Energy access and living standards: some observations on recent trends

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LETTER

Energy access and living standards: some observations on recent trends

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Abstract

A subset of Sustainable Development Goals pertains to improving people's living standards at home. These include the provision of access to electricity, clean cooking energy, improved water and sanitation. We examine historical progress in energy access in relation to other living standards. We assess regional patterns in the pace of progress and relative priority accorded to these different services. Countries in sub-Saharan Africa would have to undergo unprecedented rates of improvement in energy access in order to achieve the goal of universal electrification by 2030. World over, access to clean cooking fuels and sanitation facilities consistently lag improved water and electricity access by a large margin. These two deprivations are more concentrated among poor countries, and poor people in middle income countries. They are also correlated to health risks faced disproportionately by women. However, some Asian countries have been able to achieve faster progress in electrification at lower income levels compared to industrialized countries' earlier efforts. These examples offer hope that future efforts need not be constrained by historical rates of progress.

1. Introduction

The Sustainable Development Goals (SDG) agenda sets ambitious goals for accelerating the pace of basic human development. A subset of these goals includes improving people's living standards at home, including the provision of access to electricity, clean cooking energy, improved water and sanitation. These amenities play a critical role in reducing deprivations known to constitute multidimensional poverty (Alkire and Santos 2010, UNDP 2010). These goals carry common practical and distributive challenges, in that they require the extension of infrastructure directly to every single home in all countries. Are these goals feasible? Are there challenges within countries related to equitable access? In this study, we examine historical progress in energy access in relation to other living standards. We assess regional patterns in the pace of progress and the relative priority accorded to these different services. We give specific attention to the rate and drivers of electrification in a select set of countries that achieved close to universal access at different times and income levels. We draw lessons for their future replicability and the likely achievement of the energy access SDG.

Our main findings are as follows. Countries in sub-Saharan Africa would have to undergo unprecedented rates of improvement in access in order to achieve the goal of universal electrification by 2030. However, some Asian countries have been able to achieve faster progress in electrification at lower income levels compared to industrialized countries' earlier efforts. These examples offer hope that future efforts need not be constrained by historical rates of progress. On a less optimistic note, we find that, world over, access to clean cooking fuels and sanitation facilities consistently lag improved water and electricity access by a large margin. These two deprivations are more concentrated among poor countries, and poor people in middle income countries. They are also correlated to health risks faced disproportionately by women.

The rest of the paper is organized as follows. In section 2 we describe the data sources and methods used in this analysis. In section 3, we present and

discuss results. We focus first on electrification efforts, where we quantify the rates and time for full electrification in ten countries, industrialized and developing, and relate them to average income. We then describe past progress in the four living standard indicators across countries, and compare them to nourishment, which has historically received high priority in development. Finally, we examine distributive patterns of living standards within five countries—India, Brazil, Ghana, Indonesia and South Africa. In section 4, we conclude with some policy implications and topics for further research.

2. Data and methods

In general, we rely on standard macro indicators from the World Bank and United Nations Organizations databases for cross-country analysis for the period 1990–2010, as further specified in section 2.2 below. For the within-country analysis, we use microdata from the two most recent rounds of nationally representative household surveys for the chosen countries. We next describe the specific data sources and methods for each analysis.

2.1. National electrification progress

In order to investigate the pace and time till full electrification, we use historical electricity access data for ten countries compiled for the Global Energy Assessment (Pachauri *et al* 2012, Grubler *et al* 2014), and average GDP per capita data from the Maddison Project version 2013 (Bolt and Zanden 2014). These are the only countries for which data going back further than 1990 are available. We fit S-curves over the historical electricity access data in relation to time period and average income per capita using R's Non-Linear Minimization (nlm) package.

