
11	missing or None (0)	11	missing or Inc/None (1)	3	11	**11**
12	missing or None (0)	12	missing or Inc/None (1)	3	12	**12**
13	missing or None (0)	13	missing or Inc/None (1)	3,4	13	**13**
14	missing or None (0)	14	missing or Inc/None (1)	4	14	**14**
15	Bachelors (1)			6	15-16	**15.5**
		15	BA/BSc/B.Com/BCA/BBA (2)	6	15	**15**
		16	BE/B.Tech. (3)	6	16	**16**
		16	MBBS/BAMS (4)	7	17-18	**17.5**
15	Master's (2)	16	Master's degree/Ph.D. (5)	7,8	17-20	**18.5**
15	Professional (3)	16	Professional degree(MD, Law, MBA, CA etc.) (6)	*6,7,8*	*17-20*	**18.5**
15	Vocational (4)			6	16-19	**17.5**
		16	Diploma < 3 years (7)	6	16-17	**16.5**
		16	Diploma 3 & more years (8)	6	18-19	**18.5**
15	Others (5)	16	Others (9)	6	*16*	**16**

For the health sub-index, *life expectancy at birth (LEB)* for the decile must be found. LEB for a decile represents the number of years an infant born into that decile during the year of study can expect to live. Methods for estimating LEB using IHDS data are provided in Toson and Baker [100] along with Shah and Gosavi [101], who use a London Health Observatory [102] report for methodological guidance. While needed deaths data is readily available in the 2005 IHDS data set, deaths data for the 2012 LEB analysis needed to be pieced together using multiple 2012 IHDS data sets[xl]. This introduces both difficulty and error into 2012 LEB estimations[xli] not present in 2005 estimations.

More problematic (but less obviously so) in the calculation of LEB by quantiles, are adult deaths – especially older adult deaths – that have been excluded from IHDS mortality tracking between survey years due to death [103], and/or migration prior to death [100]. These deaths result in a

2005 household not be resurveyed in 2012 and that death not being captured by IHDS data. The addition of new households to the survey to maintain sample representativeness of India's population is not able to account for this loss – especially as recent deaths of adults in the newly added households was not recorded[xlii]. Table 6 shows the share of the population represented by new households in each income decile in the 2012 analysis.

Table 6 Share of population represented by new households in each income decile in the 2012 analysis.

Decile	Share of population represented by new households
1	1.2%
2	1.3%
3	2.1%
4	3.3%
5	3.0%
6	4.0%
7	5.8%
8	6.1%
9	8.5%
10	9.8%

For the 2012 LEB analysis, this study decided to proceed with only households that are included in both 2005 and 2012 IHDS survey rounds. These households comprise over 95% of the total Indian population represented by the 2012 survey, but when considered by decile groups, can comprise as little as 90.2% of the population represented by a single decile (98.8% in the poorest decile decreasing to 90.2% in the richest decile). In theory all deaths from this sample should be captured by 2012 IHDS data sets, but deaths of the very elderly will be under represented, as will a growing number of deaths across all age groups in upper deciles missing an increasingly greater share of their representative population.

Following consultation with relevant literature [100, 102, 104], a few methodological decisions were made to improve accuracy of estimate of expectation of life for 2012.

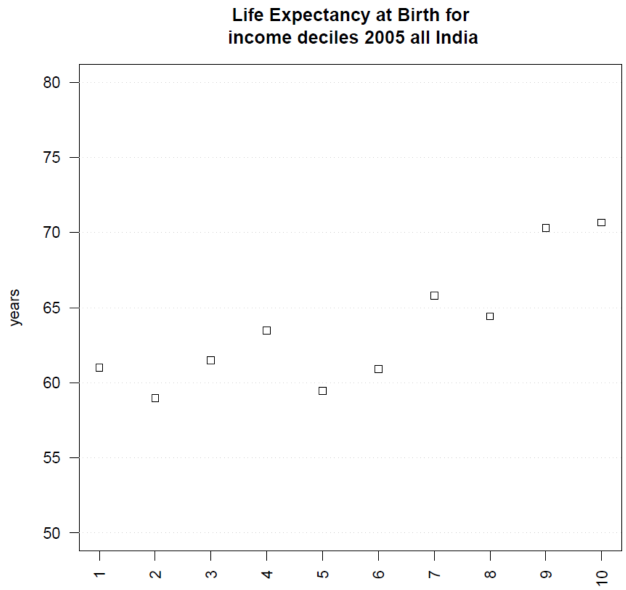
1. The study increase number of years from which 2012 deaths data is drawn from one to three, in order to increase "the number of deaths for a particular age band and improves the accuracy of our estimation of expectation of life" [102]. This alteration

makes the LEB less accurate for an infant born in 2012 by merging the death and life counts over the three years prior to 2012.

2. The top age group of the analysis was set with a "lower age limit as high as possible" [100], in order to attempt to account for differences in the social structures of decile populations [100, 104]. This upper limit was chosen at 95 as this was the first open ended age group (in increments of five) in which zero deaths began to appear in deciles. Toson and Baker [100] suggest that in the UK, an upper age band of 90 and over might be advisable when analysing large regions and note that raising the upper age group may introduce bias in populations with lots of elderly migration.
3. The study decided to use a method suggested by Toson and Baker [100] for dealing with a lack of data on elderly deaths, by replacing the average age specific death rate (asdr) for the top age group in every decile with uniform asdr, in this case simple average of male and female WHO [105] asdrs for the 95 years and above age group.

The 2005 analysis only has access to one year of recorded deaths in 2005 IHDS data, but the upper age limit of 95 years and above, and use of a year appropriate uniform top asdr from WHO [105] data was used to more closely align the methods between the two study years.

Results for the 2005 LEB analysis can be compared between Figure 6 which shows results using an 85 years and above upper age group and no uniform default top age specific death rates (asdr), and Figure 7 which shows results using an 95 years and above upper age group with uniform replacement of top asdr.



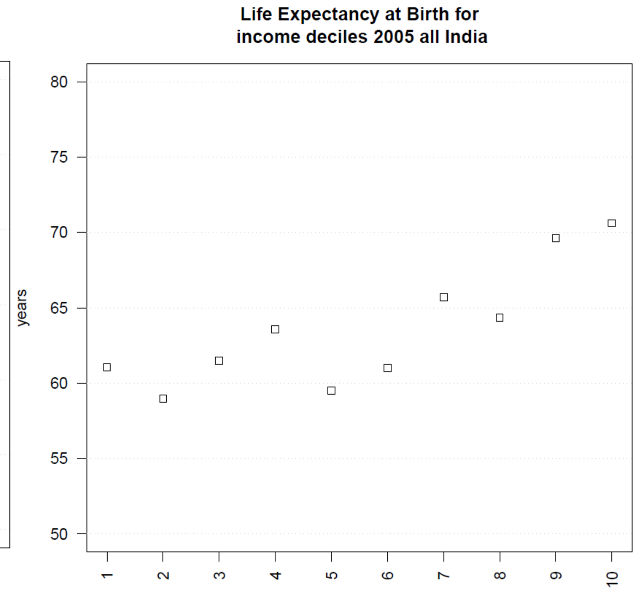
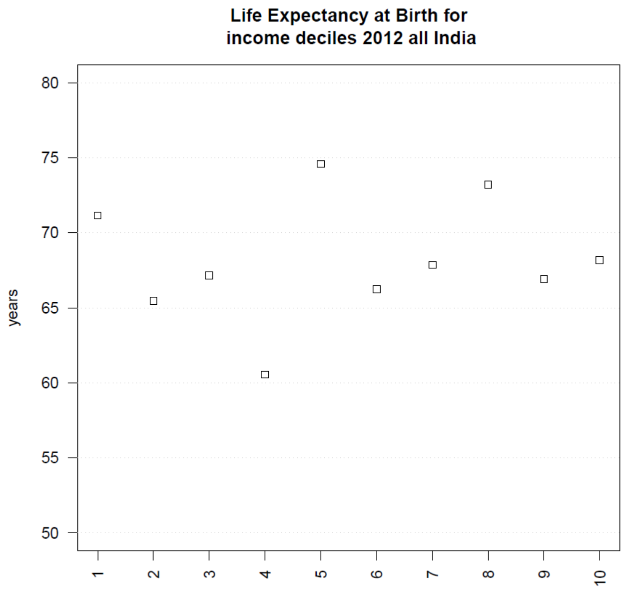


Figure 6 2005 LEB results with top age group set to 85 and without uniform use of default asdr for top age group (left)
Figure 7 2005 LEB results with top age group set to 95 and with use of a uniform asdr for top age group (right)

Figure 6 and Figure 7 show little practical difference between parameters other than the slight lowering of the LEB of the top two deciles that arises from the use of a higher upper age group and a uniform top asdr.

Results for the 2012 LEB analysis can be compared between Figure 8 which shows results using an 85 years and above upper age group, only deaths in the past year, and no uniform default top age specific death rates (asdr), and Figure 9 which shows results using an 95 years and above upper age group, all deaths in the past three years, and uniform replacement of top asdr.



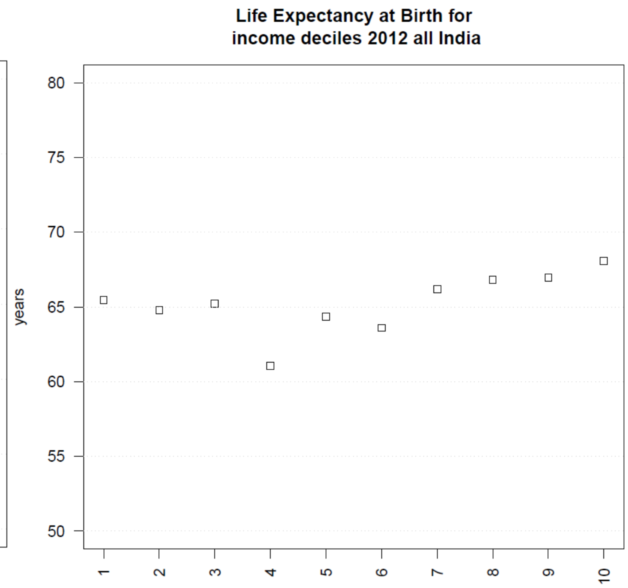


Figure 8 2012 LEB results with top age group set to 85, only deaths in the past year, and no uniform top asdr (left)
Figure 9 2012 LEB results with top age group set to 95, deaths from the past three years, and a uniform top asdr (right)

The lack of stability in 2012 results when changes are made suggests caution in interpreting 2012 LEB results.

Table 7 lists the IHDS variables used in HDI and HDI sub-index estimations.

Table 7 IHDS variables used in HDI and HDI sub-index estimations

HDI sub-index input	relevant 2005 IHDS variables	relevant 2012 IHDS variables
Income	income , npersons , sweight	income , npersons , wt
Mean Years of Schooling (MYS)	ro5 , ed5 , ed12 , sweight	ro5 , ed6 , ed12 , wt
Expected Years of Schooling (EYS)	ed4 , ed5 , ed6 , ro5 , sweight	ed5 , ed6 , ed7 , ro5 , wt
Life Expectancy at Birth (LEB)	ro5 , de4a , de4b , de4c , sweight	stateid , distid , psuid , hhid , hhsplitid, tk1ro5 , personid , th3 , idhh , bh7 , cd3date , bh5a , bh5b , bh6a , bh6b , bh8a , bh8b , ro5 , wt

Appendix C

Grunewald et al. [26] calculate the CO_2 footprint of Indian households in 2004-2005 using survey data and estimations of the total emissions intensity for 130 sectors of India's economy for 2004-2005. Unlike Grunewald et al. [26] who opt to use Global Trade Analysis Project (GTAP) data, this study selects the EORA database [3, 4]. This decision was determined by time constraints, the wide scope of the study, a view that a critical database should not be behind a paywall, and the ready availability of energy and emissions intensities for India from database providers for both years considered[xliii]. This study uses the 116 sectoral energy and CO_2 emissions intensities provided by EORA in order to calculate indirect energy use and CO_2 emissions. Despite the importance of non-commercial energy in sectors of India's economy – particularly the agricultural and industrial sectors – as noted and estimated by Pachauri [28][xliv], no effort is made to estimate the non-commercial energy involved in each sector of India's economy. Nor is the use of non-commercial energy attributed to the production of self-collected firewood, dung, crop residue or home-grown goods.[xlv]

Before calculating the indirect energy and emissions involved with each household consumption item, this study allocates the sectoral intensities provided by EORA to the IHDS consumption categories for each survey year. While Pachauri [28] and Grunewald et al. [26] were consulted during this process, common sense and IHDS questionnaire wording led to selection of the final allocations for each category. Table 8 and Table 9 detail the results of this process for 2005 and 2012. Table 10 provides a list of the 116 sectors for which energy and emissions intensity were provided by EORA.

Table 8 Allocation of Indian economic sectors to IHDS 2005 household consumption variables [columns 1-3 modified from 2]

IHDS.2005	label	Questionairre.description	India.EORA.sectors.2005	Change.to.2012
co1	Rice		1,	same
co2	Wheat		2,	same
co3	Sugar		33,	same
co4	Kerosene		58,	same
co5	Other cereals		3,4,5,	same
co6	Cereal products like bread, muri, chira, maida, suji, noodles		38,	moved to co13
co7	Pulses and pulse products	(includes soyabean, gram)	6,7,	co6
co8	Meat, chicken and fish		19,22,	co7
co9	Gur and other sweeteners	(includes candy, misri, honey, etc.)	19,34,38,	co8
co10	Edible oil and vanaspati		35,36,	co9
co11	Eggs		20,	co10
co12	Milk		18,	co11
co13	Milk products like ghee, butter, ice cream, milk powder, dahi, paneer, etc.		18,	co12
co14	Vegetables	(including garlic, ginger)	17,	same
co15	Salt/spices	(includes dry chillies, curry powder, oilseeds, etc.)	17,32,	same
co16	Other food items like tea/coffee, processed foods such as biscuits, cake, pickles, sauce		12,13,37,38,	split to co16 and co17
co17	Paan/ tobacco/ intoxicants		39,40,	co18
co18	Fruits/nuts	(includes mango, banana, coconut, dates, kishmish, monacca, other dried fruits.)	9,15,17,	co19
co19	Food at restaurants, eating out, etc		108,	co20
co20	Fuel and light	(LPG, firewood, electricity) exclude kerosene	51,58,100,	split to co21 and co22
co21	Entertainment	(includes cinema, picnic, sports club fees, video cassettes.)	114,	co23
co22	Telephone/cable/internet		114,	co24
co23	Personal care	(includes spectacles, torch, umbrella, lighter, etc.)	98,	co47
co24	Toilet articles	(includes toothpaste, hair oil, shaving blades, etc.)	52,56,57,66,	co25 and renamed
co25	Household items	(includes electric bulb, tubelight, glassware, bucket, washing soap, agarbati, insecticides, etc.)	57,63,66,71,76,86,90,	split to co26 and co27
co26	Conveyance	(includes railway, bus, hired taxi, rickshaw, air fares, porter charges, auto,school bus/van, etc.)	103,104,114,	co28 and renamed
co27	House rent, rent (also for rented household appliances, furniture, etc.)		109,111,114,	co30
co28	Consumer taxes, cesses, and fees	(includes water charges)	102,115,	co31
co29	Services	(domestic servants, other)	114,	co32
co30	Medical expenses	(out patient services)	65,113,	co33
co31	Medical (in-patient)		65,113,	co34
co32	School / Private Tuition Fees	(includes private tutor, school / college fees)	112,	split to co35 & co36
co33	School books and other educational articles	(includes newspaper, library charges, stationery, internet charges)	52,53,82,114,	co37
co34	Clothing/bedding		42,43,44,45,46,48,49,55,	co38
co35	Footwear		54,56,	co39
co36	Furniture/fixtures	(includes bed, almirah, suitcase, carpet, paintings, etc.)	47,49,50,56,64,	co40
co37	Crockery/utensils	(includes stainless steel utensils, casseroles, thermos, etc.)	57,77,	co41
co38	Cooking and household appliances	(includes electric fan, AC, sewing machine, washing machine, pressure cooker, refrig.)	87,	co42
co39	Goods for recreation	(includes TV, radio, tape recorder, musical instruments)	51,52,77,90,98,	co43
co40	Jewelry and ornaments		98,	co44
co41	Personal transport equipt	(includes bicycle, two-wheeler, car tyres, etc.)	58,93,94,95,96,98,101,	split co45 & co29
co42	Therapeutic appliances	(includes eye-glass, hearing aids, orthopedic equipment, etc.)	98,	co46
co43	Other personal goods	(includes clock, watch, PC, telephone, mobile, etc.)	82,88,97,98,	co48
co44	Repair/maintenance	of residential buildings, bathroom equipment, etc. [NOT NEW BUILDING]	114,	co49
co45	Insurance premiums		110,	co50
co46	Vacations		58,103,104,108,114,	co51
co47	Social functions	(marriage, funerals, gifts, etc.)	108,114,	co52
	non commercial energy use in MJ		20,21,23,	
fu1c	commercial electricity		100,	
fu5b	commercial firewood		51,	
fu6b	commercial dung		20,	
fu7b	commercial crop residue		17,	
fu8b	commercial kerosene		58,	
fu9b	commerical LPG		58,	
fu10b	commercial coal/charcoal		23,	

