Understanding international energy sufficiency: comparing countries in terms of the role of energy in delivering human well-being

Julia K. Steinberger

Sustainability Research Institute, University of Leeds

j.k.steinberger@leeds.ac.uk

Paper prepared for DEMAND Centre Conference, Lancaster, 13-15 April 2016

Abstract

Energy use has for many decades been analysed in terms of its links with economic performance and development. In contrast, the role of energy in satisfying basic human needs has received much less (although somewhat increasing) attention. Two recent developments deserve mention: in 2014, the UN-led "Sustainable Energy for All" was launched, focusing on energy access, renewable energy and energy efficiency. More recently, the 9th Sustainable Development Goal is concerned with "affordable and clean energy." However, neither of these is based on a clear theoretical understanding of how exactly energy contributes to satisfying human needs, or what level of energy is required for this. My research compares international energy use from a sufficiency perspective. I first develop a theoretical framework which connects specific types of direct and indirect energy use with human needs, building on Max-Neef's "Human-Scale Development" framework and the "Theory of Human Need" of Doyal & Gough. Using both dynamic and static analysis of international energy use contrasted with socio-economic indicators of human need satisfaction, countries are compared in terms of their performance in satisfying human needs with different levels and types of energy use. Moreover, using this framework, energy use can be categorised as contributing to satisfying human needs (sufficiency energy) or used for other purposes: luxury consumption, destructive or negative uses, and so on. This research can thus inform and guide international debates on the social (as opposed to economic) requirements for energy use. It also can be used to understand the potential for energy savings by learning from countries with particularly high performance in satisfying universal human needs at low levels of energy use. More broadly, the area of energy use for human needs and human development deserves much more attention, given the twin challenges of achieving universal human development within the limits set by planetary boundaries. It is my hope that more social-science oriented energy research will move into this space.

1. Introduction

This paper should be read as a companion paper to *"Relating energy services to human needs: a proposed framework*" by Lina Brand Correa and myself, for the same conference. Based on the theoretical framework proposed by Brand Correa & Steinberger, this paper focuses on specific quantitative methodological applications to test the international connections between human needs and energy services.

2. Framework summary

This research builds upon several established, but disconnected, theoretical areas: human needs, energy services and social provisioning. We approach well-being through the lens of human needs (1, 2), which are defined as finite and non-substitutable prerequisites for living well within society. Human needs are objective and universal, but the means to achieve them, known as "satisfiers", change depending on social and geophysical circumstances (3). In terms of physical resources, the research focuses on technical (non-food) energy requirements, analysed through the lens of energy services: the physical service provided by energy (4). These approaches allow for robust (clear definitions), empirical (quantifiable metrics), systemic (not focusing on one single need or supply chain) analysis, which enables the study of decoupling needs from energy use: both through the open nature of need "satisfiers" (3) and the large efficiency potential in energy service delivery (4).

Importantly, some of the most important opportunities for decoupling energy from need satisfaction are likely to be found at the community level: economies of scale through provision of efficient networks of energy service delivery (5). Transport systems, by definition, are community-level infrastructures determining the technological options (and hence energy use) for need satisfaction of residents. Mattioli (2016) provides a brilliant perspective on this topic, showing how considering the ultimate goal of transport system users can open new perspectives in transport system priorities and design Mattioli (6). To study such community-level constraints, a heterodox economics approach can be adopted to study the social provision of energy services across different societies

(7). The heterodox analysis of supply chains (Systems of Provision, Fine (8)) is also amenable to considering the role of power in actors along the supply chains: such power imbalances have been notoriously understudied in fields such as sustainable consumption and ecological economics (9).

Figure 1 below is a schematic representation of the framework outlined above. It shows the dependency between planetary processes; energy use, energy services as an intermediary stage; and need satisfiers and well-being. This framework is designed to allow the estimation of the energy required to satisfy universal human needs: we now turn to the question of how this could be done in practice, with readily available international data.