2.2. Regional progress in access to electricity and other living standards

We analyze differences in access to electricity, clean cooking, improved water sources and sanitation facilities, applying consistent definitions at both the micro and macro scale. For access to improved drinking water sources and sanitation facilities, we adopt the definition of the indicators from the Millennium Development Goals (WHO & UNICEF 2006). Improved water sources include piped water in the home or plot, tubewells or public taps. Improved sanitation facilities include flush toilets connected to a sewer system, septic tanks, pit latrines or composting toilets. Note that access to shared facilities, such as public taps, counts as households' access to improved water supply, which is not the case for sanitation. This may serve to overstate household access to improved water supply relative to improved sanitation (Cumming *et al* 2014), and overstate the convenience assumed in the corresponding service. On the other hand, concerns of hygiene and safety in shared toilets may merit a stricter standard for sanitation. In any case, data limitations prevent a more nuanced measure of access. Clean cooking is defined as households using any fuel other than solid (biomass-based or coal) as their primary cooking fuel, which could include electricity, liquid petroleum gas (LPG) or kerosene. The numbers likely overstate the extent of clean fuel use, because many households enter their 'best' fuel as their primary fuel even if they use traditional (solid) fuels for the bulk of their cooking. There aren't sufficient data available in most countries that enable one to infer primary fuel based on the actual fuel shares. Electricity access refers to a central grid connection in the home and use of electricity as a primary lighting source. This indicator might understate the extent of electricity access as decentralized and off-grid lighting systems tend to be poorly represented, either because they are excluded from survey samples, or because respondents may associate electricity with the grid. Furthermore, these data do not account for the actual supply or quality of electricity, which, from few household surveys that do measure reliability, can vary widely (Rao 2013).

National data on energy access and living standard indicators and their socio-economic correlates are drawn from the World Bank's World Development Indicators Database (WB 2016), which use the definitions described above. Data on the share of population adequately nourished are from the FAO statistics (FAO 2015). Health impacts data for female Disability-Adjusted Life Years (DALY) associated with health risks from household air pollution (HAP) and unsafe water, sanitation, and handwashing (WaSH) are from the Global Burden of Disease (IHME 2013).

We present progress in aggregate for the four developing regions: East Asia & Pacific, Latin America & Caribbean, South Asia, and sub-Saharan Africa, using population-weighted country data on living standards. High income countries in the East Asia & Pacific region are excluded from the analysis. We further omitted countries for which data on any of the living standard indicators are missing. We also exclude countries in Middle East and North Africa, North America and Europe, since access rates are close to hundred percent for all indicators in these regions. In total, we used a dataset comprising 68 developing and emerging countries for the period between 1990 and 2010. Table S1 in the supplementary materials (available at stacks.iop.org/ERL/12/025011/mmedia) lists included countries by region.

2.3. Living standards distribution within countries

We also examine access to electricity, clean fuels, water and sanitation within countries. Microdata are drawn from nationally representative household consumer expenditure and living standards surveys from Brazil, Ghana, India, Indonesia and South Africa. We use data from the two most recent rounds of surveys for the

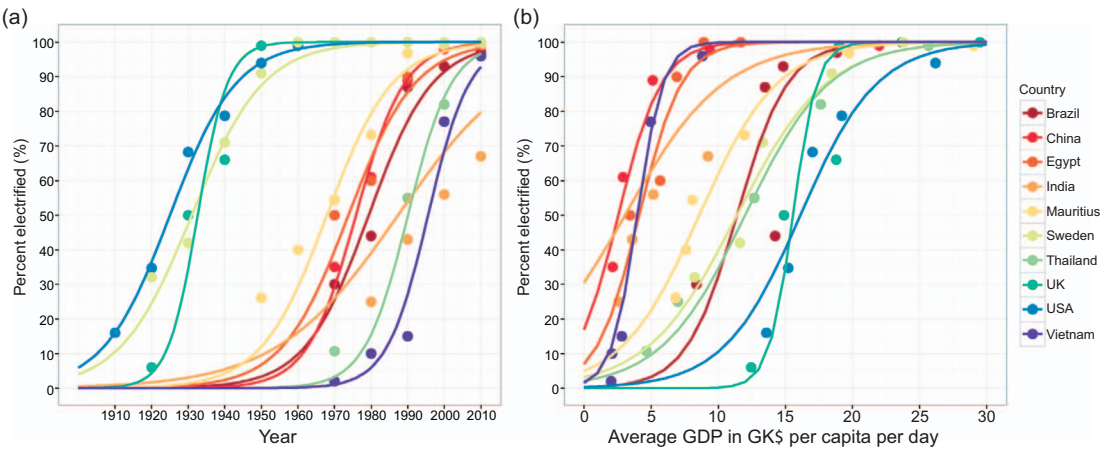

Figure 1. S-curve fits to historical electricity access data by year and average income level in international Geary–Khamis dollars (GK$).

selected countries other than Indonesia, for which we had access to only a single survey. Table S2 in the Supplementary Materials includes a list of national household surveys employed in this analysis and sample sizes. We excluded some living standard indicators for particular countries where either questions were missing from a specific survey or data quality are extremely poor. We further excluded observations from all surveys at the tails of the expenditure distribution (the bottom 2.5 percentile and top 5 percentile) where sampling is very thin and unreliable. The surveys in each country have different options for the responses to water and sanitation access availability, but these options were all easily interpretable under the MDG definitions described above. In the case of electricity access, none of the surveys provide information on the quality or reliability of supply. Knowing that conditions vary widely, this is a caveat of the analysis.