Table 9 Allocation of Indian economic sectors to IHDS 2012 household consumption variables [columns 1-3 modified from 1]

IHDS.2012	label	Questionairre.description	India.EORA.sectors.2012
co1	Rice		1,
co2	Wheat/Flour		2,
co3	Sugar		33,
co4	Kerosene		58,
co5	Other cereals		3,4,5,
co6	Pulses and pulse products	(includes soyabean, gram)	6,7,
co7	Meat, chicken and fish		19,22,
co8	Gur and other sweeteners	(includes candy, misri, honey, etc.)	19,34,38,
co9	Edible oil and vanaspati		35,36,
co10	Eggs		20,
co11	Milk		18,
co12	Milk products like ghee, butter, ice cream, milk powder, dahi, paneer, etc.		18,
co13	Cereal products like bread, muri, chira, maida, suji, noodles.		38,
co14	Vegetables	(including garlic, ginger)	17,
co15	Salt/spices	(includes dry chillies, curry powder, oilseeds, etc.)	17,32,
co16	Tea/Coffee		12,13,37,
co17	Processed food	(such as biscuits, cake, pickles, sauce, etc.)	38,
co18	Paan/ tobacco/ intox.		39,40,
co19	Fruits/nuts	(includes mango, banana, coconut, dates, kishmish, monacca, other dried fruits.)	9,15,17,
co20	Food at restaurants, eating out, etc		108,
co21	Household fuel	(LPG, firewood, cowdung) Exclude kerosene	20,51,58,
co22	Household electricity		100,
co23	Entertainment	(includes cinema, picnic, sports club fees, video cassettes.)	114,
co24	Telephone/Mobile, cable/dish, internet charges		114,
co25	Cosmetics/toilet	(includes toothpaste, hair oil, shaving blades, etc.)	52,56,57,66,
co26	Household items	(includes electric bulb, tubelight, glassware, bucket, etc.)	57,71,76,86,90,
co27	Soap, detergent/washing powder, agarbati, insecticide, etc.		63,66,
co28	Transportation	(includes railway, bus, hired taxi, rickshaw, air fares, porter charges, auto,school bus/van, etc.)	103,104,114,
co29	Diesel/petrol/CNG, maintenance	(Owned vehicle)	58,101,
co30	House rent, society charges, house loan installment, other rent (includes appliances, cooler, AC, etc.)		109,111,114,
co31	Consumer taxes, cesses, and fees	(includes water charges & house tax)	102,115,
co32	Services	(domestic servants, barber, laundry, etc.)	114,
co33	Medical expenses	(out patient services)	65,113,
co34	Medical (in-patient)		65,113,
co35	School/colleg fee		112,
co36	Private tuition	(Coaching fees)	112,
co37	School books and other educational articles	(includes newspaper, library charges, stationery, internet charges)	52,53,82,114,
co38	Clothing/bedding		42,43,44,45,46,48,49,55,
co39	Footwear		54,56,
co40	Furniture/fixtures	(includes bed, almirah, suitcase, carpet, paintings, etc.)	47,49,50,56,64,
co41	Crockery/utensils	(includes stainless steel utensils, casseroles, thermos, etc.)	57,77,
co42	Cooking and household appliances	(includes electric fan, AC, sewing machine, washing machine, pressure cooker, refrig.)	87,
co43	Recreation goods	(includes TV, radio, tape recorder, musical instruments)	51,52,77,90,98,
co44	Jewelry and ornaments		98,
co45	Personal transport equipt	(includes bicycle, two-wheeler, car tyres, etc.)	93,94,95,96,98,
co46	Therapeutic appliances	(includes eye-glass, hearing aids, orthopedic equipment, etc.)	98,
co47	Personal care & houehold items	(includes spectacles, torch, umbrella, lighter, etc.)	98,
co48	Other personal goods	(includes clock, watch, PC, telephone, mobile, etc.)	82,88,97,98,
co49	Repair/maintenance	of residential buildings, bathroom equipment, etc. [NOT NEW BUILDING]	114,
co50	Insurance premiums		110,
co51	Vacations/Holidays		58,103,104,108,114,
co52	Social functions	such as marriage, funerals, etc. other than reported above	108,114,
	non commercial energy use in MJ		20,21,23,
fu1c	commercial electricity		100,
fu7b	commercial firewood		51,
fu8b	commercial dung		20,
fu9b	commercial crop residue		17,
fu10b	commercial kerosene		58,
fu11b	commerical LPG		58,
fu12b	commercial coal/charcoal		23,

Table 10 Sectors for which EORA provides energy and CO_2 emissions information for 2005 and 2012 [altered from 3, 4]

#	Country, country code, type, sector	#	Country, country code, type, sector
1	India,IND,Commodities,Paddy	59	India,IND,Commodities,Coal tar products
2	India,IND,Commodities,Wheat	60	India,IND,Commodities,Inorganic heavy chemicals
3	India,IND,Commodities,Jowar	61	India,IND,Commodities,Organic heavy chemicals
4	India,IND,Commodities,Bajra	62	India,IND,Commodities,Fertilizers
5	India,IND,Commodities,Maize	63	India,IND,Commodities,Pesticides
6	India,IND,Commodities,Gram	64	India,IND,Commodities,Paints, varnishes and lacquers
7	India,IND,Commodities,Pulses	65	India,IND,Commodities,Drugs and medicines
8	India,IND,Commodities,Sugarcane	66	India,IND,Commodities,Soaps, cosmetics & glycerin
9	India,IND,Commodities,Groundnut	67	India,IND,Commodities,Synthetic fibers, resin
10	India,IND,Commodities,Jute	68	India,IND,Commodities,Other chemicals
11	India,IND,Commodities,Cotton	69	India,IND,Commodities,Structural clay products
12	India,IND,Commodities,Tea	70	India,IND,Commodities,Cement
13	India,IND,Commodities,Coffee	71	India,IND,Commodities,Other non-metallic mineral prods.
14	India,IND,Commodities,Rubber	72	India,IND,Commodities,Iron, steel and ferro alloys
15	India,IND,Commodities,Coconut	73	India,IND,Commodities,Iron and steel casting & forging
16	India,IND,Commodities,Tobacco	74	India,IND,Commodities,Iron and steel foundries
17	India,IND,Commodities,Other crops	75	India,IND,Commodities,Non-ferrous basic metals
18	India,IND,Commodities,Milk and milk products	76	India,IND,Commodities,Hand tools, hardware
19	India,IND,Commodities,Animal services(agricultural)	77	India,IND,Commodities,Miscellaneous metal products
20	India,IND,Commodities,Other livestock products	78	India,IND,Commodities,Tractors and agri. implements
21	India,IND,Commodities,Forestry and logging	79	India,IND,Commodities,Industrial machinery(F & T)
22	India,IND,Commodities,Fishing	80	India,IND,Commodities,Industrial machinery(others)
23	India,IND,Commodities,Coal and lignite	81	India,IND,Commodities,Machine tools
24	India,IND,Commodities,Crude petroleum, natural gas	82	India,IND,Commodities,Office computing machines
25	India,IND,Commodities,Iron ore	83	India,IND,Commodities,Other non-electrical machinery
26	India,IND,Commodities,Manganese ore	84	India,IND,Commodities,Electrical industrial Machinery
27	India,IND,Commodities,Bauxite	85	India,IND,Commodities,Electrical wires & cables
28	India,IND,Commodities,Copper ore	86	India,IND,Commodities,Batteries
29	India,IND,Commodities,Other metallic minerals	87	India,IND,Commodities,Electrical appliances
30	India,IND,Commodities,Lime stone	88	India,IND,Commodities,Communication equipments
31	India,IND,Commodities,Mica	89	India,IND,Commodities,Other electrical Machinery
32	India,IND,Commodities,Other non metallic minerals	90	India,IND,Commodities,Electronic equipments(incl.TV)
33	India,IND,Commodities,Sugar	91	India,IND,Commodities,Ships and boats
34	India,IND,Commodities,Khandsari, boora	92	India,IND,Commodities,Rail equipments
35	India,IND,Commodities,Hydrogenated oil(vanaspati)	93	India,IND,Commodities,Motor vehicles
36	India,IND,Commodities,Edible oils other than vanaspati	94	India,IND,Commodities,Motor cycles and scooters
37	India,IND,Commodities,Tea and coffee processing	95	India,IND,Commodities,Bicycles, cycle-rickshaw
38	India,IND,Commodities,Miscellaneous food products	96	India,IND,Commodities,Other transport equipments
39	India,IND,Commodities,Beverages	97	India,IND,Commodities,Watches and clocks
40	India,IND,Commodities,Tobacco products	98	India,IND,Commodities,Miscellaneous manufacturing
41	India,IND,Commodities,Khadi, cotton textiles(handlooms)	99	India,IND,Commodities,Construction
42	India,IND,Commodities,Cotton textiles	100	India,IND,Commodities,Electricity
43	India,IND,Commodities,Woolen textiles	101	India,IND,Commodities,Gas
44	India,IND,Commodities,Silk textiles	102	India,IND,Commodities,Water supply
45	India,IND,Commodities,Art silk, synthetic fiber textiles	103	India,IND,Commodities,Railway transport services
46	India,IND,Commodities,Jute, hemp, mesta textiles	104	India,IND,Commodities,Other transport services
47	India,IND,Commodities,Carpet weaving	105	India,IND,Commodities,Storage and warehousing
48	India,IND,Commodities,Readymade garments	106	India,IND,Commodities,Communication
49	India,IND,Commodities,Miscellaneous textile products	107	India,IND,Commodities,Trade
50	India,IND,Commodities,Furniture and fixtures-wooden	108	India,IND,Commodities,Hotels and restaurants
51	India,IND,Commodities,Wood and wood products	109	India,IND,Commodities,Banking
52	India,IND,Commodities,Paper, paper prods. & newsprint	110	India,IND,Commodities,Insurance
53	India,IND,Commodities,Printing and publishing	111	India,IND,Commodities,Ownership of dwellings
54	India,IND,Commodities,Leather footwear	112	India,IND,Commodities,Education and research
55	India,IND,Commodities,Leather and leather products	113	India,IND,Commodities,Medical and health
56	India,IND,Commodities,Rubber products	114	India,IND,Commodities,Other services
57	India,IND,Commodities,Plastic products	115	India,IND,Commodities,Public administration
58	India,IND,Commodities,Petroleum products	116	India,IND,Commodities,Re-import

After calculating per capita indirect energy and CO_2 emissions for each household consumption item, consumption categories are then aggregated to seven general consumption categories drawn from Pachauri [28]. Table 11 lists these categories along with direct energy use categories and the IHDS variables used in estimations of direct and indirect energy use and CO_2 emissions for each category.

Table 11 Aggregation categories and IHDS variables used in estimating the energy focused results of this analysis

No.	Categories	relevant 2005 IHDS variables	relevant 2012 IHDS variables
1	Food, Beverages & Tobacco	co1a , co1b, co1c , co1d through co3a , co3b, co3c , co3d, co5a ; co5b, co5c , co5d ; co6a , co6b, co6c , co6t through co14a ,co14b, co14c , co14t ; co15 through co19	co1a , co1b, co1c , co1d through co3a , co3b, co3c , co3d, co5a ; co5b, co5c , co5d ; co6a , co6b, co6c , co6t through co14a ,co14b, co14c , co14t ; co15 through co19
2	Clothing & Footwear	co34 , co35 , co40	co38 , co39 , co44
3	Education & Recreation	co21 , co32 , co33 , co39 , co43 , co46 ,co47	co20 , co23 , co35 , co36 , co37 , co43 , co51 , co52
4	Medical care & Hygiene	co23 , co24 , co30 , co31 , co42	co25 , co27 , co33 , co34 , co46 , co47 , co48
5	Transport	co26 , co41	co28 , co29 , co45
6	Other Services	co22 , co28 , co44 , co45	co24 , co31 , co49 , co50
7	Housing & HH effects	co25 , co27 , co29 , co36 , co37 , co38	co26 , co30 , co32 , co40 , co41 , co42
8	Non-commercial energy [firewood, dung, crop residue, coal/charcoal]	fu1 , fu1c , fu5 , fu5a , fu5b , fu6 , fu6a , fu6b , fu7 , fu7a , fu7b , fu8 , fu8a , fu8b , fu9 , fu9a , fu9b , fu10 , fu10a , fu10b , hhassets , stateid , urban , fu4 , vp5b , vp8 , vp8a	fu1 , fu1c , fu7 , fu7a , fu7b , fu8 , fu8a , fu8b , fu9 , fu9a , fu9b , fu10 , fu10a , fu10b , fu11 , fu11a , fu11b , fu12 , fu12a , fu12b , assets , stateid , urban2011 , fu6 , vp7b , vp10 , vp10a
9	Electricity	fu1b , fu1c , fu8a , fu9a , urban	fu1 , fu1c , fu10a , fu11a , urban2011
10	Coal and solid wastes		
	Firewood	fu5 , fu5b , fu4 , vp5 , vp5a , stateid	fu7 , fu7b , fu6 , vp7b , stateid
	Dung	fu6 , fu6b , fu4 , vp8 , vp8a , stateid	fu8 , fu8b , fu6 , vp10 , vp10a , stateid
	Crop residue	fu7 , fu7b , fu4	fu9 , fu9b , fu6
	Coal/charcoal	fu10 , fu10b	fu12 , fu12b
11	Petroleum Products		
	Kerosene	co4a , fu8 , fu8b	co4a , fu10 , fu10b
	LPG	fu9 , fu9b , vp7 , vp7a , stateid	fu11 , fu11b , vp9 , vp9a , stateid
	Common to all	npersons , sweight	npersons, wt

Appendix D

The result of estimations of the 2005 and 2012 HDI income sub-indices from annual average per capita income for each income decile are presented in Figure 10. The income index value for each decile can be found by comparing solid lines with the values on the left axis and the average mean and median per capita incomes for the deciles can be found by comparing dotted lines with the 2011 $PPP income values shown on the right axis.