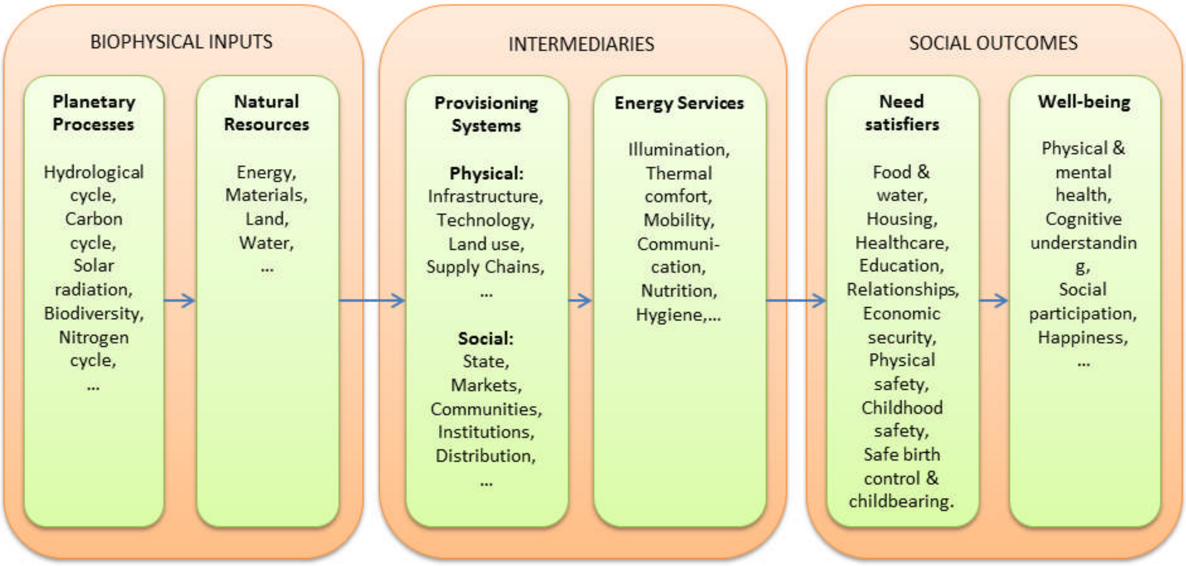

Figure 1. Schematic representing the links between planetary processes, social and physical intermediaries and well-being outcomes

3. Methodological approaches

The methods I wish to highlight in this paper include cross-country and dynamic analysis of international datasets on energy use, process-chain efficiency and human need satisfaction. The goal here is to empirically come closer to understanding the energy requirements of different dimensions of well-being, and how socio-technical organisation and priorities can enable these to be accessible to all, as well as low enough to bring human need satisfaction within planetary boundaries.

In this section, several methodological approaches which would enable researchers to estimate the energy requirements of human well-being are proposed. The goal is to estimate minimum threshold (sufficiency) requirements, or requirements within certain socio-economic and technical contexts: indeed, there is no such thing as a maximum requirement, since needs could be provided in very wasteful or convoluted ways. The concept of threshold is key for the methodological discussion below. A threshold is a point or a state of a system that, if surpassed or altered, it can cause fundamental changes in the system's properties, as for example in ecological thresholds for tipping points. In the context of a physically and climate constrained world, where human needs are prioritised over economic growth, finding the level of energy services required to satisfy human needs is vital for policy recommendations, since these services can be delivered at different levels of primary energy use and emissions, depending on the specific properties of their supply chains.

The methods described below have either been already implemented, in which case the relevant work is cited, or could be implemented in the near future, in which case the steps are sketched out in more detail. Most past studies have used proxies for both energy services (for example total primary energy supply, final energy consumption or CO_2 emissions[1]) and human needs (for example life expectancy or the human development index): indeed, the use of such proxies is almost inevitable at the present given the lack of readily available data on energy services and human needs at relevant levels of analysis. Hence, to the best of our knowledge, the links between energy services and human needs specifically have not been analysed, despite the theoretical advantages of using these particular concepts in the context of achieving well-being within planetary boundaries.

In several cases, I apply the methods using international data used for the calculation of the Human Development Index (Life Expectancy, Mean Years Schooling and Gross National Income) and final energy categories of electricity and transport per capita (all data for the year 2012). The human development indicators showcase different dimensions (health, education, economy) of well-being, available internationally from UNDP (10), whereas electricity and transport energy (both from the International Energy Agency) are examples of final energy use, which at least comes closer to energy services than primary energy.