3. Results and discussion

3.1. Electrification progress and prospects

Despite significant improvements in access to electricity over the last few decades, in several sub-Saharan African countries the vast majority of population remains unconnected even today (IEA 2015, WB 2015). Historical rates of electrification among the ten selected countries show a large variation across countries and time (figure 1). In general, countries that embarked on electrification more recently progressed faster, and starting from lower average income levels, than earlier adopters.

We find that for countries in our sample that achieved close to full electrification, progress is well represented by an 'S' curve, with respect to both time and income (figure 1). This implies that countries achieve up to 80 percent electrification relatively fast, but take comparatively longer to achieve universal access. It took the UK only 11 years to increase access coverage from 20% to 80% of its population, but a further 17+ years to reach full access. For countries that embarked on electrification prior to 1970, countries took from 19 to 27 years to achieve from 20% to 80% electrification, and an additional 20 to 40 years to get to universal access. However, Vietnam and Thailand, which embarked on electrification after 1970, took 15 years to increase access coverage from 20% to 80%, and a further 11 to 20 years to reach full electrification.

Geographic expanse and population density play a part. While the US started a decade after the UK, it took 25 years to reach from 20% to 80% access. China, with a similar geographic area but much larger population size and density than the US, took 19 years to achieve the same percent of coverage. Rapid rural electrification in Vietnam and Thailand was also aided by the relatively high population densities in these nations. This contributed to lowering costs of transmission and distribution and ensured a larger industrial and commercial base of customers that helped with revenue generation and the financial sustainability of the efforts (Shrestha *et al* 2004, WB 2011a).

Early achievers, like the UK and USA, started electrification at a relatively higher average per capita income level compared to recent adopters. Average income in the UK and the USA was around GK $15/capita/day when electricity access was about 20%. More recently, China and Vietnam started the electrification process when average income was less than GK $5/capita/day. However, countries achieved >90 percent electrification only when average incomes reached about GK $15–20/capita/day. One exception is China, which achieved universal access at relatively low income levels (<GK $10/cap/day).

The relationship to income doesn't necessarily imply that countries require a certain financial or industrial base in order to have the capability to extend access. Rather, it may just be that governments give priority to electrification at a certain development stage indicated by the income level. Indeed, the experiences from countries that have successfully

extended electricity access to their populations suggest that strong and sustained public commitment and coordination between central and regional bodies was critical (Brew-Hammond 2010, ADB 2011, WB 2011b, Bouille *et al* 2012).

While country specific contexts and conditions certainly contributed to successful electrification in particular countries, certain broader lessons can be drawn from such cases that are relevant to other regions. In particular, prioritized and sustained government policy, dedicated institutions that coordinate closely with local governments, and the embedding of electrification efforts within the broader framework of rural development, are common features of successful electrification efforts in Vietnam, Thailand and other nations (Shrestha *et al* 2004, WB 2011). In addition, following a gradual phased approach, with clear planning, effective institutions and dedicated funding that allows for flexibility are also common features of the efforts in these successful cases (Barnes 2007).

Today, many low-income countries are still far from achieving universal access. What would it take for them to achieve the SDG goal of universal electrification by 2030? The cases of Vietnam and Thailand provide evidence of rapid upscaling of electrification efforts that might be replicated elsewhere. For sub-Saharan Africa in general, if countries were to follow Vietnam's rate of progress (20% to 80% of the population in 15 years, and crossing 95 percent access in 25 years), close to full electrification might be achieved by about 2035. In India, universal electrification might be achieved even by 2020, if it were to follow Vietnam's experience. In any case, achieving the SDG in these regions will require unprecedented growth rates in access provision compared to past trends. The deployment of decentralized, small-scale systems in remote regions, as in Bangladesh and China, may also offer options for more rapid electrification (Alstone *et al* 2015, Groh *et al* 2016). However, whether such systems are scalable to support growing demand from rural development is still an open question (Practical Action 2014, Rao *et al* 2016).