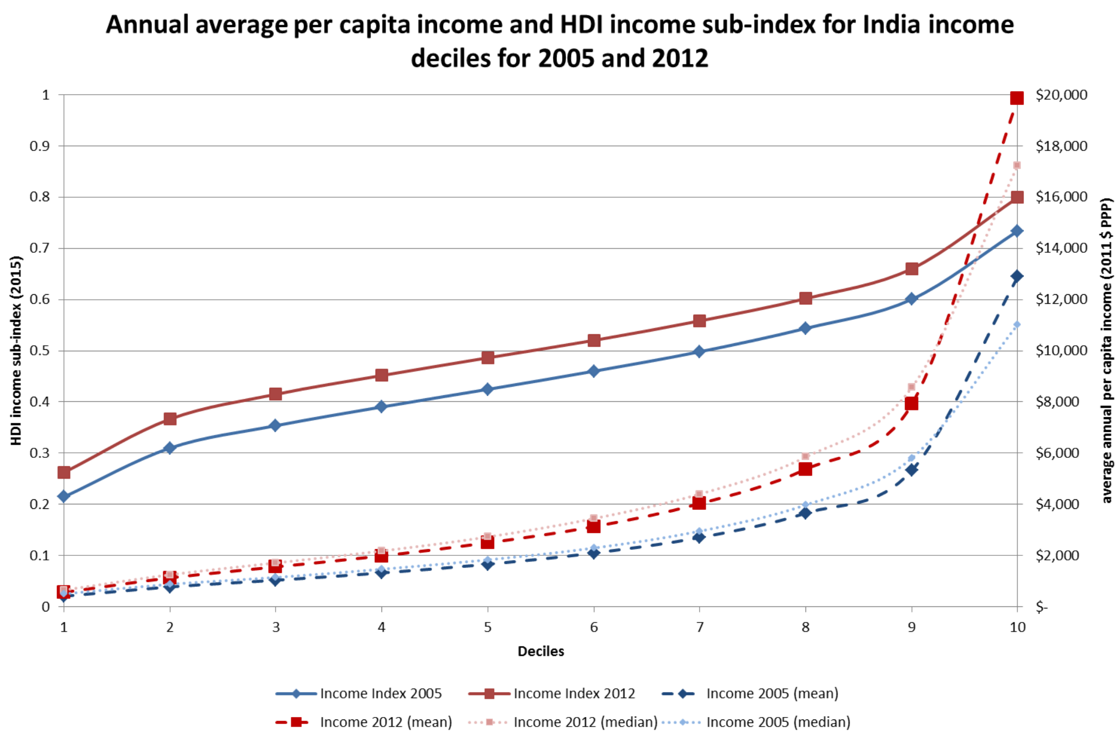


Figure 10 Annual average per capita income and HDI income sub-index for India income deciles for 2005 and 2012

Average per capita income results for both 2005 and 2012 show modest but increasing income gains through the first nine deciles followed by a large income increase for the top decile. The impact of rising incomes on the income sub-index – especially for the top decile – is minimized by current HDI methodology which uses the log of income to compute the income sub-index. In other words, the income index rises quickly at lower incomes but saturates at higher incomes. When comparing incomes across study years, results show increasing income gains across all deciles, with the largest growth ($6,000 – 7,000 in 2011 $ PPP) occurring in the richest decile.

The observed income increase for the bottom decile between years was the smallest at only $154 (2011 $ PPP).

Results for the median income for the richest decile have been plotted alongside the mean income in order to deflate the impact of the incomes of the very richest Indian's (~top 1%) on top decile average per capita income values. Given a bigger sample population, this suggests that the very richest of Indians by income should be treated as a separate group from the top decile in future analyses. In their study of the connections between GHG emissions and income, Chancel and Piketty [7] choose to analyse the top 1% of national populations separately from decile groups (ventiles for India).

Figure 11 presents the result of estimations of the 2005 and 2012 HDI education sub-indices from the average mean and expected years of schooling for each income decile. The education index value for each decile can be found by comparing solid lines with the values on the left axis and the average mean and expected years of schooling for the deciles can be found by comparing dotted lines with years shown on the right axis.

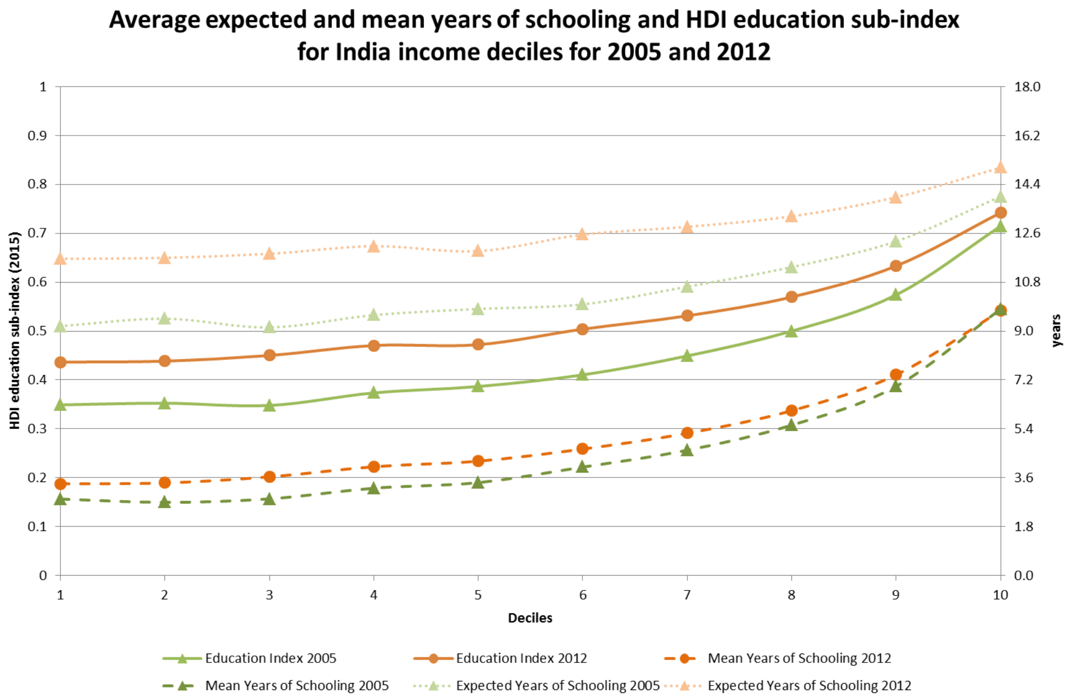


Figure 11 Average expected and mean years of schooling and the HDI education sub-index for India income deciles in 2005 and 2012

MYS results for the adult populations in both 2005 and 2012 survey years show a slow rise across the bottom five deciles with a slightly quicker increase across the next two deciles followed by a rapid increase across the top three deciles. When comparing 2005 and 2012 survey years, small gains in MYS are observed for all but the top decile. EYS results for children entering school in each study year show similar trends across the bottom five deciles in both 2005 and 2012. However, EYS increases for each of the top five deciles in 2005 are greater than gains for each of the top five deciles in 2012, suggesting less inequality both across the top five deciles in 2012 (2.5 year difference in 2012 as opposed to 4 years in 2005) as well as across all deciles in that survey year (3.4 year difference in 2012 as opposed to 4.8 in 2005). When comparing EYS between 2005 and 2012 survey years, improvements across all deciles are apparent with the bottom decile making a 2.5 year jump and the top decile seeing a 1.1 year improvement over seven years.

Results of the overall education sub-index, which is based on both MYS and EYS values and is not log adjusted, is dominated by gains in the EYS both across deciles in a study year and between study years. The largest gains in the education sub-index between study years are registered for the bottom six deciles with decreasing gains observed across the top four deciles. In fact, the top decile's education index gain was roughly a third of the bottom deciles index gain. Overall, the education sub-index trends shown in Figure 11 support an observation of decreasing education based inequality in India between 2005 and 2012.

Figure 12 presents the result of estimations of the 2005 and 2012 HDI health sub-indices using life expectancy at birth found for each income decile. The health index value for each decile can be found by comparing solid lines with the values on the left axis and the average mean and expected years of schooling for the deciles can be found by comparing dotted lines with the years shown on the right axis.

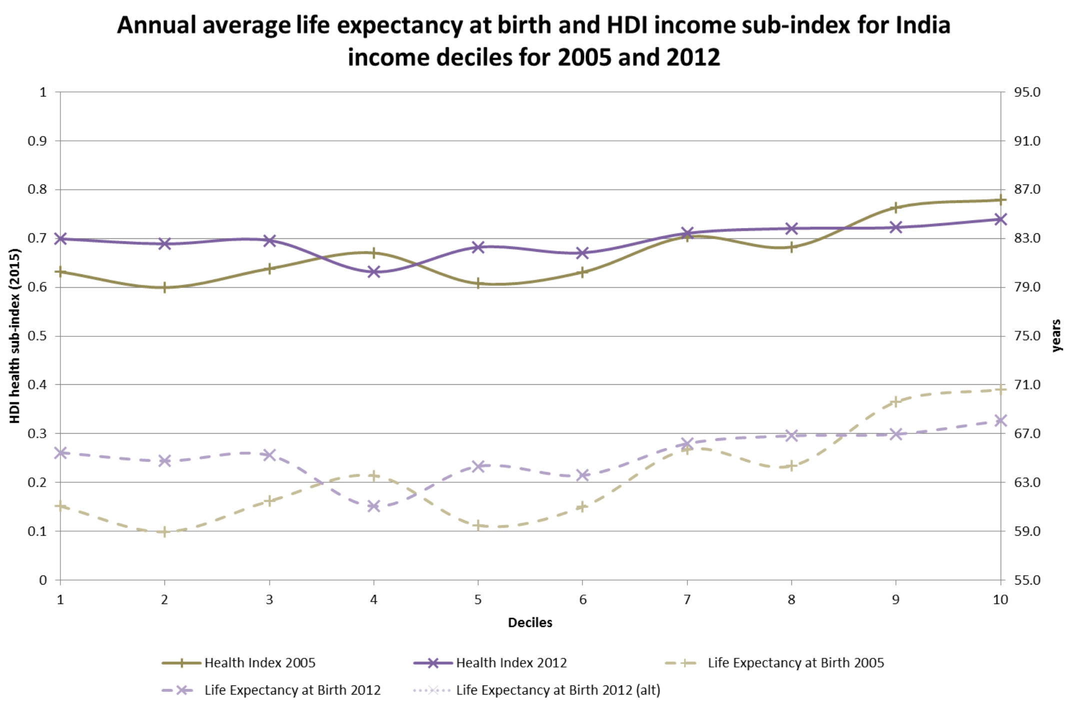


Figure 12 Annual average life expectancy at birth and HDI income sub-index for India income deciles for 2005 and 2012

The estimated LEB results shown in Figure 12 for survey years are the least clear of the HDI focused results. The 2005 data set which contains less sources of error both in collection, interpretation and analysis of data, shows a noisy[22] but fairly large inequality in LEB of 9.6 years between top and bottom deciles. The 2012 data set contains a much greater scope for error (see methodology section, Appendix B and connected end notes). In particular, the lack of recorded elderly deaths in all deciles for 2012 is expected to hamper observation of longevity gains made by elderly populations in richer deciles, and potentially overstate the LEB of poorer deciles. The 2012 LEB analysis shows less inequality (only 2.6 years) across deciles top and bottom deciles. As the HDI health sub-index based on LEB is not log adjusted, the sub-index and overall HDI score for each decile in both study years – but particularly 2012 – will be impacted by the large fluctuations and uncertainty connected to the LEB analysis.

[22] Noise in LEB is expected to arise from the intersection of small sample sizes and IHDS assigned household weighting factors which can be anywhere from 220 to 308,216. It should be noted that the average decile population sample sizes of over 20,000 people for each study year, exceeds the minimum sample size of 5,000 people identified by a UK government statistical study as the smallest acceptable sample size they would use for LEB calculations [100]. However, that study's minimum sample size was based on UK conditions and survey methods. A similar in depth study would need to be run on Indian data to determine the minimum sample size suggested for a specific survey.

Appendix E

Figure 13 through Figure 15 present analysis results for the inputs that would be entered into HDI sub-index estimations for urban and rural deciles in 2005 India. As populations are divided into deciles only after urban or rural populations have been removed from the data set, this means that deciles results do not correspond to all-India decile findings which represent mixed populations of rural and urban households. Note that per capita income results in Figure 13 have not been scaled using the World Bank Gross National Income for India in 2005 as happens to decile incomes in the all-India estimations before calculating the HDI sub-index value.[23] Unscaled income ranges for 2005 all-India, rural and urban deciles are shown in 2011 $PPP in Table 12.

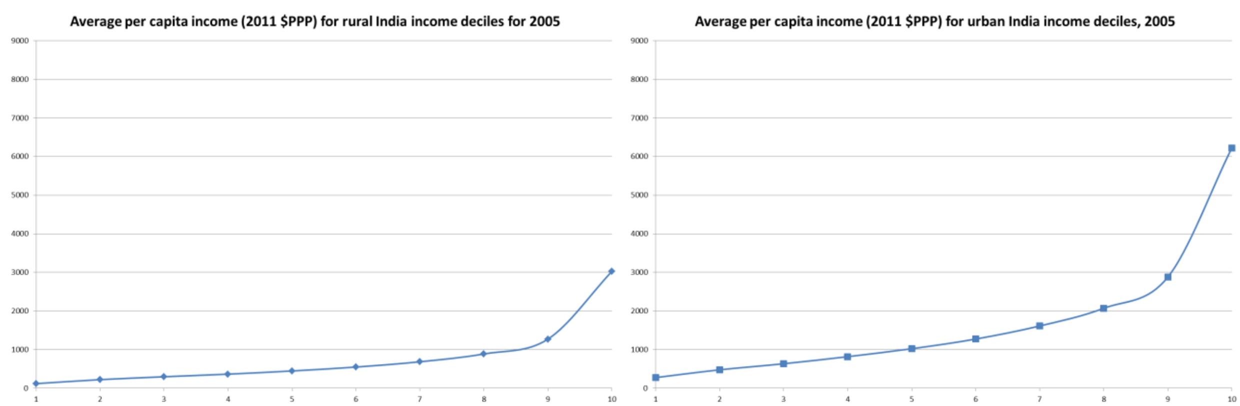


Figure 13 Average per capita income (2011 $PPP, unscaled) for rural (left) and urban (right) India income deciles in 2005

[23] The author is still in the process of determining whether it is possible (and reasonable) to independently scale rural and urban incomes using a modified method. Until such a method is developed, comparisons between all-India scaled incomes for deciles and rural and urban unscaled incomes for deciles are not possible. Unscaled incomes for all-India deciles can be compared with rural and urban findings. Rural and urban income findings for 2005 can be compared with each other, as they also can be compared with 2012 rural and urban income findings.