3.1. Bottom-up: starting from human needs to estimate energy requirements

"Bottom-up" approaches starts from a list of requirements of population or households, both within and outside the home, and translates these into energy requirements, based on assumptions regarding technological efficiencies and prevalent infrastructures (for transportation, for instance). The most well-known and to date probably still the most thorough of these is the Goldemberg et al's 1985 study: "Basic needs and much more with one kilowatt per capita" (11).

Goldemberg et al. (1985) identified the energy requirements to meet basic human needs for a hypothetical individual/household in a hypothetical developing country with warm climate (11). They analysed the mix of energy consuming activities (very similar to useful work categories, although including the energy required to produce materials) of Western Europe in the 1970s and their levels of use, but matched them with more efficient end-use technologies. These technologies were available at the time of the study or would be commercially available in the next 10 years. "The resulting total final energy use per capita, obtained by summing overall activities, is about 1.0 kW"of final energy (Goldemberg et al., 1985, p. 192) (11).

Another consumption based approach was undertaken by Zhu and Pan (2007) (12) for the specific case of China. The authors use lifecycle data on energy in order to include indirect energy requirements, i.e. embodied energy in goods and infrastructure. However, the way they identify what constitutes "decent" living energy requirements seems somewhat arbitrary.

In the future, this approach could be extended and formalised, taking the human needs frameworks described above as a starting point, then considering what types of satisfiers would enable these, then the physical supply chains and infrastructures that these satisfiers would require (see Figure 2). Mattioli's (2016) work is very much in this direction for the specific case of transport (6).

[1] Given the current fossil fuel dependency of the global energy system, energy and CO_2 emissions are closely correlated, and therefore can be considered proxies.

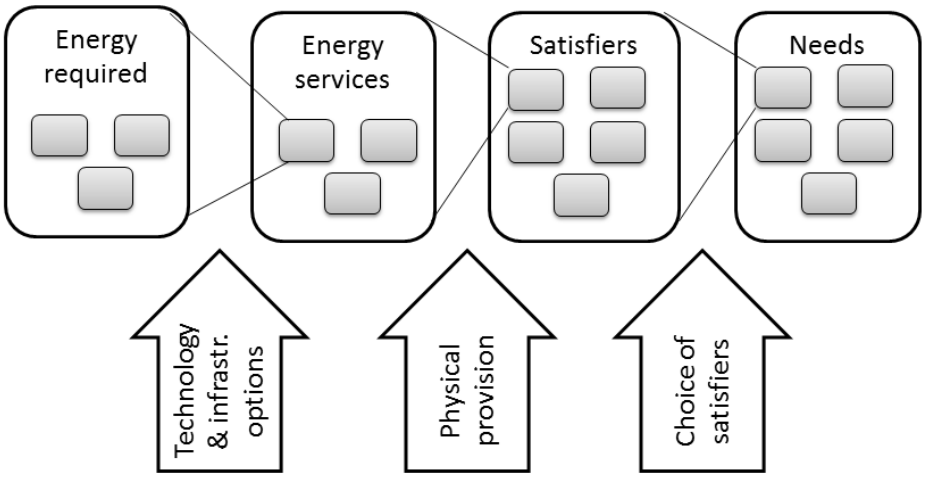

Figure 2. Schematic showing the process of bottom-up estimation of the energy requirements
At each step, the arrows indicate explicit choices to be made regarding the type and level of satisfiers, energy services and energy itself (final or primary) required.

3.2. Top-down: macro assessments of need satisfaction at different energy levels

The next family of methods share a macro-level and often international scope. Their goal is to observe larger systems, such as countries or regions within countries, in order to estimate their performance in terms of delivering well-being outcomes (human need satisfaction) at varying levels of environmental impact or energy use. This means they take macro (country) level variables and use statistical techniques to relate energy and human well-being, as well as finding a threshold level after which increases in the energy variable translate into only marginal (or none at all) increases in well-being. A caveat with these approaches is that they use national averages rather than distributions, and every country will have residents that use far more than they need from a sufficiency well-being perspective, as well as residents who have far too little. Nevertheless, these methods highlight what is currently possible, given the existence of large distributional disparities within countries.