3.2. Energy access in the broader context of human development

The SDG related to living standards include access to clean cooking fuels and electricity (SDG 7), access to clean water and sanitation (SDG 6), and safe and resilient housing (SDG 11). All these elements, with some variation, also comprise the living standard dimension of the Multidimensional Poverty Index, which provides a more revealing measure of human deprivations and progress (Alkire and Santos 2010, UNDP 2010). Indeed, the headcount of the poor measured by the MPI exceeds that measured by the International Poverty Line (IPL) (PPP $1.25/day in 2005) in most developing countries, in a few cases up to 40–50 percent higher (Alkire and Santos 2014).

To raise human living standards to the level targeted by the relevant SDGs (6, 7 and 11) would go a long way towards eradicating poverty. Not only are these living standards seen as entitlements in their own right (UN 1966), but they are also instrumental to achieve a number of other goals, such as those related to health and education. Indeed, many of the SDGs are related, and implicitly even dependent on each other, in ways that have not been fully articulated (Waage *et al* 2015, Nilsson *et al* 2016). Understanding these dependencies is impportant to their collective achievement.

One potential dependency that has received attention is the relationship between income and human development (Srinivasan 1994, Boozer *et al* 2003). The widely used Human Development Index is a clear indication that income captures only one part of development. However, HDI is an aggregate 'outcome' indicator of societal progress, which gives little indication of the intermediary conditions, such as living standards, that need to be in place to make progress. Systematic evaluation of the relationship between such means indicators and income, such as one that asks whether a certain income level is required to be able to put certain infrastructure into place, are still lacking.

Dependencies between energy and SDGs are underexplored. Shifting to clean cooking fuels is known to lower health risks associated with inhaling noxious emissions from traditional cook stoves (Smith *et al* 2014). However, without electricity access, households may also inhale emissions, albeit in lower amounts, from burning kerosene for lighting (Lam *et al* 2012). Similarly, modern cook stoves free up women's time spent on collecting fuel towards productive or leisure activities. However, without in-house access to water, they may still spend as much time collecting water from remote sources (Pachauri and Rao 2013).

These dependencies help identify practical limitations of achieving some goals without others. For instance, electricity access is known to have benefits for children's education by enabling them to study at night (WB 2008, UNICEF 2015), but electricity is also necessary to create a comfortable learning environment in schools, and to treat water and pump it to people's homes. There have indeed been cases where programs in one sector have combined with programs in other sectors, such as between female reproductive health and cook stoves (WB 2011).

3.3. Regional progress in living standards

Here, we look across all countries at the progress in extending living standards to populations, compared to income growth, and to the progress in adequate nourishment, which is in some ways a benchmark, since it is typically a high priority in most countries and development aid agendas, and has been the primary basis for poverty measurement (Practical Action 2014, Groh *et al* 2016).

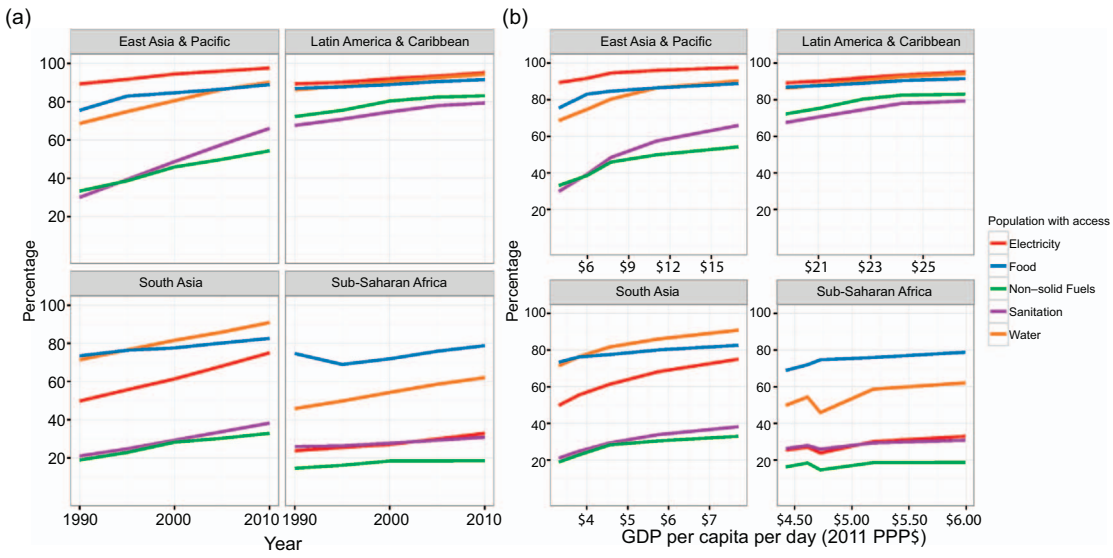

Figure 2. Regional (population-weighted) average access to living standards and nourishment 1990–2010 by year (*a*) and average income (*b*).