Table 12 Unscaled income ranges (2011 $PPP) for 2005 all-India, rural and urban deciles

Decile	All-India (2011 $PPP)	Rural (2011 $PPP)	Urban (2011 $PPP)
1	135	119	274
2	254	222	477
3	340	296	634
4	433	364	817
5	543	447	1023
6	686	548	1274
7	883	685	1612
8	1194	888	2070
9	1739	1270	2877
10	4207	3023	6223

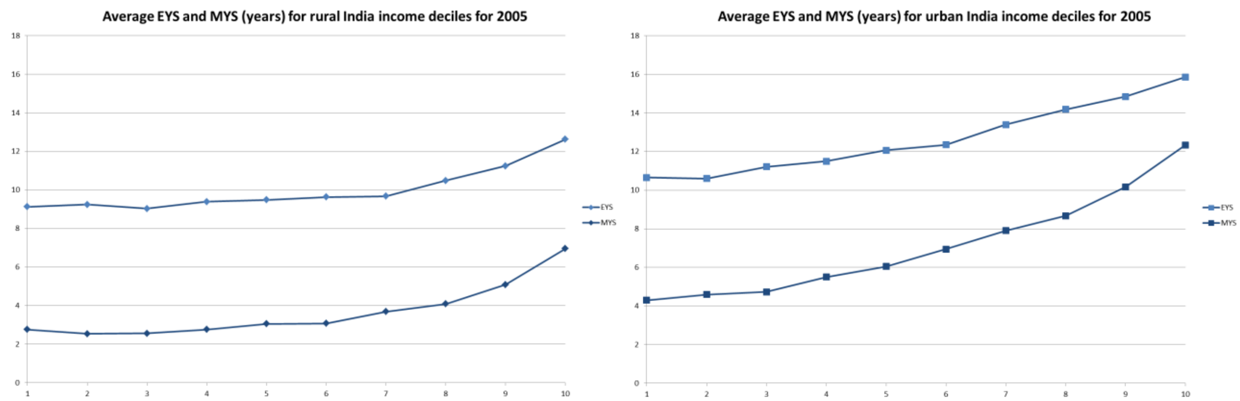


Figure 14 Average EYS and MYS for rural (left) and urban (right) India income deciles in 2005

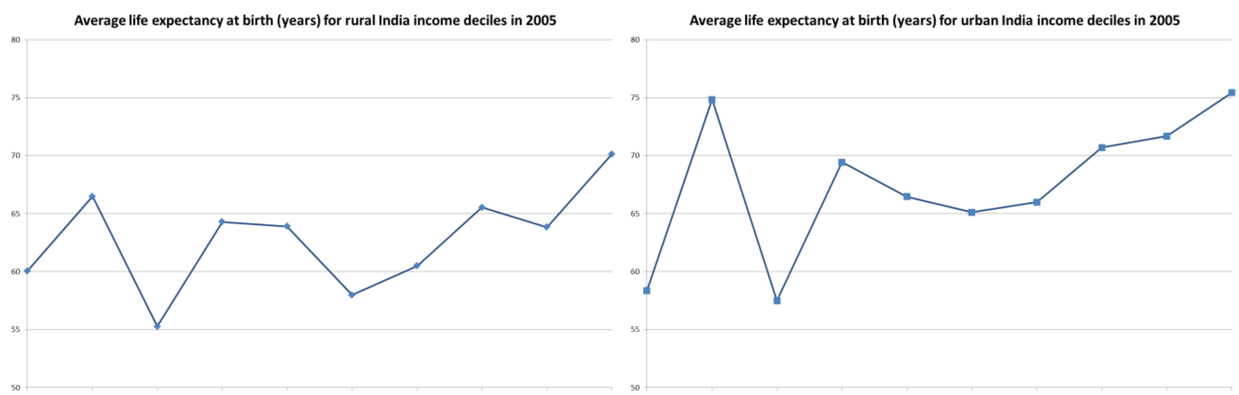


Figure 15 Average LEB for rural (left) and urban (right) India income deciles in 2005

Figure 13 and Figure 14 shows consistently higher unscaled income, MYS and EYS results for urban versus rural deciles in 2005. Figure 15's LEB results are very noisy[24], but there appears to be a general trend of higher LEB's at top verses bottom income deciles and, with the exception of the bottom and fifth deciles, higher LEB's for urban versus rural deciles.

Figure 16 through Figure 18 present analysis results for the inputs that would be entered into HDI sub-index estimations for urban and rural deciles in 2012 India. As with Figure 13 above, Figure 16 shows unscaled incomes for deciles. Unscaled incomes for 2012 all-India, rural and urban deciles are shown in 2011 $PPP in Table 13.

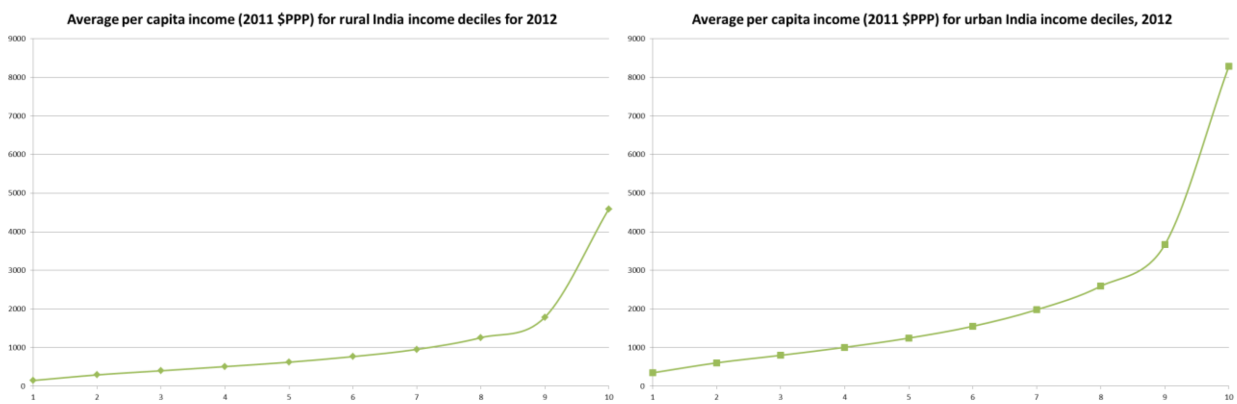


Figure 16 Average per capita income (2011 $PPP, unscaled) for rural (left) and urban (right) India income deciles in 2012

Table 13 Unscaled incomes (2011 $PPP) for 2012 all-India, rural and urban deciles

Decile	All-India (2011 $PPP)	Rural (2011 $PPP)	Urban (2011 $PPP)
1	174	147	346
2	348	293	605
3	479	400	800
4	611	507	1007
5	768	621	1245
6	962	766	1552
7	1238	954	1980
8	1651	1256	2590
9	2430	1787	3664
10	6094	4590	8285

[24] The amount of noise in this studies analyses of LEB urban and rural populations in India, suggest that average urban and rural decile populations of roughly 7,000 people and 13,500 people respectively (for both survey years) are below the minimum population sizes needed to estimate LEB using IHDS data.

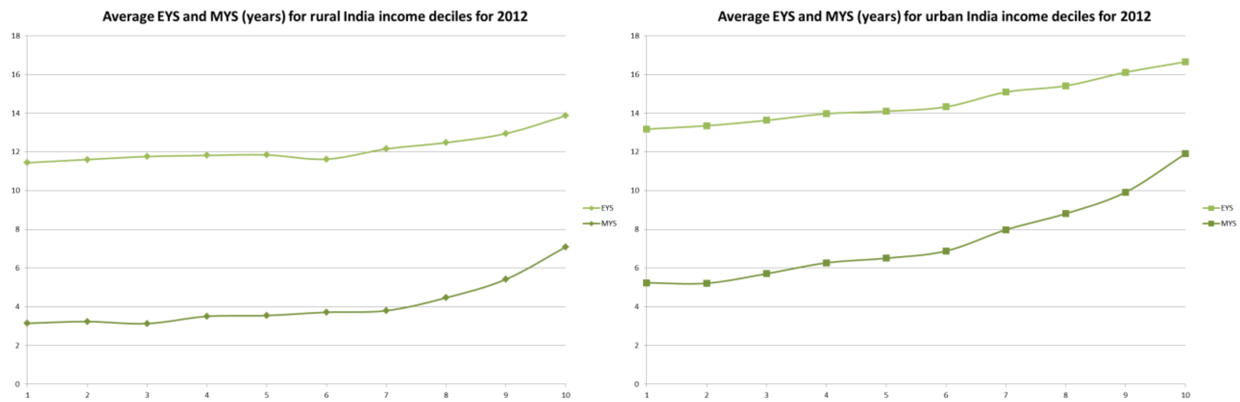


Figure 17 Average EYS and MYS for rural (left) and urban (right) India income deciles in 2012

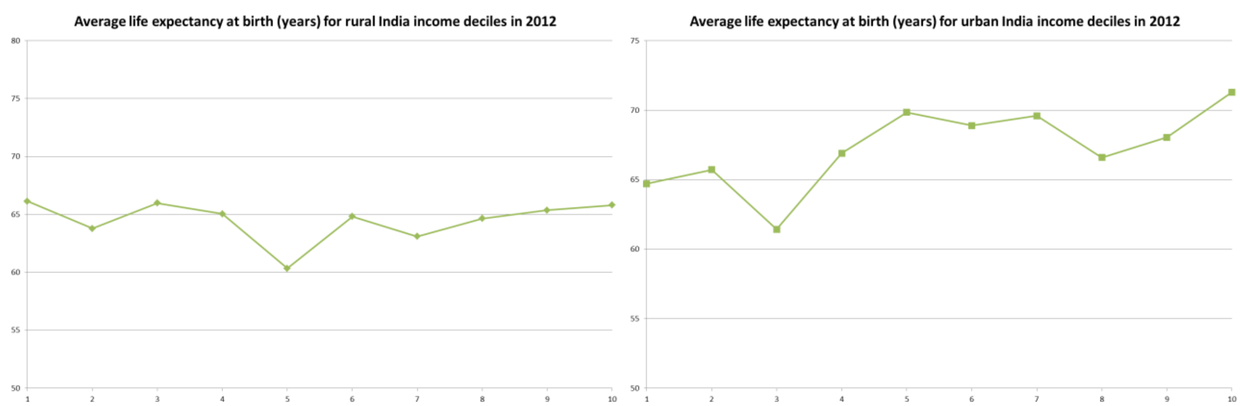
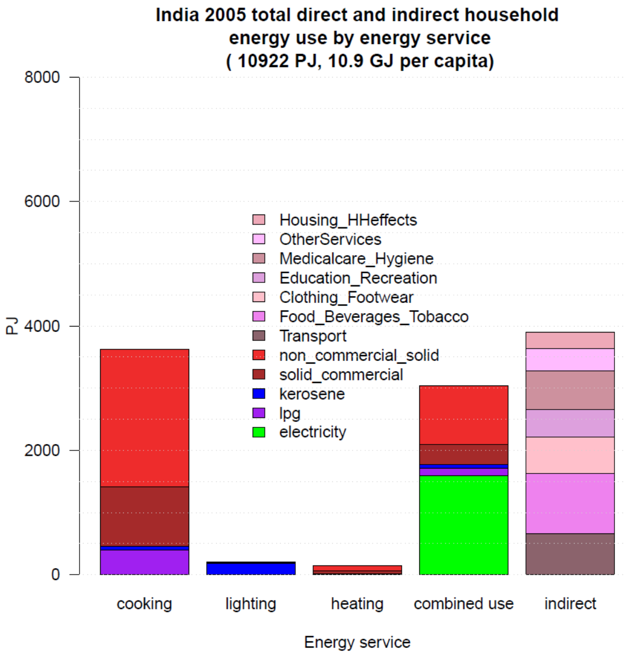


Figure 18 Average LEB for rural (left) and urban (right) India income deciles in 2012

As with the 2005 comparison between the income, MYS and EYS results of both urban and rural deciles, Figure 16 and Figure 17 show consistently higher results for all urban deciles. Figure 18’s LEB results are again very noisy, but as with the 2005 results there appears to be a general trend of higher LEB’s at top verses bottom income deciles. Eight of ten urban deciles have higher LEB’s than their rural counterparts, with most occurring in upper deciles.

Appendix F

Total aggregated direct and indirect household energy use for India in 2005 and 2012[25] are shown in Table 14, Figure 19 and Figure 20.



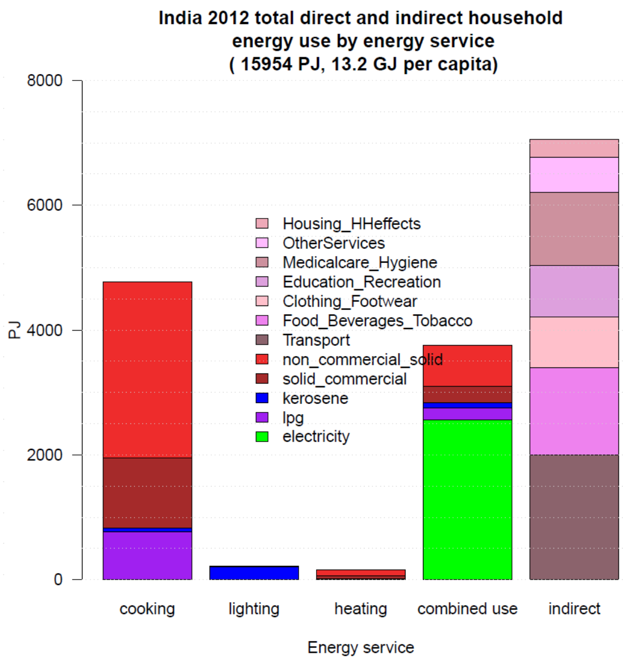


Figure 19 (left) Total aggregated direct and indirect household energy use for India 2005
Figure 20 (right) Total aggregated direct and indirect household energy use for India 2012

[25] Unlike decile reporting, aggregate India household energy and CO_2 emissions figures does not exclude households for either being below the minimum specified income boundary or for reporting per capita incomes representing the incomes of the poorest 10% of households in India, at the same time having per capita asset and consumption profiles of households from much richer deciles.

Table 14 Household energy use quantities and share by energy carrier for 2005 and 2012

Energy carrier	2005 Primary energy requirement (PJ)	2005 Share direct use	2005 Share total use	2005 CO2 emissions (Mt CO2)	2012 Primary energy requirement (PJ)	2012 Share direct use	2012 Share total use	2012 CO2 emissions (Mt CO2)
Electricity	1593	23%	15%	138	2561	29%	16%	196
LPG	518	7%	5%	27	973	11%	6%	47
Kerosene	307	4%	3%	17	345	4%	2%	18
Commercial solids	1341	19%	12%	123	1428	16%	9%	130
Non-commercial solids	3263	46%	30%	293	3599	40%	23%	319
Total Indirect	3901	-	36%	257	7049	-	44%	616
Total Direct	7021	100%	64%	598	8906	100%	56%	709
Total Requirement	10922		100%	854	15954	-	100%	1326

Figure 19 and Table 14 show a total 2005 direct household energy use of 7,021 PJ and a total indirect energy use of 3,901 PJ. As found in Figure 20 and Table 14, by 2012 total direct and indirect energy use grew to 8,906 PJ and 7,049 PJ respectively. Cooking represents the primary energy service required by Indians in both survey years[26]. Although energy from electricity use grew by 61% between survey years, bringing its share of household direct energy use up from 23% to 29%, total energy from solid fuel use in households grew by 9% between survey years. Along with a reduction in solid fuel's share of total direct household use from 65% to 56%, the share of self-collected fuels in total direct household use dropped from 46% to 40% between study years. Table 15 presents indirect energy use from household consumption aggregated to the seven general categories used by Pachauri [28].

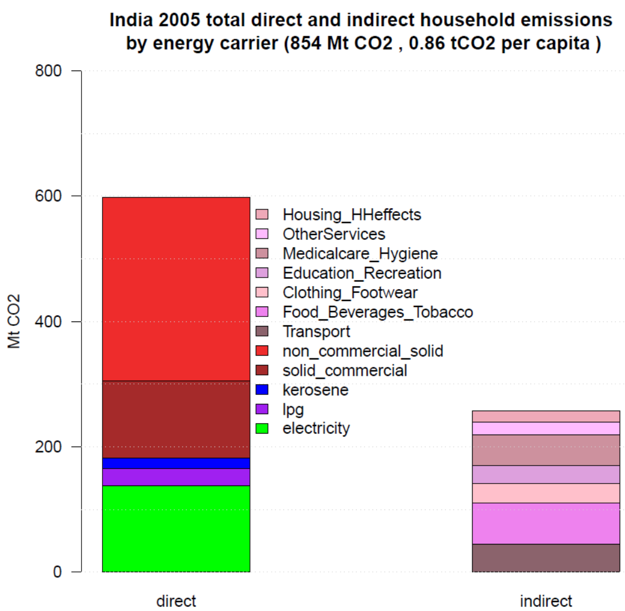
Table 15 Indirect energy use from household consumption, aggregated to general categories

Aggregate category [28]	Energy use (PJ) 2005	Share of indirect use, 2005	Energy use (PJ), 2012	Share of indirect use, 2012
Transport	661	17.0%	1999	28.4%
Food , Beverages, Tobacco	970	24.9%	1399	19.8%
Clothing, Footwear	583	15.0%	813	11.5%
Education, Recreation	435	11.2%	823	11.7%
Medical care, Hygiene	631	16.2%	1176	16.7%
Other Services	356	9.1%	562	8.0%
Housing and household effects	264	6.8%	276	3.9%

[26] IHDS did not ask about the main energy service provided by electricity in the household as it did for other direct use fuel types, this study chose to record electricity in the "combined use" category.