3.2.1. Well-being to energy efficiency ratio

This method is usually the first that springs to mind in international comparisons of energy use and well-being, due to its prevalence in environmental or ecological economics applications. The idea is to take a simple ratio of the well-being indicator divided by the energy use indicator: the result is the "efficiency" of delivery of well-being per unit energy (13-15). Several caveats should be kept in mind when interpreting the result of this method. The first is that the well-being to energy relationship is usually strongly non-linear (see below), and in fact exhibits saturation behaviour. This means, almost inevitably, that countries at the low well-being and energy use part of the spectrum will have the highest "efficiency" ratios, and the countries at the high well-being and energy use part of the spectrum will have the lowest (see Figure 3). This is informative at a very basic level: indeed, it is more effective, in well-being delivery terms, to provide additional energy to the lower end of spectrum rather than the higher. However, this method's results tend to be overwhelmed by the fact that it is measuring the ratio of two quantities related by a saturation curve, and very little additional information can be extracted (certainly no energy thresholds for well-being). The methods below that make use of the functional form of the energy-well-being relation tend, as a result, to have more analytic power.

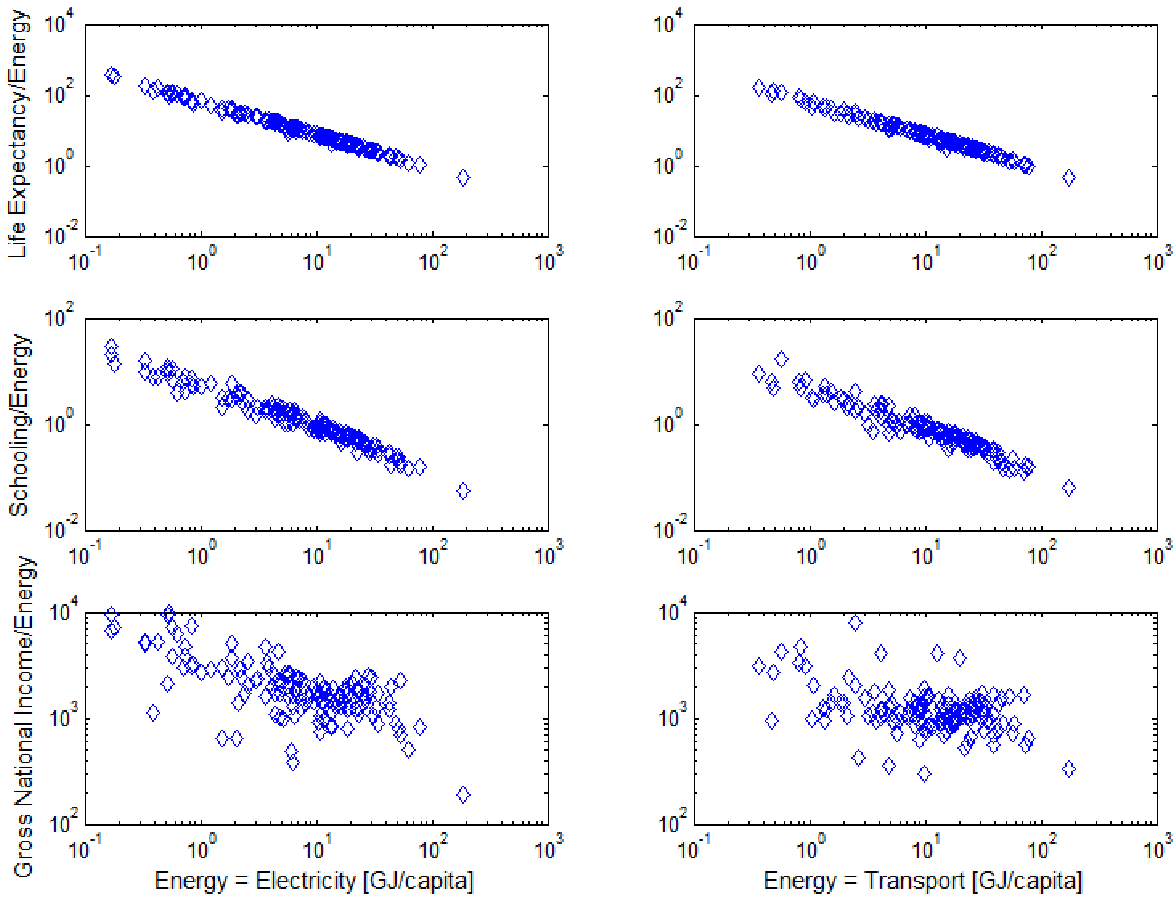

Figure 3. Ratio of different human development indicators to electricity and transport energy (year 2012). Vertical axis units are (top to bottom): Years/(GJ/cap) ; Years/(GJ/cap) ; $/GJ.

3.2.2. Goldemberg's corner (above-below)

The approach we have termed "Goldemberg's corner" (16) quite simply consists in setting a minimum level for a need satisfaction or well-being indicator, a maximum value for environmental impact or resource use indicator, and considering the countries within the "Goldemberg's corner" thus defined (see Figure 4). This can be seen as an implementation of Kate Raworth's "doughnut" concept: encouraging sufficient levels of well-being within planetary boundaries (17). Some example of results using this approach have shown that countries within Goldemberg's corner tend to have moderate incomes (between $700 and $12'000 $/cap) (18), or that the countries within Goldemberg's corner are not a uniform group, in terms of climate or trade, for instance, but have a wide range of underlying drivers of carbon emissions (19).

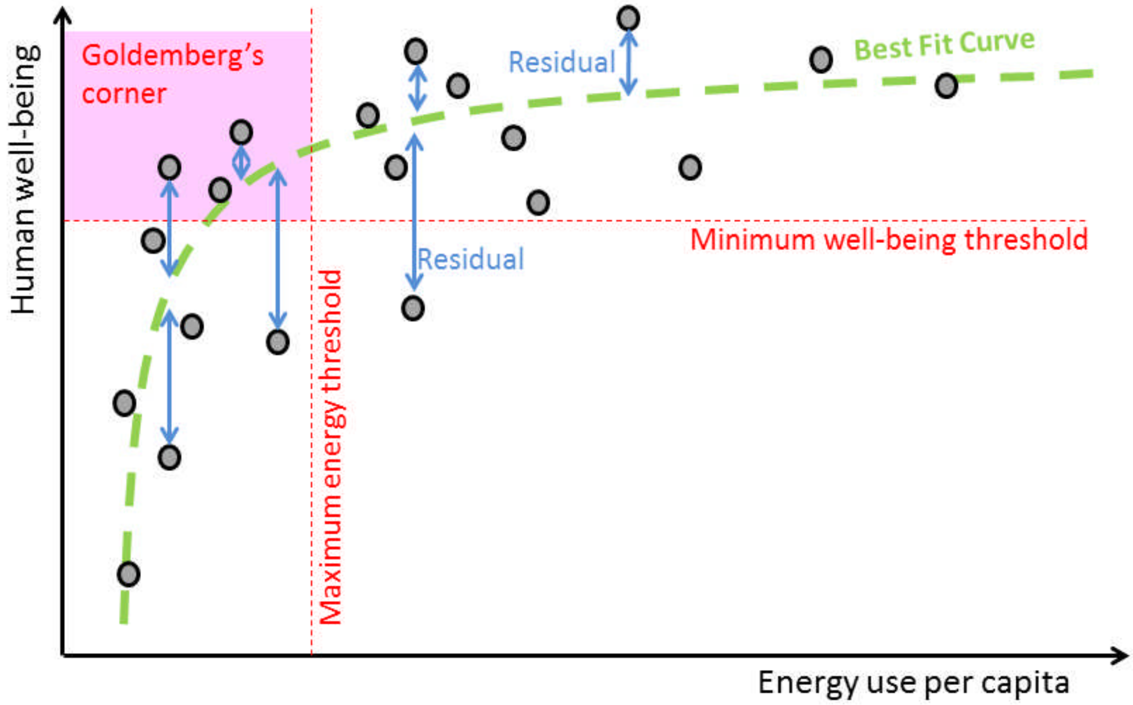

Figure 4. Schematic showing 3 top-down approaches to estimating well-being vs energy performance
(1) Goldemberg's corner, (2) best fit curve and (3) residuals from the fit curve.

