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Energy poverty alleviation and climate change mitigation: Is there a trade off?☆

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ABSTRACT

Energy poverty alleviation has become an important political issue in the most recent years. Several initiatives and policies have been proposed to deal with poor access to modern sources of energy in many developing countries. Given the large number of people lacking basic energy services, an important question is whether providing universal access to modern energy could significantly increase energy demand and associated CO^2 emissions. This paper provides one of the few formal assessments of this problem by means of a simple but robust model of current and future energy consumption. The model allows mapping energy consumption globally for different classes of energy use, quantifying current and future imbalances in the distribution of energy consumption. Our results indicate that an encompassing energy poverty eradication policy to be met by 2030 would increase global final energy consumption by about 7% (roughly 20 EJ). The same quantity of energy could be saved by reducing by 15% energy consumption of individuals with standards above current European levels. The additional energy infrastructure needed to eradicate energy poverty would produce 44–183 $GtCO^2$ over the 21st century and contribute at most 0.13 °C of additional warming.

1. Introduction and motivation

Understanding the distribution of current and future energy needs is an important goal for research and policy. On the one hand, lack of access to reliable energy is believed to hamper economic growth in poor economies. This is known as 'energy poverty', and has received increased political attention in most recent years. On the other hand, energy consumption met with the current fossil fuel based energy mix leads to emissions of greenhouse gases, which are accumulating in the atmosphere and are the major source of global climate change. Analyzing the extent to which these two global problems interact with each other would allow us to better understand which policy instruments can be put in place if both problems were to be tackled. The contribution of this paper is to provide some quantitative input to this discussion. We employ a reasonably simple model calibrated on data on consumption and income distributions, and show that it can replicate quite accurately the current distribution of final energy consumption by households. We use the model to assess the pressing policy issue of energy access to different parts of the society, and evaluate the impacts of energy poverty alleviation in terms of additional demand of energy and associated greenhouse gas emissions for different carbon intensity assumptions. Our tool is useful for mapping and representing global imbalances: we show that now the poorest 3 billion people have negligible energy consumption, and that the 1 billion people with energy consumption equal or above the European standards use 3/4th of total final energy. Taking as given the projections of international agencies such as the IEA, we show that in a Business as Usual scenario in 2030, minor changes would occur in the low energy consumption categories, with roughly the same number of people lacking access to basic human energy needs, though with an increased concentration in Africa. On the other hand, there will be a large number of additions in the higher energy consumption categories, mostly driven by economic development in the fast growing economies. We estimate the additional energy demand which would be required to eradicate energy poverty at about 20 EJ in 2030, less than 10% of the projected consumption in a BAU, and 15% of consumption of the most affluent categories. With different assumptions about the carbon intensity of energy infrastructure, this additional demand would generate carbon emissions over the century in the range of 44–183 $GtCO_2$. This corresponds to a relatively minor contribution to global warming. Our analysis thus supports the thesis that energy poverty and climate change policies can be set independently from each other.

2. Measuring energy needs

The debate surrounding energy access has become a key one in energy policy-making over the last few years, an acknowledgment of