Table 15 shows that with the exception of "housing/household effects", there is clear growth in all indirect energy categories between survey years. Table 15 also shows that indirect energy use connected with transportation shows the greatest growth, overtaking food as the biggest contributor to indirect household energy use in 2012.

Total aggregated direct and indirect household CO_2 emissions for India 2012 are shown in Figure 21 and Figure 22. Table 14 provides a comparison of total household energy requirements by year and energy carrier.



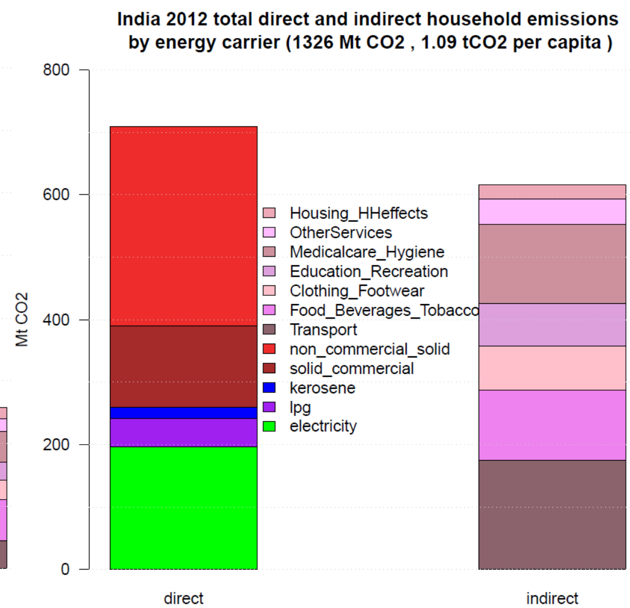


Figure 21 (left) Total aggregated direct and indirect CO_2 emissions for India 2005
Figure 22 (right) Total aggregated direct and indirect CO_2 emissions for India 2012

Emission related growth results shown for 2012 in Figure 22 largely increase as expected from the 2005 results shown in Figure 21 according to observed changes in energy use patterns between study years. However, both CO_2 emissions growth connected to electricity and indirect energy use do not propagate across the years as expected. In particular, despite the 61% growth in household electricity use between survey years, emissions have not increased by nearly that much. As will be discussed later, a lessening of the emission's intensity of the electricity sector in India between 2005 and 2012 arises from a combination of the overall lowering of the average Indian grid emissions factor and a reduction in T&D losses between survey years.

Secondly, while there was an 81% increase in indirect energy use between study years, emissions from indirect energy use grew by 140%. Overall CO_2 emissions connected with indirect energy use depend on the proportionate growth in consumption arising from each sector of the Indian economy and the CO_2 emission's intensity of each sector. For example, Figure 19 and Figure 20 show a large increase in indirect energy use connected with transportation, a sector with a fairly high CO2 emissions intensity in both survey years, which results in the large emissions growth in transportation witnessed in the move from Figure 21 and Figure 22.

Appendix G

Figure 23 presents the average annual per capita CO_2 emissions from direct and indirect energy requirement for rural India income deciles in survey years. Figure 24 presents the average annual per capita CO_2 emissions from direct and indirect energy requirement for urban India income deciles in survey years. The income deciles presented in these two figures have been separated into deciles only after being divided from one another so cannot be directly compared with all-India decile results connected with welfare inequality.

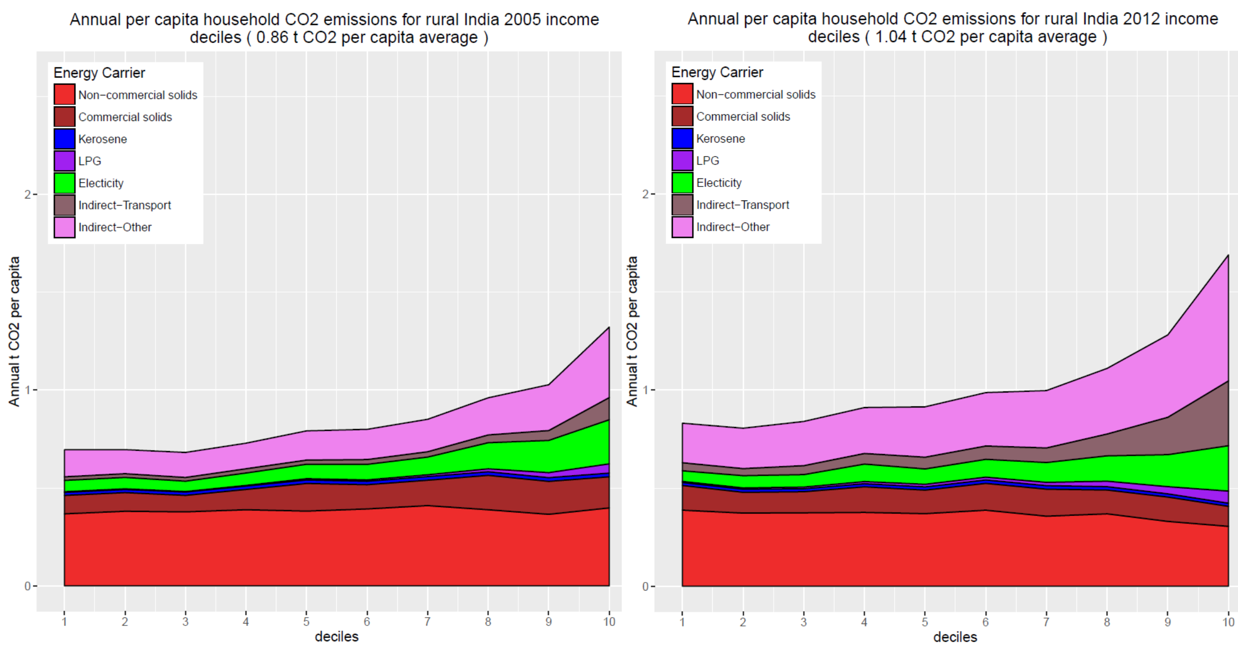


Figure 23a (left) Annual per capita rural household based CO_2 emissions for rural India 2005 income deciles
Figure 23b (right) Annual per capita rural household based CO_2 emissions for rural India 2012 income deciles

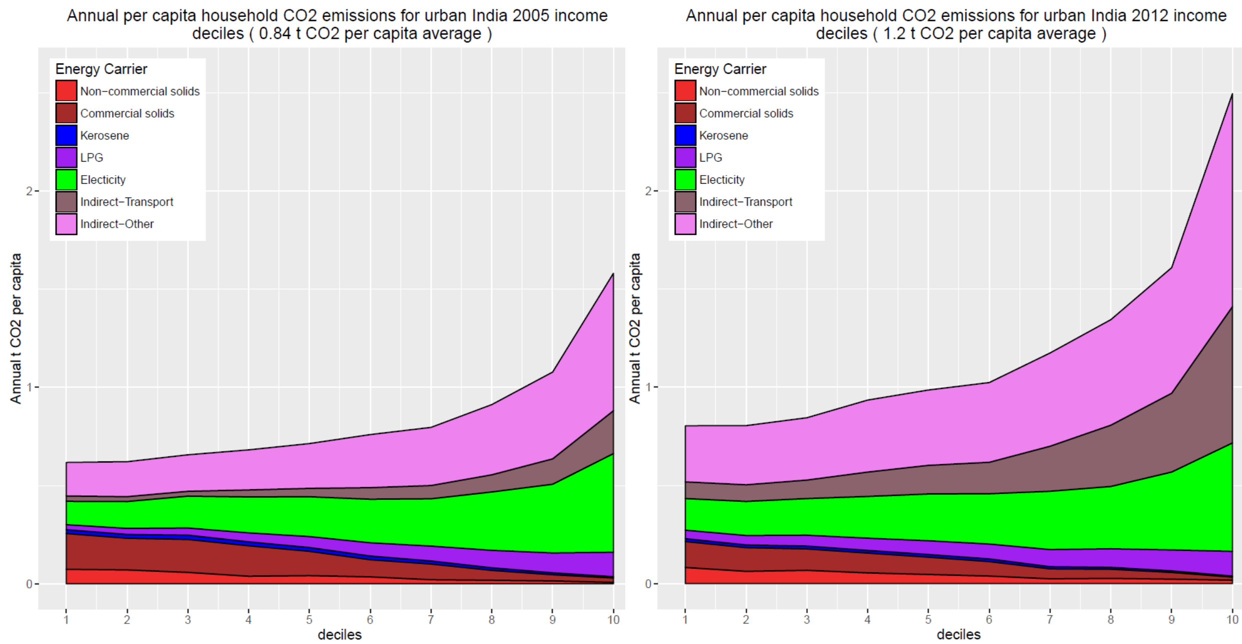


Figure 24a (left) Annual per capita urban household based CO_2 emissions for urban India 2005 income deciles
Figure 24b (right) Annual per capita urban household based CO_2 emissions for urban India 2012 income deciles

Figure 23 shows clearly that direct energy use emissions arising from rural populations in all deciles can be attributed to the use of self-collected sold fuels in households. Figure 24 shows just as clearly that not only do solid fuels play a decreasing role in direct CO_2 emissions as urban households get richer, but that self-collection of fuels plays on the most minor role in poorer urban households. Figure 24a also indicates that indirect CO_2 emissions grow as incomes grow and represent more than half of total per capita emissions in urban households starting with the sixth decile in 2012, as compared to this transitions occurring around the ninth decile in 2005 in Figure 24b. Although the indirect CO_2 emissions of rural households is also shown to grow across rural deciles in both Figure 23a and Figure 23b, indirect CO_2 emissions only near the halfway mark of any rural deciles per capita emissions for the richest 20% of rural households in 2012 in Figure 23b.

Most strikingly, although the average 2005 rural and urban per capita CO_2 emissions shown in Figure 23a and Figure 24a are reasonable close in magnitude, their qualitative difference is massive. Most rural emissions arise from self-collected solid fuels and are released locally at the household level, rather being occurring further away from inhabitants in power generation plants or occurring indirectly in the greater Indian and global economy as happens with most emissions for urban deciles.

Figure 25 presents the average annual per capita household energy requirement for rural India income deciles in survey years. Figure 26 presents the average annual per capita household energy requirement for urban India income deciles in survey years.

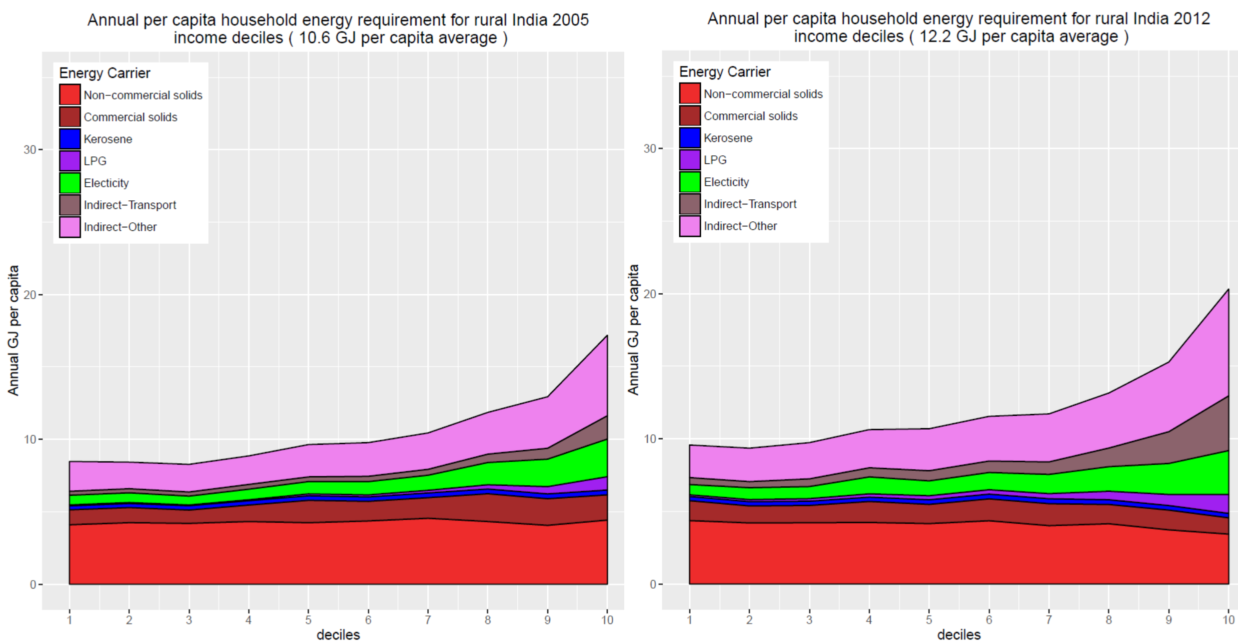


Figure 25a (left) Annual per capita household based energy requirement for rural India 2005 income deciles
Figure 25b (right) Annual per capita household based energy requirement for rural India 2012 income deciles

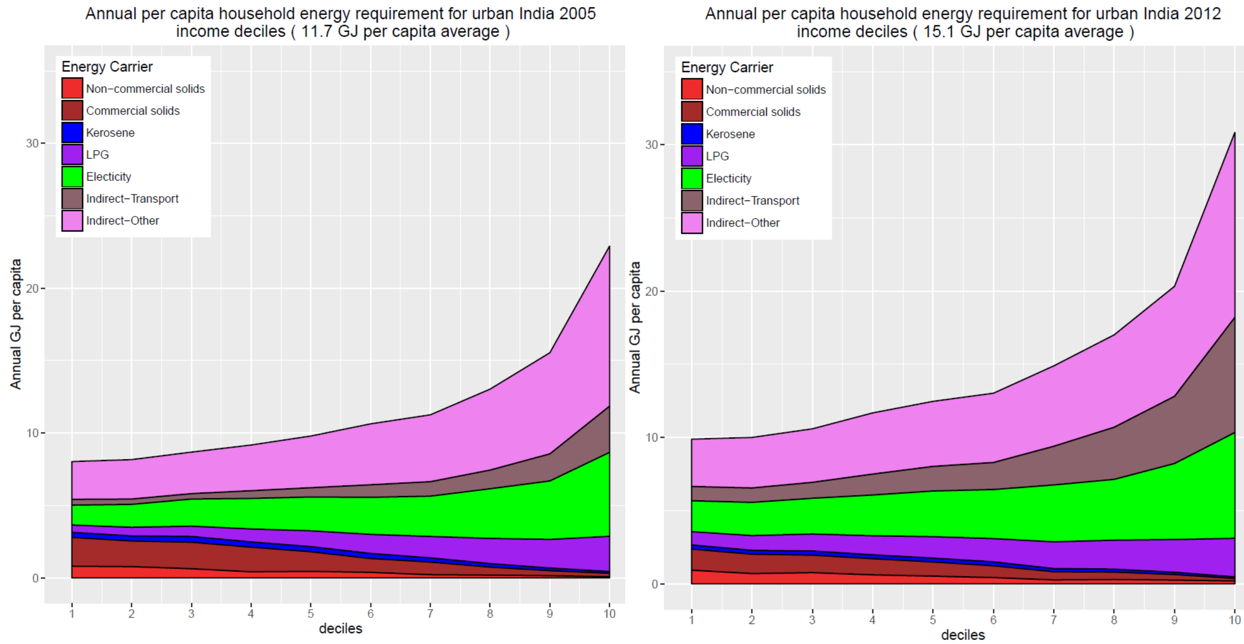


Figure 26a (left) Annual per capita household based energy requirement for urban India 2005 income deciles
Figure 26b (right) Annual per capita household based energy requirement for urban India 2012 income deciles

When the energy requirement results presented in Figure 25 and Figure 26 are combined with the CO2 emissions results presented earlier in Figure 23 and Figure 24, some interesting observations are possible. Most notably, although urban populations used more energy per capita than rural in 2005 as shown when comparing Figure 25a and Figure 26a, their per capita emissions were lower when comparing Figure 23a and Figure 24a, leading to the observation that the energy consumed by urban households in that year was less emissions intense than that consumed by rural households. However, the same did not hold true for the rural and urban energy and emissions relationship in 2012. The growth in indirect energy use – especially in energy intense sectors such as transportation – in urban locations was too large to maintain relative CO_2 emissions equality between the populations, even with energy and CO_2 emission efficiency gains in both the Indian electricity system and the overall economy.