Table 1. Average annual growth rate in GDP and access to living standards 1990–2010.

Region	GDP pc	Electricity	Sanitation	Improved Water	Adequate Nourishment	Clean Cooking
Pacific/East Asia	7.6%	0.4%	4.0%	1.4%	0.8%	2.5%
Latin America	1.5%	0.3%	0.8%	0.4%	0.3%	0.7%
South Asia	4.3%	2.1%	3.0%	1.2%	0.6%	2.8%
Sub Saharan Africa	1.2%	1.7%	0.9%	1.5%	0.3%	1.2%

Figure 2(*a*) shows regional progress from 1990 to 2010 in access to adequate nourishment and to different living standards, including electricity, clean cooking, improved water source and sanitation.

One common observation is that in all regions of the world, over the entire period, sanitation and clean cooking have the lowest access rates. Between South Asia and sub-Saharan Africa, by 2010 less than 30% (700 billion) had access to clean cooking fuels. It is perhaps some consolation that, with few exceptions, growth rates in access to sanitation have been higher than other living standard indicators, though from a lower base (table 1). In contrast to clean cooking and sanitation, improved water access is most widely available and growing relatively fast.

In sub-Saharan Africa, uniquely, electricity access is equally low as sanitation access, and clean cooking is even lower than both. In contrast, in Latin America and East Asia & Pacific, electricity access is the most widely prevalent living standard, substantially more than even the population with adequate nourishment. Adequate nutrition remains unavailable to around 15% of the population even in these regions that have done relatively well in expanding access to basic living standards. In South Asia and sub-Saharan Africa around 20% of the population still lacks access to adequate nutrition.

We expect that deprivations in some of these living conditions, particularly clean cooking fuels, but also sanitation, would increase health risks, due to exposure to smoke from cook stoves, and hygiene-related illnesses from water-borne diseases. However, other factors that may mediate between exposure and health effects, such as immunity from healthy diets and health care, could diminish the relative importance of living conditions. We examine the correlation between these two living conditions and the associated female disability-adjusted life years (DALYs) for household air pollution and water-borne illnesses respectively. We examine these statistics for women in particular, because these risks are likely to affect women to a greater extent, due to common gender roles related to household chores, such as cooking and washing clothes.

The results show that indeed there is a strong and similar relationship between living condition and health impact for both sanitation and clean cooking access, both mediated by general economic conditions (GDP) (figure 3). In the poorest countries in Sub-Saharan Africa small improvements in access are associated with large reductions in DALYs. Greater vulnerability to illness, poorer health facilities, among other factors, likely contribute to a greater extent in poorer countries. With increasing income, DALYs reduce substantially, leading to diminishing returns for further reductions in DALYs from improving access levels.

In other words, the greatest gains for reducing health risks are to be had in the poorest countries