Figure 4 shows a schematic of Goldemberg's corner, whereas Figure 5 demonstrates an application for the same human development and energy indicators as in section 3.2.1. The levels chosen for minimum human development and maximum energy use are admittedly arbitrary: they are set at 70 years life expectancy, 8 years mean schooling and 5'000 $/cap for income, with 5 GJ/cap in final energy for both electricity and transport.

The countries within Goldemberg's corner in Figure 5 are listed in Table 1. There are always more countries below 5 GJ/capita electricity than transport, demonstrating that setting the same level for both is an oversimplification: more final energy in transport than in electricity is probably required to reach equivalent human development levels. This is also not surprising considering that transport final energy is, for the most part, petrol or diesel, relatively close to crude oil extraction, whereas electricity is, for the most part, the culmination of a several energy transformations involving significant losses. The only countries in all "corners" are Cuba and Sri Lanka, for this particular dataset.

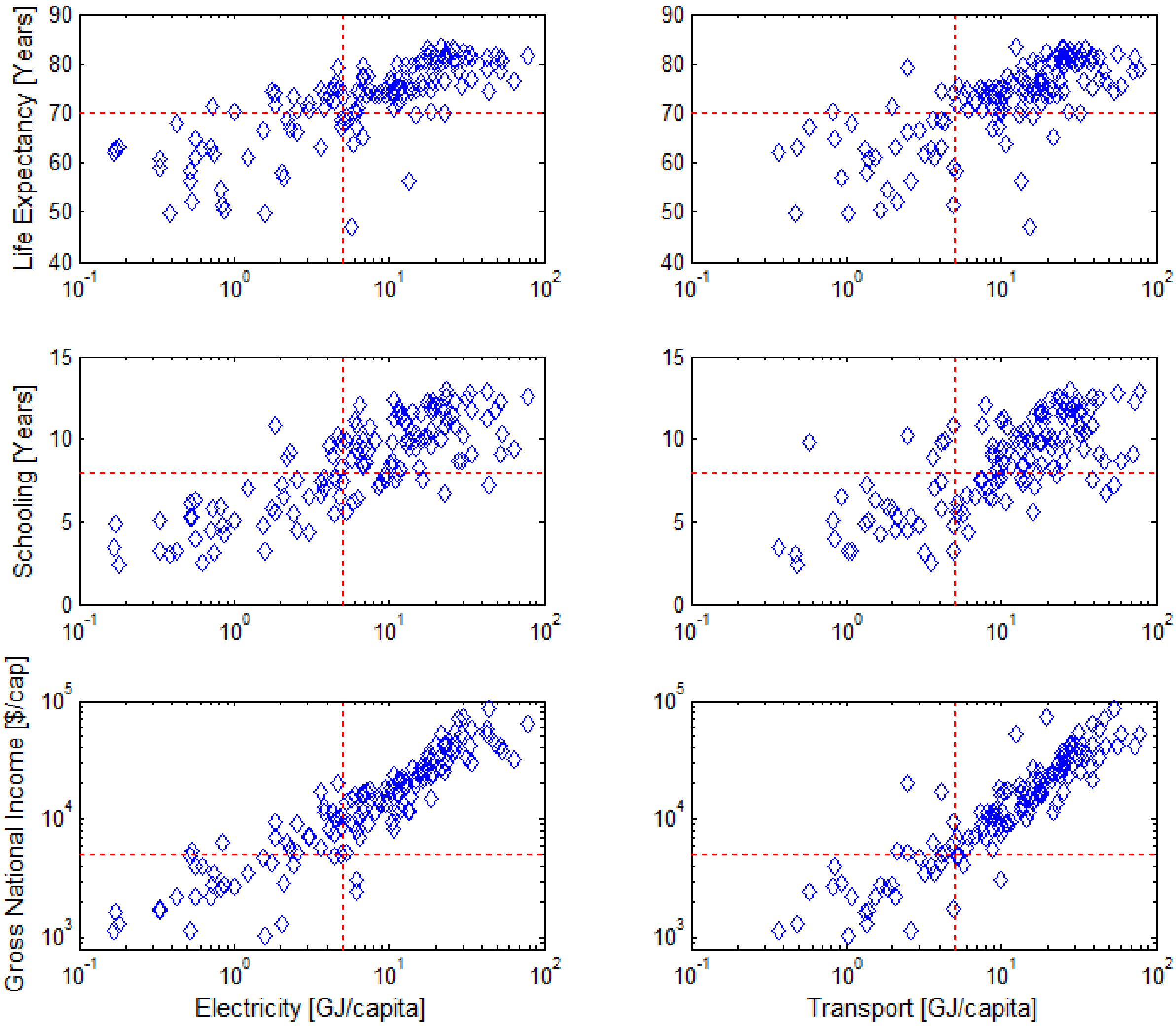

Figure 5. Goldemberg's corner applied to life expectancy, mean years of schooling and GNI per capita, with respect to electricity and transport energy.

All data from year 2012, countries with energy use above 100 GJ/capita and income above 100'000 $/capita not shown. Above/below levels: 70 years life expectancy, 8 years mean schooling and 5'000 $/capita for income, 5 GJ/capita in final energy for both electricity and transport.

Countries in Goldemberg's corner	Electricity < 5 GJ/cap	Transport < 5 GJ/cap
Life expectancy > 70 years	BANGLADESH	BANGLADESH
	COLOMBIA	CUBA
	CUBA	CAMBODIA
	ALGERIA	SRI LANKA
	ECUADOR	NICARAGUA
	GUATEMALA	
	HONDURAS	
	INDONESIA	
	JAMAICA	
	CAMBODIA	
	SRI LANKA	
	MOROCCO	
	NICARAGUA	
	PERU	
	PARAGUAY	
	EL SALVADOR	
	SYRIAN ARAB REPUBLIC	
	TUNISIA	
	VIET NAM	
Mean years schooling > 8 years	BOLIVIA	CUBA