Appendix H

Figure 27 presents the annual per capita household boundary energy use and end-use energy use in GJ for India income deciles in 2005 and 2012.

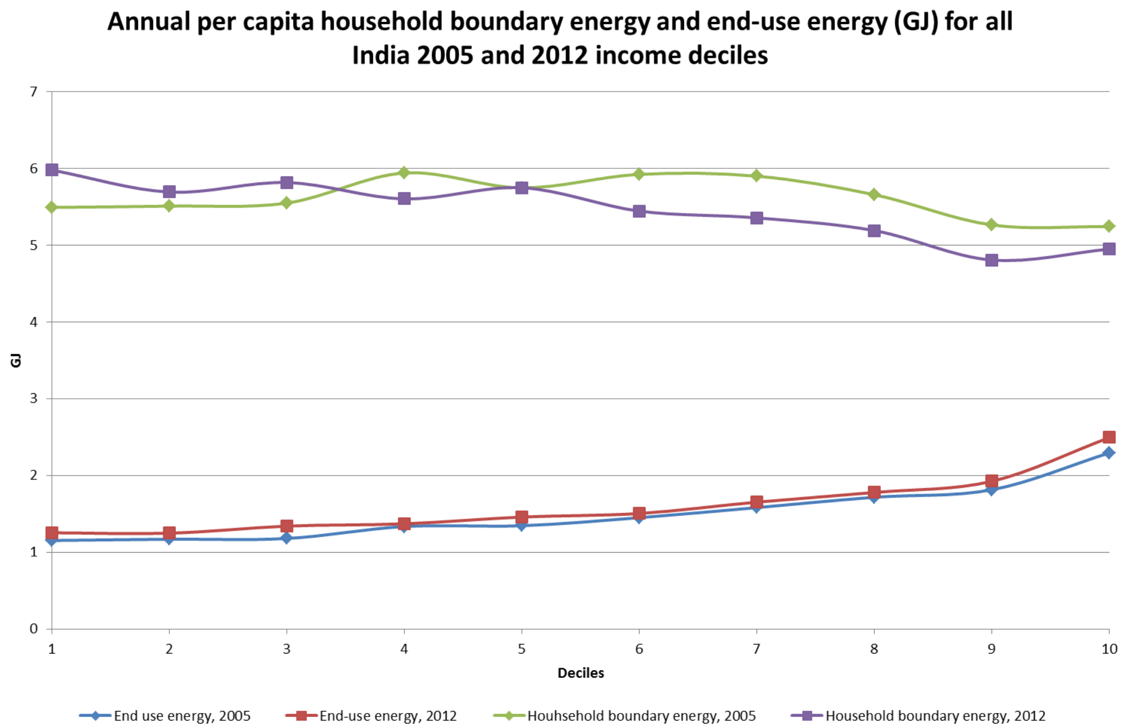


Figure 27 Annual per capita household boundary energy and end-use energy (GJ) for all India 2005 and 2012 income deciles

For deciles six through nine in both study years, Figure 27 shows increasing end-use energy while direct household boundary energy shows a decreasing trend. For 2012 results this trend appears to hold generally true from the poorest to richest deciles. An increase in end-use energy with decreasing household boundary energy suggests an increase in the efficiency of energy services in richer deciles.

Figure 28 presents the annual per capita household boundary energy and CO_2 emissions from total direct primary energy use for all India 2005 and 2012 income deciles. Energy in GJ is shown on the left axis of Figure 28 while CO_2 emissions in tonnes are shown on the figure's right axis.

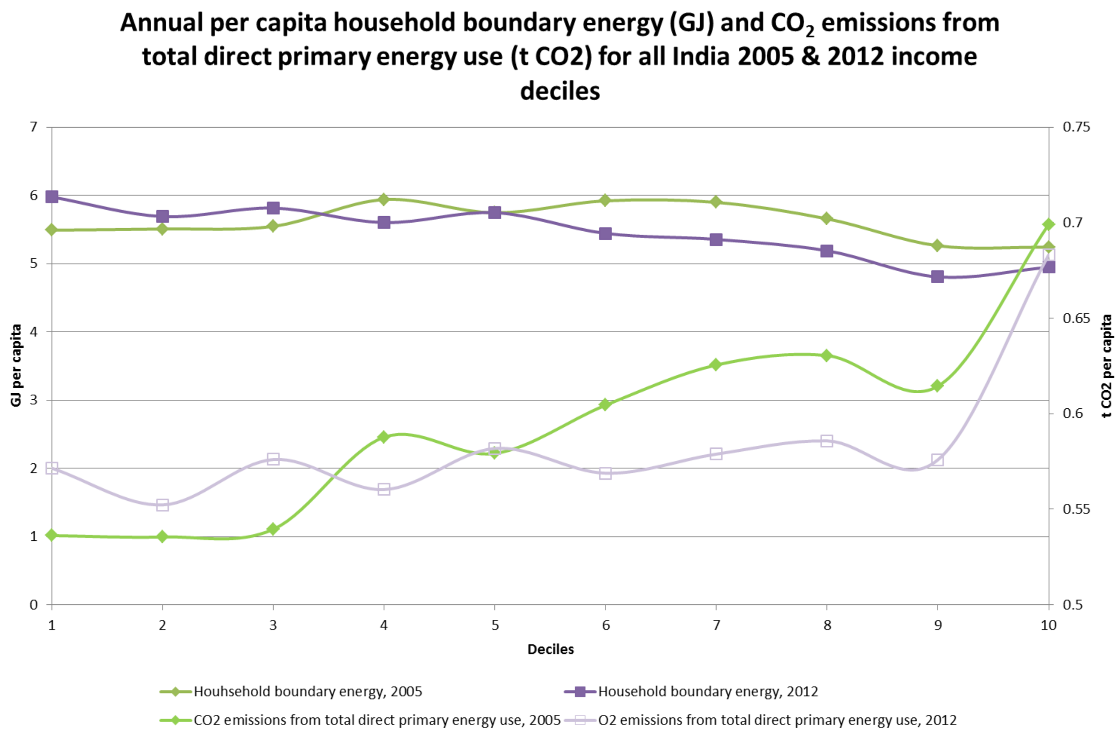
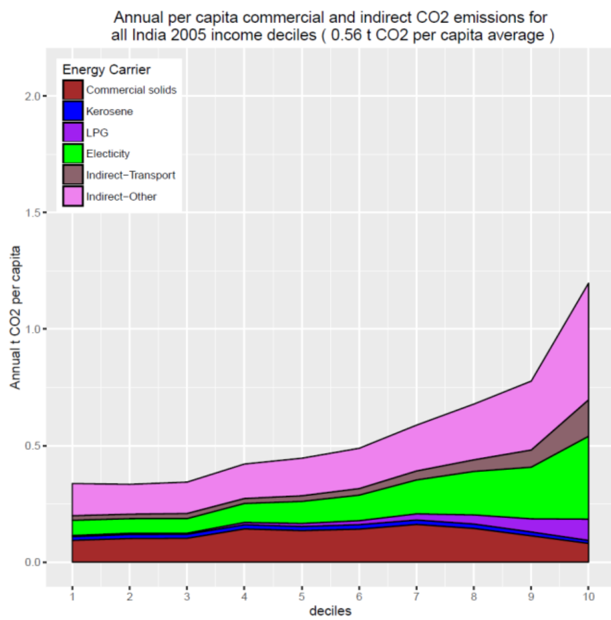


Figure 28 Annual per capita household boundary energy and CO_2 emissions from total direct primary energy use for all-India 2005 and 2012 income deciles

The same household boundary energy use trends described for Figure 27 hold for Figure 28, namely that there is a decrease seen in deciles six through ten in 2005 and a general decrease across all deciles in 2012. However, despite these decreases, Figure 28 indicates that the richest decile in 2005 has greater CO_2 emissions from direct primary energy use than the sixth decile, and emissions hold nearly constant across all deciles in 2012 but the final decile, which sees a noticeable increase in per capita CO_2 emissions. When comparing across study years in Figure 28, the three poorest deciles see both increases in CO_2 emissions and energy use from 2005 to 2012 and the five richest deciles all see both decreased CO_2 emissions and energy use during the same time frame.

Appendix I

Figure 29 presents the average annual per capita CO_2 emissions from use of commercial energy carriers and household consumption for all India income deciles in survey years and contain the same households for each year as those presented in Figure 4.



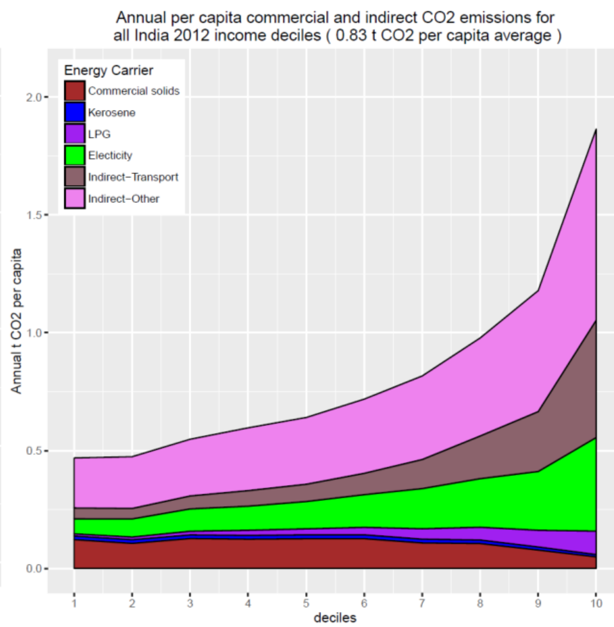


Figure 29a (left) Annual per capita household based CO_2 emissions from use of commercial energy carriers and household consumption for all India 2005 income deciles
Figure 29b (right) Annual per capita household CO_2 emissions from use of commercial energy carriers and household consumption for all India 2012 income deciles

Both Figure 29a and Figure 29b show a clear increase in CO_2 emissions from use of commercial energy carriers and household consumption across all India 2005 income deciles within survey years. Figure 29 also shows that CO_2 emissions from household use of commercial energy carriers between survey years appears to stay roughly the same or reflect a small decrease between deciles in survey years. What is extremely clear when comparing deciles between survey years in Figure 29 is that CO2 emissions from household consumption has grown for all deciles between 2005 and 2012, with the greatest increases occurring in the richest deciles.

Appendix J

Figure 30 presents annual per capita household boundary energy use and end–use energy in GJ plotted against HDI for India income deciles in 2005 and 2012.

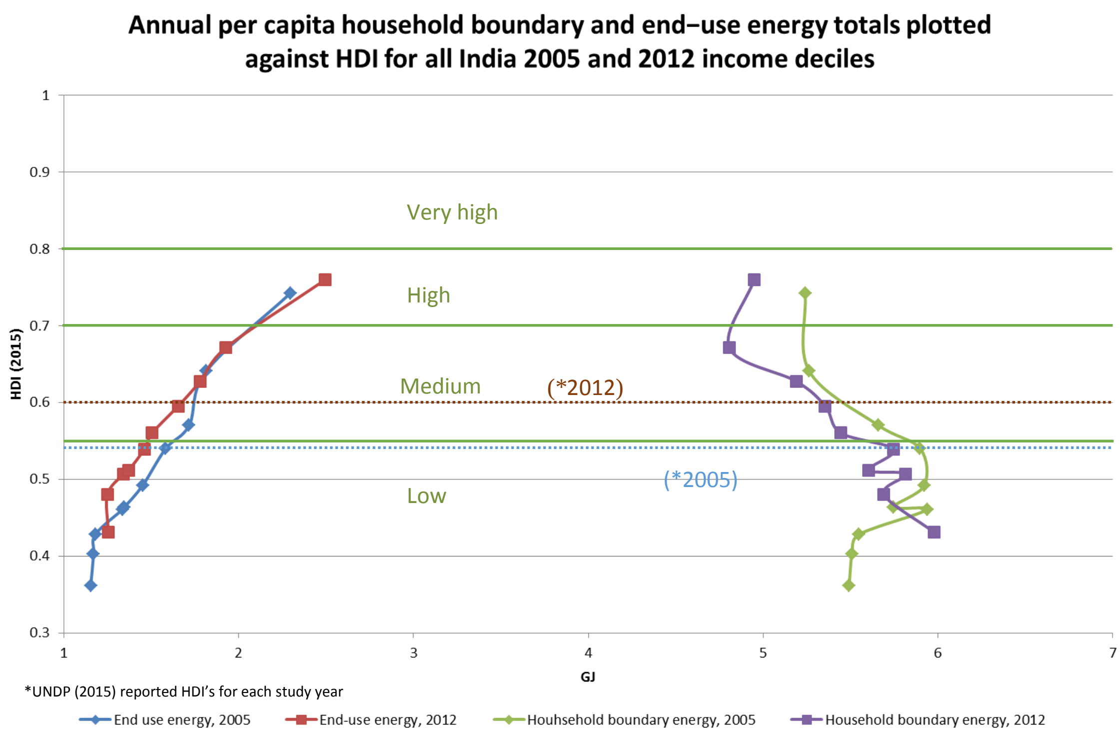


Figure 30 Annual per capita household boundary and end–use energy totals plotted against HDI for all India 2005 and 2012 income deciles

Figure 30 suggests that in general as HDI increases with decile group within years, the total amount of useful energy harnessed by a household increases even while they consume less direct energy within household boundaries. This might be explained as not only the result of the use of more efficient energy services in richer households, but also the ability of richer households to consume modern energy carriers that gain their energy dense form through energy (and emissions) intense processing that occurs outside of household boundaries. This exporting of energy use and emissions beyond household boundaries in part explains the seeming contradiction between Figure 30's general decrease in household boundary energy with increasing incomes and HDI scores while Figure 4 or Figure 28 shows a slight increase (2005) or fairly flat direct CO_2 emissions (2012, with exception of growth in tenth decile) profile across deciles.

Appendix K

Harttgen and Klasen's [42] HDI by decile results, estimated from a 2005 Demographic and Health Survey (DHS), represent the best point of comparison for this study's 2005 HDI by decile results.[27] Harttgen and Klasen find first and last decile HDI's of 0.305 and 0.636, resulting in a ratio of the tenth to direst decile of 2.09. This study estimates higher first and last decile HDIs of 0.362 and 0.742 for 2005, but has a tenth to first decile ratio of nearly the same at 2.05. Harttgen and Klasen's use of 2010 UNDP [106] methods to estimate their decile HDI are a likely source of lower scores for all deciles – particularly because use of the upper income goalpost of 108,211 (PPP $), rather than the $75,000 (2011 PPP $) used by this study, produces a lower income index. Furthermore, DHS data does not include income or expenditure values for households, so Harttgen and Klasen's [42] estimations of household incomes from asset data may result in differing results. Differing methods used for the estimation of the education index, along with differing goalposts for both health and education indices also create sources for differences between results.