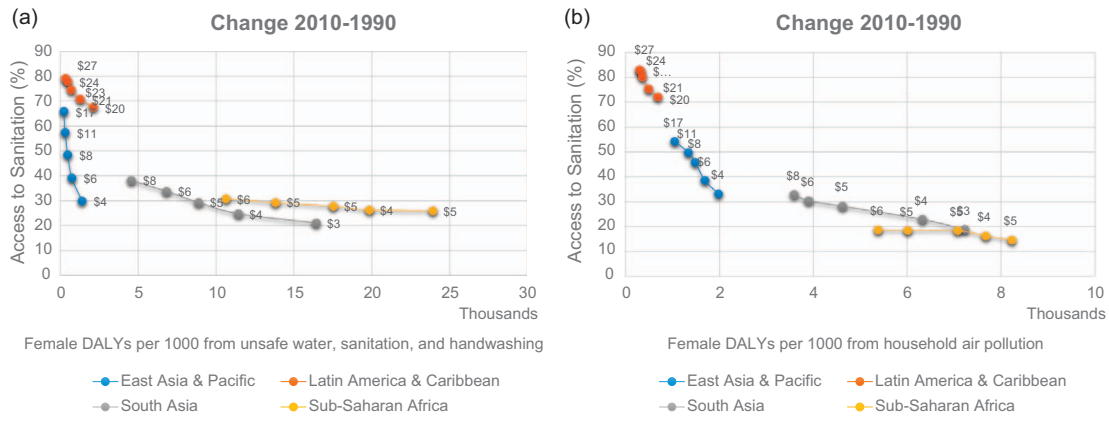

Figure 3. Relationship between average living conditions and women's health risks by region. Data labels show average per capita GDP/day ($2011 PPP) (*a*) Sanitation access vs water-borne illnesses DALYs; (*b*) Clean cooking fuel access and household air pollution DALYs.

where access is neglected the most. Though this is sadly a recurrent phenomenon in the developing world, we show that this extends to the provision of safe living conditions as well.

3.4. Living standards and income growth

Figure 2(*b*) shows progress in living standards and nourishment against average GDP over the period 1990–2010. While in general countries with higher GDP have higher living standards, national income growth isn't sufficient or even necessary on its own to achieve improvements in living standards. This point has been made earlier with regard to other 'outcome' indicators such as life expectancy (Bloom *et al* 2007). It has also been used as an argument for expanded public policy engagement that is more holistic, inclusive and universalistic, and that recognizes the multidimensionality of poverty (DESA 2010). However, it has only been implied, but not explicitly assessed, for 'means' indicators such as household living conditions (Rao *et al* 2014). GDP growth rates far exceed those of living standards improvements (table 1). In rare cases, such as clean cooking in SSA, access has increased at a rate exceeding that of GDP growth, but from a very low base. There is considerable variation in access levels for all living standard indicators with income across countries. At similar income levels (considering only country averages at this point), South Asian countries have higher levels of access than in sub-Saharan Africa. Countries in East Asia have equally high (or higher) levels of access for electricity and water at lower incomes than those of Latin American countries.

3.5. Distribution of living standards within countries

To what extent do the national averages in access to living standards mask differences in access within countries? We examine this question for five countries for which we have microdata, including at least one in each of the four developing regions South Asia, sub-Saharan Africa, Latin America, and East Asia & Pacific (figure 4). We focus on the rural population, since most of the population without access live in rural areas. As expected, access levels show the same pattern with respect to income within countries as they do between countries, except with starker differences across income levels. What is striking is that in countries that have relatively lower average access levels (India, Indonesia and Ghana), clean cooking access is persistently worse than other living standards even at high income levels. Brazil may look like an exception, in that improved water supply is the least available of the four indicators among the poor. However, overall access levels are high (the national estimates suggest much higher improved water access at 99.4% for the country as a whole) (IBGE 2010), so the differences in living standards apply to a very small population, while the rest of the population have comparably high living standards. High access to living standards in South Africa show that it is an outlier in sub-Saharan Africa. This may be related to the fact that the average GDP per capita of South Africa is over four times that of the average in sub-Saharan African countries (~$7300 K vs $1700 K in 2012). South Africa is unique also with regard to the significant political and social transformation that occurred in its post-apartheid history. Significant shifts in non-income welfare, in particular, have occurred in South Africa since 1993 (Leibbrandt *et al* 2016).

Earlier, we discussed the extent to which countries' income reflect their general living standards. Here, we ask a similar question of populations within countries—are people with poorer living standards also income poor? We compare the population share with access to each living standard to the share of total expenditure held by them (table 2). If those with access are particularly concentrated in higher income groups, their expenditure share would be higher, except at very high levels of access, where there isn't much room for income share to be higher. As expected, by and large the total expenditure share of