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the important role of energy in development. Though energy poverty cannot be completely distinguished from traditional poverty alleviation, its independent assessment is important for various reasons. First, though poverty traps have long been recognized, their solution in terms of policy intervention is still highly debated, with the traditional divide between strong government intervention and laissez-faire being blurred by the large evidence now accumulated in randomized experiments (Duflo and Banerjee, 2011). Second, the policy relevance of the subject has motivated a push towards new measurements and data collection of energy poverty, paving the way for additional and more accurate research in the field. Finally, energy access is intertwined with other pressing global issues, in particular the fight against global climate change. A joint solution of these two issues is required even if their exact interdependence is still to be resolved. Against this background, most of the academic discussion on energy poverty has focused on measurement and policy, but has not yet developed formal tools to generate numerical estimates of the impacts of energy poverty alleviation, with only few recent exceptions (Bazilian et al., 2012). Similarly, the integrated assessment modeling community – which plays an active role in the assessment of climate mitigation scenarios in the IPCC – has recently made steps forward towards an integrated modeling approach to energy sustainability (McCollum et al., 2011), but has dealt only to a limited extent with energy poverty (Ekholm et al., 2010). The objective of this paper is to shed light on these issues by providing a quantitative assessment of the distribution of future energy needs at the global level. This allows us to pin down where energy demand growth will come from, not only in terms of country of residence but also in terms of segments of population, defined by levels of energy consumption. We estimate the energy needs of the poorest segments and the range of additional emissions, depending on the possible primary energy sources. The magnitude of global poverty cannot be exaggerated and energy poverty is no exception. The IEA estimates that about 1.3 billion people do not have access to electricity, the FAO states that 1 billion people are undernourished and the WHO estimates that 830 million urban residents live in slums. And the latest estimates of poverty measured in dollar terms from the World Bank suggest that roughly 1.3 billion people live below the poverty line of 1.25$ a day. The various dimensions of poverty – energy, food, health and sanitation – have significant overlap but are not perfectly correlated (Pachauri and Spreng, 2011). This has led to a considerable effort in the field to construct relevant measures of energy poverty. Several indices have been proposed in the past few years, among which are the Energy Indicators for Sustainable Development (Foster et al., 2000; Vera and Langlois, 2007), the Access–Consumption matrix (Pachauri et al., 2004), the Energy for Development Index (?), the Total Energy Inconvenience Threshold (Mirza and Szirmai, 2010) and the Multidimensional Energy Poverty Index (Nussbaumer et al., 2012). This incomplete list reflects the challenge of measuring and even of defining poverty: this should come as no surprise to poverty experts, who are aware that the concept of absolute poverty is a contested one, as testified by the existence of poverty glossary books (Spicker et al., 2007). The Copenhagen declaration of the world summit for social development defines absolute poverty as "a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to social services". Strikingly, energy does not appear in the list, though its availability is instrumental for most if not all the listed basic needs. As noted above, energy poverty experts have struggled to generate indexes which capture the multidimensional essence of energy poverty, but generally speaking two main approaches have been followed (Kemmler and Spreng, 2007): either based on engineering/bottom up estimates of energy needs and access to energy services, or from standard income/consumption poverty measures. Direct estimates of energy needs and services are more accurate, but are not available for all countries, and vary in definition and measurement. Income and consumption poverty data is much richer, mostly as a result of significant data collection through surveys coordinated by the World Bank, but is an imperfect indicator of energy poverty. A trade-off between the two is unavoidable. For the sake of this paper, we will stick to the consumption poverty definition, since our intention is to build a global mapping of energy needs, and to focus not only on the poorest but across all the main different energy consumption classes, for which a strong correlation between energy and income has been established (see for example, Lenzen et al., 2006).

3. Data and methods

Our approach is to build a transparent but rigorous model which can generate global, regional and national maps of final energy consumption for households, by different classes of energy consumption. We then use it to project forward in time the distribution of energy demand. This approach builds upon and extends that of Chakravarty et al. (2009). We build distributions of household energy consumption at the country level assuming that household energy consumption and income or consumption are related by a power law relation, as suggested in several empirical studies (Lenzen et al., 2006).

In order to do so, we avail of a comprehensive database on income and consumption distributions using World Bank and UNU-WIDER income distribution survey databases. We model each country income distribution using a Beta-2 (B2) probability distribution (Chotikapanich et al., 2007). The B2 function has a small number of parameters, and is sufficiently flexible for almost all cases. The B2 function is

$$f(y) = \frac{y^{p-1}}{b^p B(p,q)\left(1+\frac{y}{b}\right)^{p+q}}, y>0 \tag{1}$$

where $b>0$, $p>0$, $q>0$ and $B(p,q)$ is the Beta function,

$$B(p,q) = \frac{\Gamma(p)\Gamma(q)}{\Gamma(p+q)} = \int_0^1 t^{p-1}(1-t)^{q-1}dt. \tag{2}$$

The p and q parameters control the shape of the Lorenz curve (or the inequality) of the distribution which is independent of the parameter b. We also assume that $q>1$ which is required for the first moment (mean income) to exist. The mean income I is linear in the parameter b

$$I = \frac{bp}{q-1}. \tag{3}$$

The cumulative distribution function (c.d.f.) of the B2 function is

$$F(y) = \frac{1}{B(p,q)}\int_0^{y/(b+y)} t^{p-1}(1-t)^{q-1}dt = B_{y/(b+y)}(p,q) \tag{4}$$

where $B_t(p,q)$ is the incomplete Beta function (in Eq. (2), $B(p,q) = B_{t=1}(p,q)$). We also use the fact that the p.d.f. of $y^k f(y)$, for integer k, are themselves B2 functions.

Income distribution data is usually provided in terms of income or expenditure share of quintiles or deciles. The plot of cumulative income share vs. cumulative population share is referred to as the Lorenz curve in the income distribution literature. Essentially, it is a plot of the c.d.f. of the normalized first moment vs the c.d.f. The Lorenz curve provides a visual measure of the inequality in the distribution. The Gini coefficient is defined as twice the area between the diagonal line and the Lorenz curve. A Gini coefficient of 0 implies perfect equality and 1 implies maximum inequality. We estimate the parameters of the B2 function using a weighted non-linear least square fit of the Lorenz curve of the