This study estimates a household boundary energy use of 5,651 PJ in India in 2005. That figure seems low when compared with the expected growth (~1.8% per annum) from Pachauri's [28] series results for direct residential energy consumption which showed 3,542 PJ and 6,007 PJ in 1970 and 2000 respectively. This study's household boundary energy use figure is also low when compared with Reddy and Srinivas's [64] report of 6,092 PJ of household energy consumption in 2005[28]. A very tentative comparison can also be made with the IEA [75] residential direct energy use total for India in 2005 of 6,468 PJ as this figure contains direct energy used by households for transportation and energy from natural gas, and does not include the primary energy involved in electricity production. Table 16 provides a comparison of literature sources, with household energy use in India in 2005 broken down by energy carrier.

[27] Grimm et al. [41] also represent a comparison point, but their India results are calculated by quintile using older HDI estimation methods and goalposts even further from this study's.

[28] Data is from the Centre for Monitoring Indian Economy and is behind a paywall.

Table 16 Comparison of study findings for 2005 household boundary energy use with relevant literature

Energy carrier (all in PJ)*****	Results 2005	Pachauri [28] 2000 (1970)	Reddy and Srinivas [64] 2005	IEA [75] 2005
Biomass	4563	4,955 (3,091)	4,950	5,057***
Coal/Charcoal	34.5	22 (86)	0*	119******
Kerosene	248	390 (117)	265	0
LPG	395	227 (0)	427	0
Electricity	411	272 (14)	450	382
Others	0	141 (235)	0	909****
Total	**5651**	**6,007 (3,542)**	**6,092****	**6,468**

* Potentially partially included in biomass
** Total given in Table 2 in [64] is 5642 PJ, but the figures given in that table add up to the total shown here.
*** Biofuels and waste category in IEA [75]. IEA [107] balance definitions do not indicate whether the figure includes non-commercial energy sources, but from the size of the figure, it is assumed to.
**** Combines IEA categories for Oil products (882), natural gas (23) and Geo, solar, etc. (3)
***** Categories align with Pachauri [28]
****** Includes coal, peat and oil shale [75].

A additional comparison of this study's household electricity findings of 411 PJ (this shows electricity used in the household only and does not reflect primary energy) for 2005 can be made with national energy statistics [108] which place an overall domestic consumption of electricity in 2005-2006 at 360 PJ. When placed alongside IEA [75] estimation of 382 PJ and Reddy and Srinivas [64] estimation of 450 PJ, this study's household boundary electricity use results appear reasonable.

Energy focused results from this analysis can also be compared with Khandker et al.'s [27] estimates of urban and rural household boundary energy use from the IHDS 2005 dataset. In general this analysis arrives at a much lower monthly household energy use for rural populations (68.4 vs 93.7 kgoe[29]/household/month) and almost the same energy use a month for urban populations (33.8 vs. 36.1 kgoe/household/month). As solid fuel usage makes up over 95% of that difference in rural populations and 85% of that difference in urban populations, it is expected that differing non-commercial fuel imputation methods are the main point of divergence between analyses.[30] Differing electricity price estimates (electricity prices are not part of IHDS data sets) provide a smaller point for potential divergence. Despite methodological

[29] 1 kgoe = 41.868 MJ
[30] Imputation methods are not detailed in the journal paper or related working paper [118].

differences, Khandker et al.'s [27] findings on the relative differences in energy use and carriers between urban and rural populations are supported by the this paper's findings.

Table 17 presents a comparison of literature sources, with this study's finding for 6,639 PJ of household energy use in India in 2012. Study results appear reasonable, if not a little low, when compared with Bhattacharyya's [88] report of 6,978 PJ for residential energy demand in India for 2009-2010.[31] Another very tentative comparison, with the same issues as 2005, can also be made with the IEA [79] residential direct energy use total of 7,420 for India in 2012.

Table 17 Comparison of study findings for 2012 household boundary energy use with relevant literature

Energy carrier (all in PJ)	Results 2012	IEA [79] 2012
Biomass	4987	5,591*
Coal/Charcoal	33.8	140**
Kerosene	258	0
LPG	692	0
Electricity	669	678
Others	0	1012***
Total	**6639**	**7,420**

* Biofuels and waste category in IEA [79]. IEA [107] balance definitions do not indicate whether the figure includes non-commercial energy sources, but from the size of the figure, it is assumed to.
** Includes coal, peat and oil shale [79].
*** Combines IEA [79] categories for Oil products (882), natural gas (23) and Geo, solar, etc. (3)

If the comparison is extended to this study's 2012 household electricity findings of 669 PJ, national energy statistics [108] for 2012-2013 estimate the same number. The IEA [79] residential electricity use estimate of 678 PJ is also fairly close.

This study's results differ more widely with reported findings in literature when considering indirect primary energy results. Pachauri [28] reports an annual per capita figure of 7.3 GJ for the year 1998-1999. This study finds for an annual per capita figure of 3.9 GJ for the year 2005. A comparison of the sectoral energy intensities calculated by Pachauri [28] for 1998-1999 and the sectoral energy intensities taken directly from the EORA database for India in 2005 show that with the exception of three (of 99) comparable sectors, EORA energy intensities are lower

[31] These results are derived from NSS survey data and residential energy demand does not appear to include direct use for transportation. Total is estimated from a chart in the referenced paper.

than Pachauri's intensities. The most striking differences involve agricultural products with EORA's paddy and wheat sectoral intensity being 10% and 8% of Pachauri's figures respectively.

One reason for the difference between Pachauri's [28] and EORA's sectoral intensities arises from Pachauri's inclusion of non-commercial energy in each sector's energy intensity. Pachauri [28] estimates that non-commercial energy comprised 21.4% of total final energy consumption in the industrial sector and 32.3% in the agricultural sector in 1999-2000. While non-commercial energy's role in industrial and agricultural sectors will have changed between 2000 and 2005 and then again by 2012, the lack of inclusion of non-commercial energy in EORA's database is expected to systematically lower EORA energy (and emission) intensities across all sectors when compared to databases that do include non-commercial energy. Specifically with respect agricultural sectors in India, EORA's global approach[32] is almost certainly unable to capture the impact of electricity pilferage and heavily subsidized electricity for irrigation on sectoral energy and emissions intensities [28] that India focused intensities like Pachauri's are able to account for.

In a comparison of changes in India's sectoral energy intensities over time, Pachauri [28] not only found reduced intensities for five of the most energy intensive sectors supporting the Indian economy between 1983 and 1999, but also a 34% reduction in the overall energy intensity of the Indian economy during that period. The likely continuation of this trend between 1999 and 2005 represents a general driver pushing Pachauri's [28] higher intensities in the direction of EORA's lower intensities. However, the omission of drivers for higher intensities such as widespread sectoral non-commercial energy use and pilfered and heavily subsidized electricity in an irrigation needy agricultural sector suggest the need to adjust EORA intensities in the direction of Pachauri's much higher intensities. Without such an adjustment, this study suspects that its indirect energy (and GHG emission) results for Indian households in 2005 and 2012 are at the low end of the spectrum.

[32] EORA's standard application of methodology across every country in its database means that unless context specific energy/emissions drivers such as non-commercial energy, subsidized electricity and pilferage are included for each sector in the nationally reports that EORA is drawing from, they will not be included in country results.

This study's emission results for 2005 can be tentatively compared with other literature sources. Grunewald et al. [26] report a mean annual per capita household carbon footprint of 0.3 t CO_2 that they calculate solely based on consumption reported in household survey data. The indirect emission of CO_2 associated with the purchase of energy carriers is included in their analysis but the direct emission of CO_2 from the end-use of those carriers is not included; nor are CO_2 emissions from the use of non-commercial energy sources. Although this study's 2005 average annual per capita figure of 0.84 t CO_2 is a good deal higher as expected, the CO_2 emissions figure covering only consumption related emissions (not including energy carriers) is 0.26 t CO_2. If this finding was adjusted to include the indirect emissions connected with the household consumption of energy carriers[33], it is expected that the resulting figure would approach if not overtake Grunewald et al.'s [26].

Although, EORA's sectoral emissions intensities for paddy and wheat are roughly 40% of Grunewald et al.'s GTAP based intensities, there appears to be no obvious pattern to sectoral intensity differences across the rest of India's economy as there was when comparing EORA sectoral energy intensities with Pachauri [28]. The proximity of overall average per capita results of consumption related emissions despite the difference in intensities in two key consumption sectors in each study, suggests an emission accounting boundary difference between the two MRIO databases and an area for further study and understanding.

Literature such as Pathak et al. [90] is useful in better understanding the emission intensity of key food commodities in India. However, one of the key findings from Pathak et al. is that the CO_2 represents only 16% of total GHG's (considers methane and nitrous oxide as well) emitted on average over the life cycle (production, processing, transport, preparation) of common food items in India. Taken alongside literature such as Chancel and Piketty [7], such findings provide a solid argument for the need for studies such as this one to consider all greenhouse gases arising from consumption rather than just CO_2. The provision of GTAP and EORA provide table

[33] For future work.

outputs for GHG emission intensities in CO_2-equivalent as well as the just the emission intensities for CO_2 used in this study, make this a possibility.

Parikh et al. [81] report a total aggregate India household CO_2 emissions of 707 Mt from direct use of fossil fuels and indirect emissions from consumption. That finding does not appear to include direct emissions from biomass sources, which comprise over two-thirds of direct household emissions in this study as shown in Figure 20, but does include direct use of fossil fuels for transportation which this study was unable to include. Allowing for these large differences, only the grossest of comparisons can be made between this study's aggregate 2005 figure for India household CO_2 emissions from commercial fuels and indirect consumption of 562 Mt and Parikh et al.'s. A more informed comparison requires more detailed information on Parikh et al.'s [81] allocation of emissions to Indian households given in Table 2 of that paper. It can be generally observed that the total CO_2 emissions from all sources (direct use of fossil fuels including transportation, direct use of biomass fuels, and indirect emissions related to non-energy consumption), will be higher than either this study's or Parikh et al.'s estimate.

Appendix L

Growing end-use energy despite a decrease in household boundary energy use for deciles 6-10

Figure 27 indicates that households in income deciles six to ten in both 2005 and 2012 have been able to decrease the energy used in their houses for cooking, heating, lighting and general energy services while at the same time deriving greater utility from that energy. That trend also appears to hold true in general across all deciles in 2012. This seems counter intuitive at first glance, but when the increase in efficiencies of energy services is considered, then the reason for this trend becomes clearer. For example, a household that indicates it cooks in an 18% efficient [63] traditional stove using firewood, requires 3 times as much household boundary energy for that service as a household that burns LPG in an average 54% efficient stove. Furthermore, if a household were to replace a household lighting source using the same firewood and stove combination with electric lighting at 95% efficiency [27], then less than five times the amount of household boundary energy would be required. These are simplifications, but it is clear from such comparisons, and the results shown in Figure 3, that the explanation for increasing end-use energy with decreasing household boundary energy lies in richer households choosing to replace low efficiency energy services with higher efficiency ones. Khandker et al. [27] who estimate direct household boundary and end-use energy from IHDS 2005 data using similar methods, but present results separately for urban and rural Indian populations, depict very similar household boundary and end-use efficiency trends to the one described in this section among all but the top three 2005 urban deciles.

That solid fuels provide the energy for 83% of IHDS 2012 reported cooking energy services[34] and represent a quarter of the 2012 total household energy requirement shown in Figure 20, makes it clear that improvements in cooking energy service efficiency remain a critical potential area for reductions in solid fuel use in Indian households. Although efforts to increase the efficiency of India's solid fuel household cooking systems have been underway for over 50 years [6, 109], less than 7% of households represented by the IHDS 2012 survey indicated using an

[34] The IHDS survey does not allow a respondent to indicate the energy services that electricity provides in the house. This percentage would be lower if electricity's role in cooking energy services was included.

improved[35] solid fuel cook stove against 58% which reported using open or traditional cooking solutions. Over 34% of households reported a household chulha type of "Other/not biomass (Kerosene, LPG, etc.)".[36] IHDS reported results from 2012 represent a large improvement from 2005's IHDS findings of 24% of represented households with a "No biomass stove", 4.3% with an improved chulha, and over 70% cooking on open or traditional cooking solutions. Despite such gains, in 2012 nearly 700 million people in India lived in households using unimproved traditional or open fire solid fuel cooking solutions and fewer than 400 million reported living in households using modern cooking solutions.

[35] As the question focuses on whether or not the chulha has a chimney ("Improved chulha, with chimney"), there are no grounds to determine whether using an improved chulha also results in an energy efficiency gain.

[36] This figure is slightly less than the IEA and World Bank [9] reported WHO results which found that 36% of India's population had access to non-solid fuels in 2012. IHDS 2005 analysis results showing only 24% modern cooking solution use differ with an interpolation of WHO estimates for 2005 that suggest that 33% of India's population [9] had access to non-solid fuels in that year. WHO estimation methodology in India would need to be consulted, but IHDS results may better reflect a population's ability to reliably afford to use a modern cooking solution, rather than the availability of the solution in a location.

Methodological endnotes

---

[i] Although there are 204,569 individuals included in the IHDS 2012 individual data set, only 204,568 are recorded in the household dataset. The missing individual is not included in this analysis.
[ii] As 89% of households were interviewed in 2012, IHDS results are labelled 2012.
[iii] It is assumed that the difference between the total weighted representative population of the survey of 998 million people and the UN reported population of 1.14 billion people for 2005 [114] arises from the areas not able to be reached by the survey. By comparison, Woodbridge et al. [121] report that the weighted population of the nationally representative National Sample Survey Consumer Expenditure survey in 2005 was 982 million people. The difference between the weighted population covered by the 2012 survey of 1.21 billion people and the UN's estimation of 1.26 billion people is expected to similarly arise.
[iv] HDI goalposts are the maximum and minimum allowable values for life expectancy, mean years of schooling, expected years of schooling and income per capita for each HDI calculation year. This analysis uses the goalposts from 2015 (LEB min=20, max=85) (MYS min=0, max=15) (EYS min=0, max=18) (Income min=100, max=75,000 $PPP 2011). Use of consistent methodology and goalposts while calculating the HDI for other years (such as 2005 and 2012 as in this paper) allow HDI index and sub-index scores to be compared across years.
[v] Although kerosene is included under this label, when compared to LPG and electricity, its relatively low end-use efficiency cooking energy services [63] and greater indoor air pollution [122] make it the least attractive of the modern fuels.
[vi] Methods of estimation in this study consider non-commercially sourced fuels to be of the same quality as commercially sourced fuels, even though non-commercial fuels lack formally stated and enforceable quality standards (it might be argued that some commercially sold fuels do too). Use of fuels below commercial standards may result in a non-commercial fuel providing less useful energy and releasing more emissions than the same amount of a commercial fuel.
[vii] 1 kWh = 1 KJ/s x 3600s x 1 MJ/1000 KJ = 3.6 MJ. 1 tonne CO_2 = 1000 kg CO_2 = 1,000,000 g CO_2.
[viii] Khandker et al. [27] follow the same procedure when dealing with weights.
[ix] Khandker et al.'s [27] study uses the term "Total Energy" to refer to this value. We do not use that term to avoid confusion when we include energy arising from the household consumption of non-energy items. Pachauri and Spreng [29] call this "Total direct final energy use".
[x] This term is aligned with Khandker et al.'s [27] study to allow interaction with the findings of the study. Khandker et al. take the view that end-use energy represents the best energy measure of the benefit that a energy household derives from its energy use.
[xi] Aligned with Pachauri and Speng's [29] use of the term.
[xii] This analysis follows Pachauri [28] in assigning no additional indirect energy or emissions to non-commercial dung and firewood. Non-commercial crop residue and coal/charcoal are treated the same.
[xiii] Pachauri and Speng's [29] label this variously the "total household primary energy requirement", "total household energy requirement", "total (direct and indirect) energy requirements of households" and "total (direct and indirect) energy consumption of households".
[xiv] In cases where additional information is needed to make calculations involving those categories, required assumptions or needed values are sourced from relevant literature. However, although different end-use efficiencies should be used when a fuel's main designated use was heating, lighting or a combination of uses, the average efficiency across all fuel specific cook stoves measured by Smith et al. [63] was used when calculating end-use energy available from any energy carrier use category. In the case of crop residue, residues included were limited to those reported in Smith et al. [63]. Although Smith et al. [63] include rootfuels in their study, it was neither included in firewood or crop residue categories and thus is the only fuel covered by that study not included in this one. The specific gravity of kerosene in India is taken from Misra et al. [65]. Electricity end-use efficiency was taken from Khandker et al. [27].
[xv] Transportation fuels directly consumed by a household to power private transportation are not included in the 2005 IHDS survey. In 2012, the IHDS asks a specific question about expenditure on "Diesel/Petrol/CNG", but unfortunately also include maintenance also in the same category making it impossible to even calculate the grossest direct transportation energy figure.