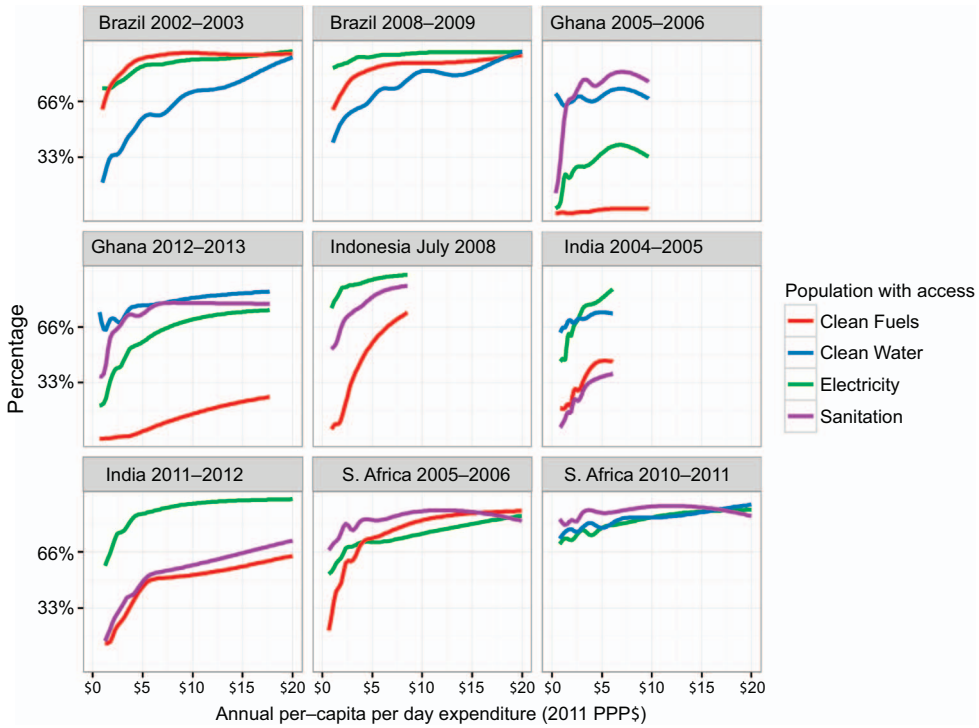

Figure 4. Distribution of living standards access by income, rural areas in select countries.

Table 2. Income share of those with access to living standards. NA: missing or poor data quality.

Income Share % (Popn Share with Access)	Clean cooking	Electricity	Improved Water	Sanitation	Solid roof (shelter)
Brazil 2008–2009	90 (90)	99 (99)	97 (93)	NA	99 (99)
India 2011–2012	53 (40)	91 (83)	NA	52 (46)	86 (80)
South Africa 2010–2011	NA	96 (87)	97 (93)	98 (94)	54 (26)
Ghana 2012–13	37 (23)	83 (72)	92 (87)	88 (81)	18 (14)
Indonesia 2007–8	70 (51)	96 (93)	69 (73)	NA	64 (66)

those with access is higher or roughly the same for all groups. What stands out looking across countries, except in Brazil (where living standards are high across most of the population), is that those lacking clean cooking fuels and a solid roof seem to be more concentrated among the income poor. The two groups likely correspond to rural poor and urban slum dwellers.

4. Conclusions and policy implications

The conditions of our homes, their hygiene, livability and basic amenities, influence our basic wellbeing. We have examined recent global trends in the provision of energy access in the context of these living conditions, including energy for cooking and electricity, water and sanitation, and to a limited extent, nutrition. Growth rates for all living conditions are far below those of GDP. Among the living conditions, inadequate sanitation and solid cooking fuel use, both of which are associated with high health risks, lag other services everywhere, but to the greatest extent in sub-Saharan Africa. The differences in progress in these two living standards across regions are stark, and correlate with improvements in women's health. We find even starker inequities in provision within the developing countries we examined, wherein deprivations in living standards are concentrated among the income poor.

There is potential for the SDGs to rectify this imbalance by generating the necessary impetus at the global level to alter development priorities, provided that the goals are subdivided and targeted equally to women and men, and to urban and rural areas. To achieve full electrification in sub-Saharan Africa by 2030 would require unprecedented growth rates in Africa, but which have been found elsewhere in Asia. To achieve universal access to clean cooking, annual growth in SSA would have to increase from the historical rate of ~1 percent to almost 9 percent.

That energy access is its own SDG (7) represents significant progress in the recognition of the importance of energy for development. Yet, the potential interaction of the achievement of other SDGs related to living conditions on energy access merits further exploration. Best practices in the non-energy sectors should also be examined to determine

the feasibility of achieving other SDGs related to living conditions. That these SDGs serve the same end point, share similar infrastructure and the need for financial support to ensure affordability, offer considerable scope for coordinating their future provision, notwithstanding the known institutional silos and coordination issues prevalent in policymaking. Ultimately, the nature of public policy and actions that target access to the necessary range of basic needs and infrastructure services at appropriate levels and with quality assurance are likely to have the greatest bearing on outcomes that directly impact the living standards of the poor.

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