[xvi] This is used as the better measure of consumption than estimations of consumption taken from expenditure on kerosene. This also avoids the need to account for whether the kerosene was purchased at a subsidized price.
[xvii] Village level price data for kerosene, LPG, firewood and dung is available as part of the both IHDS data sets. In cases where a village did not respond to a question on price for listed fuels or consumption items, average state level prices are calculated from IHDS data and inserted into household calculations. For LPG, subsidy information is needed in addition to price and expenditure information in order to estimate LPG use. For 2005 results, the average reported village level LPG prices were already in line with 2005 average subsidized prices given by Reddy and Srinivas [64]. No additional alterations were made to LPG pricing when a household indicated accessing the subsidy. Although this does suggest the need to increase the reported village price upward when a household reported buying unsubsidized fuel, this correction has not been implemented. Additional research is needed to determine whether reported 2012 LPG prices require adjustment when a household indicated accessing LPG through a 'government subsidized program'. No attempt made for either 2005 or 2012 to adjust LPG pricing when a black market source was reported by a household.
[xviii] Coal/charcoal, crop residue and electricity prices are not part of the IHDS data set. Additional assumptions need to be made for each fuel type. **Coal/charcoal:** In order to arrive at an estimate of the average charcoal price for 2005 and 2012, reported wholesale charcoal prices from a 2011 National Sample Survey Office report are given a 10% retailer mark-up on the conservative side of RWEDP [76] estimates, and then deflated or inflated to the appropriate survey year using World Bank [77] inflation data. This assumes that the basic price of the charcoal remains unchanged except for inflation. Also, although coal is included with charcoal in the fuel category, all fuel purchases/savings in this category are assumed to take place at charcoal prices. **Crop residue:** in the absence of relevant data, the crop residue price is set in the following manner. S. Singh et al.'s [66] estimates of daily crop residue use for an Indian household in Uttar Pradesh provides the only apparent time relevant data (although the paper was published in 2014, no year is given for data collection) this analysis could find for fixing the 2012 (or 2005) crop price. First the daily household usage for households using crop residue for energy in either traditional or improved stoves in the S. Singh et al.'s study is averaged (2.85 kg/day/hh) and then compared to Barnes [124] estimated daily average per capita usage of 0.5 kg/day in 1996 (Table 3.1, p28, does not give a year, but an adjacent table gives 1996 as a year) for six states in India. The lesser of the two figures (2.2 kg/day/hh) is selected after turning Barnes's [124] figure is turned into a household number using the average IHDS 2012 household size from this analysis (4.8 persons/household, although the per capita figure in Barnes is averaged against the entire population of six states rather than just the number of people using crop residue, so this figure is probably too low for a household using crop residue). It is then turned into an annual figure (800 kg/yr/HH). Then that total is multiplied by the representative national number of households estimated to be using crop residue for any purpose in IHDS 2012 reported data (60,276,150 or 24.2% of nationally represented households). The 2012 crop residue price is then adjusted until the total usage arising from commercial and non-commercial use in the survey approximates the number from the prior estimation (724 PJ/year). The average national crop residue price arising from this method is 2.8 Rs/kg. Whether price and total usage are reasonable or not is hard to determine given literature is unable to conclude whether it is a preferred [124] or inferior fuel in India. [123] The 2005 crop waste price (1.16 Rs/kg) was estimated using the average firewood price in 2005 (1.58 Rs/kg) and the per kg crop waste to firewood price ratio from 2012 (0.73). **Electricity:** State level electricity price estimates for 2005 are found by averaging three domestic tariffs (including taxes and duties) provided for each state/region by the Central Electricity Authority (CEA) [71] in 2009. Khandker et al. [private communication related to 27] created their estimates using the same data set. State level electricity rates for 2012 represent the average of six domestic tariffs provided by more recent CEA [72,73] reports. For some states/regions the data includes both rural and urban rates. The lowest tariff for each state/region for each survey year was substituted for the average rate across all tariffs when a household had indicated taking the LPG or kerosene subsidy or answered "No bill" [2] or "No bill/Govt. scheme" [1] to the survey question on electricity payments. See page 22 of CEA [73] for a description of various poverty related government electricity schemes in 2012.
[xix] The differences noted by India focused regional price [113] and electricity grid [69] studies compel further attention.
[xx] Pachauri [28] estimates that in 2000, non-commercial energy carriers comprised nearly 85% of total energy use in India's household sector. Recognizing that non-commercial energy use in India will still be prevalent in 2005,

Khandker et al. [27] use 2005 IHDS survey responses to impute for self-collected biomass in their analysis of household energy use in India.
[xxi] The statistical method of estimation (imputation) used in this analysis is taken from section 25.4 in Gelman and Hill [116].
[xxii] In the case a household answered “both”, the reported purchase amount is subtracted off the imputed amount to give the portion saved through self-collection. If the imputed amount is smaller than the purchased amount, self-collection savings are reported as zero rupees – or in other words, no self-collection is recorded.
[xxiii] Pachauri [28] does not include any indirect energy in the creation of firewood or dung.
[xxiv] As opposed to Pachauri [28], this analysis does not use a dimensionless energy multiplier to arrive at total primary energy use for these fuels but rather uses the sectoral energy and emissions intensities given in MJ/Rs to calculate indirect energy use. This study’s inclusion of location pricing differences is expected to overcome some of the energy price challenges that the use of energy specific dimensionless multipliers is meant to deal with. Subsidy pricing differences have not been included in estimation methods, resulting in underestimations of the indirect energy and emissions connected with the energy carriers.
[xxv] In both instances, single average figures are used; one for overall grid T&D losses, and one overall generation efficiency figure as calculated by dividing energy consumed in generation by electricity generated before T&D losses but after self-consumption. Total primary energy use = household boundary energy use / (1-T&D losses) / overall generation efficiency. In order to calculate the energy breakdown by fuel for electricity generation in India, electricity production from each fuel source was divided by the total production estimate using IEA [77,79].
[xxvi] Direct CO_2 emissions = household boundary energy use / (1-T&D losses) * grid emissions factor (transformed from CO_2 / kWh to CO_2 / MJ.
[xxvii] Adjusted expenditure represents household expenditure in rupees calculated by multiplying the consumption total in units of the commodity by the market price available to that household regardless of whether that unit was purchased at a market price, purchased at a subsidized price or home grown. Additional assumptions are needed when a household indicated that a portion of the consumption item was home-grown. As households gave no indication of what share of consumption was commercially purchased or home grown, this analysis arbitrarily chose to allocate half of indicated consumption as commercial purchase and the other half as home-grown.
[xxviii] Kerosene is one of those items. As it was already accounted for in the previous section, its estimation is not included in this section. The other IHDS consumption categories excluded from this section are a 2005 question on total spent on electricity, LPG and firewood and 2012 questions on electricity and household fuel (firewood, cow dung, LPG) consumption as these items were included in the analysis in the direct energy section’s calculations.
[xxix] In this iteration, the sectoral intensity of home-grown goods is assumed to be zero which is in-line with this study’s treatment of commercial and self-collected firewood, dung and crop residue as well as non-commercial coal/charcoal in direct fuel usage, but requires further consideration for the next iteration.
[xxx] As sectoral intensities for each of the global IO databases can vary widely when compared across a common year, country and sector, comparison of results with past literature or even other IO databases should be undertaken with close attention to each databases methodology.
[xxxi] Urban and rural comparisons for 2005 are delineated using an IHDS 2005 provided indicator representing 2001 census urban/rural classifications for the village/town’s surveyed. Urban and rural comparisons for 2012 are delineated using a similar IHDS 2012 indicator based on 2011 census data. Although indicators in both the 2005 and 2012 IHDS data set allow for more nuanced rural/urban classifications, this analysis chose to focus on the rural / urban divide as broadly referred to in prior literature, while acknowledging that pursing such classifications as part of future analyses might provide additional insight. IHDS 2005 and 2012 variables also allow results to be additionally divided into urban slums (2005), and metro, more developed village, and less developed village (2012).
[xxxii] For analyses that do not separate the population into quantiles, these households are left in the data set. However, for the HDI analysis, 838 households were removed for this reason in 2005 and 750 in the 2012 analysis. The inflation adjusted cut-off (using WB [77] inflation values for India) for 2012 in Rs 2012 is 1,723 Rs. If should be noted that although the number of households reporting negative farm and business incomes increased from 1,537 in 2005 to 4,531 in 2012, then total number of households with negative overall incomes stayed fairly constant, moving from 461 households in 2005 to 452 in 2012.

[xxxiii] Due to the observation of inflated bottom decile results in early iterations of the analysis, the study takes the additional step of removing a household from the bottom decile if both its household per capita consumption and per capita asset count rank are above the average value calculated for the fifth decile. The fifth decile was independently chosen for each survey year from a graphical analysis (finding the plot's "knee" – or the minimum of the radius of curvature function) of a plot of the number of households in the first decile having both a reported negative farm income and consumption and asset values greater than the average value for each decile. Households meeting such criteria in 2005 and 2012, numbered 69 and 109 respectively.

[xxxiv] Per capita in this study is in alignment with standard per capita measures from the UN [115] and uses the total population in calculation of per capita indicators. Such measures include all adults as well as children. In the case that an income estimate has not been given for a household, an income of zero is assigned to the household, which in effect removes it from the analysis (see prior footnote on income cut-off). Note that households missing IHDS constructed total assets in (2005: 0 HHs, 2012: 23 HHs) and monthly per capita consumption (2005: 63 HHs, 2012: 23 HHs) variables were not removed from the study as these items are not critical. For assets, the HH's were assigned the mean value from that year (2005: 12.25, 2012: 15.44). Missing per capita consumption was zeroed.

[xxxv] In cases where a household's representative population spans a border, the entire household is placed in the lower decile and the next decile starts with the representative population of the following household.

[xxxvi] Scaling occurs because the HDI definition is in GNI per caita and GNI per capita from national accounts often differ substantially from mean incomes calculated from survey data. Such an approach is in-line with methods used by Harttgen and Klassen [42] and Grimm et al. [41] who also use household survey data to estimate sub-national HDI scores.

[xxxvii] In instances where enrolment, grade repetition, or higher degree attainment are missing, each is assigned the following entries: not enrolled, no grade repeated, no higher degree.

[xxxviii] In instances where a respondent's answer to standard years completed was "Above Bachelors" in IHDS 2012, additional years of schooling needed to be added to total years of school used in the analysis. UNESCO [98] was consulted to aid in mapping respondent answers to 2011 ISCED levels and adding an appropriate number of years to the respondent's total years of schooling. When the category selected by the respondent included degrees with different theoretical durations, the durations were averaged. In the case of "Professional degree", 2011 ISCED India mapping [98] did not offer guidance and the duration of the degree was arbitrarily chosen to have the same duration as "Master's degree/Ph.D." and "Diploma 3+ years" at 18.5 years of schooling. For an answer of "MBBS/BAMS", 17.5 years was used. For answers of "Diploma <3 years", 16.5 years was used. For answers of and "BE, B.Tech" and "Others", 16 years was used. For IHDS 2005, available responses on higher degree achievement are more limited and the respondents answer to standard years completed only when a "Bachelors" answer was also supplied. For consistency's sake, 2011 ISCED total years of duration [98] were applied to 2005 IHDS responses. For an answer of "Masters" and "Professional", 18.5 total years were assigned the individual. For an answer of "Vocational", 17.5 years was used. For an answer of "Bachelors", 16.5 years was used. For an answer of "Others", 16 years was used.

[xxxix] As per UNESCO [97], individuals missing educational attainment data for each survey year comprise less than 10% of population aged 25 years and older for each relevant decile group and have been excluded from the MYS calculation.

[xl] Deaths data for all individuals that were also part of the 2005 survey is available in the 2012 Tracking data set. Deaths for the children of any mother interviewed as part of the 2012 Eligible Woman questionnaire – both in repeat and new households – can be found in the 2012 Birth History data set.

[xli] A number of challenges exist. a) In the tracking data, the method of estimating the timing of deaths (measured in variable TH3) creates ambiguity as to whether a death happened in the past year. For example when only considering one year of deaths data in 2012, all deaths estimated at either 0 or 1 'years since died', 383 and 1352 deaths respectively, are included at the start of the analysis. The 79 deaths that do not correspond to an eligible household in the 2012 data and the 43 deaths for which a 2005 person ID exists and an age under five is given, are then removed from the analysis. In addition, the one deceased individual who has been assigned a personal ID matching an individual in the 2012 individual data set has been removed from the deaths data. b) Given limited data in the 2012 Birth data set, an estimate must be made of the deceased's date of death using the provided birth date or approximate age and the age reported at death. There is the possibility of significant estimation errors

involved in a respondent's recall of birth dates, the approximate age deceased would be at time of interview, and age at which the deceased was reported to have died. Due to that error, a death is included in the LEB analysis not only if the estimated date of death is less than a year prior to the interview date, but also if the estimated date of death appears to have occurred after the interview date. In the case of missing or confusing date or age data, the following process was followed: if a birth year was given, but month was missing, then the mean birth month (calculated from IHDS 2012 data) of 6.53 was inserted; if no birth year was given and no approximate age was given, the death was not included in analysis; if a year was missing from death age, then the deceased was removed; if no birth date was given and no approximate year of age given – but a month was given, then the deceased was assumed to be less than 1 years old; if an approximate age year is given, but the month was unknown or missing, then insert mean age month calculated from IHDs data of 4.23; if an death age year was given but a month was missing or unknown, the mean death month (calculated from IHDS 2012 data) of 3.55 was assigned to the deceased (does not include infants); if 55 was recorded as the death year (signalling infant less than one month), which should also be accompanied by a death months record of 55, but instead a month between 1 and 12 was still recorded for death months, the death was kept for analysis with zero years and the months given – due to the unusually high number of 55's recorded by the survey compared to surrounding years, this seems more appropriate than removing the deaths. Fifteen days have added to all calculated death dates, which were only calculated in years and months, to place the death in the middle of month when estimating distance from the date of interview which is given in years, months and days. And finally, any deceased individual that was eligible for the LEB analysis and recorded in both Tracking and Birth History data sets as having the same household and same death age, has been removed from analysis. For the four living members of households not given an age in the IHDS 2012 Individual data set, the mean IHDS 2012 age of 29.82 years was inserted prior to running analysis.

[xlii] If a person in a household added to the survey in 2012 died in recent years, and was not the child of an interviewed 'eligible woman' in the 2012 IHDS survey, then that death was not recorded in IHDS data.

[xliii] We did not calculate the intensities ourselves, but were supplied them by the researchers at EORA. We are grateful for their assistance as well as the researchers at UQ who facilitated the data acquisition.

[xliv] Pachauri [28] estimates that non-commercial energy comprised 21.4% of total final energy consumption in the industrial sector and 32.3% in the agricultural sector in 1999-2000. Although this partially explains why EORA sectoral energy intensities are systematically lower than Pachauri's, it does not explain the observed magnitude in difference for many sectors (paddy, wheat).

[xlv] All non-commercial energy carriers and home-grown goods are considered to have energy and CO_2 emission sectoral intensities of zero.