	CUBA	SRI LANKA
	JAMAICA	MOLDOVA, REPUBLIC OF
	SRI LANKA	PHILIPPINES
	MOLDOVA, REPUBLIC OF	TAJIKISTAN
	MONGOLIA	UZBEKISTAN
	PERU	
	PHILIPPINES	
GNI > 5000 $/cap	ANGOLA	ANGOLA
	BOLIVIA	CUBA
	COLOMBIA	GABON
	CUBA	INDIA
	ALGERIA	SRI LANKA
	ECUADOR	MOLDOVA, REPUBLIC OF
	GABON	NIGERIA
	GUATEMALA	PHILIPPINES
	INDONESIA	UZBEKISTAN
	INDIA	
	JAMAICA	
	SRI LANKA	
	MOROCCO	
	MOLDOVA, REPUBLIC OF	
	MONGOLIA	
	NIGERIA	
	PERU	
	PHILIPPINES	
	PARAGUAY	
	EL SALVADOR	
	SYRIAN ARAB REPUBLIC	
	TUNISIA	

Table 1: Countries within Goldemberg's corner in Figure 5.

3.2.3. Best fit curve

The second method takes into account the whole spectrum of national or sub-national values of energy use or environmental impact and well-being performance, in order to statistically estimate a best fit curve (either parametrically or not), shown schematically in Figure 4. The resulting fit curve represents the average performance of the system under consideration in delivering well-being at different levels of energy use, and can thus be used to make robust middle-of-the-road estimates of the energy requirements of well-being.

Using this methodology Smil (2003, p. 105) (20) found that an "annual per capita [primary] energy consumption of between 50 – 70 GJ [...] appears to be the minimum for any society [to achieve human well-being]". He uses various indicators for essential physical needs (infant mortality, female life expectancy at birth, average per capita food availability, amongst others), as well as other indicators for other important elements of social participation (e.g. literacy, education and political freedoms), and correlates them with average per capita energy use. He does this for the 57 most populated countries in the world (which represent 90% of global population). Other authors use a similar approach, where national-level data on energy use or greenhouse gas emission is coupled with some sort of indicator of human well-being and a fit curve is fitted to the data points (16, 21-25).

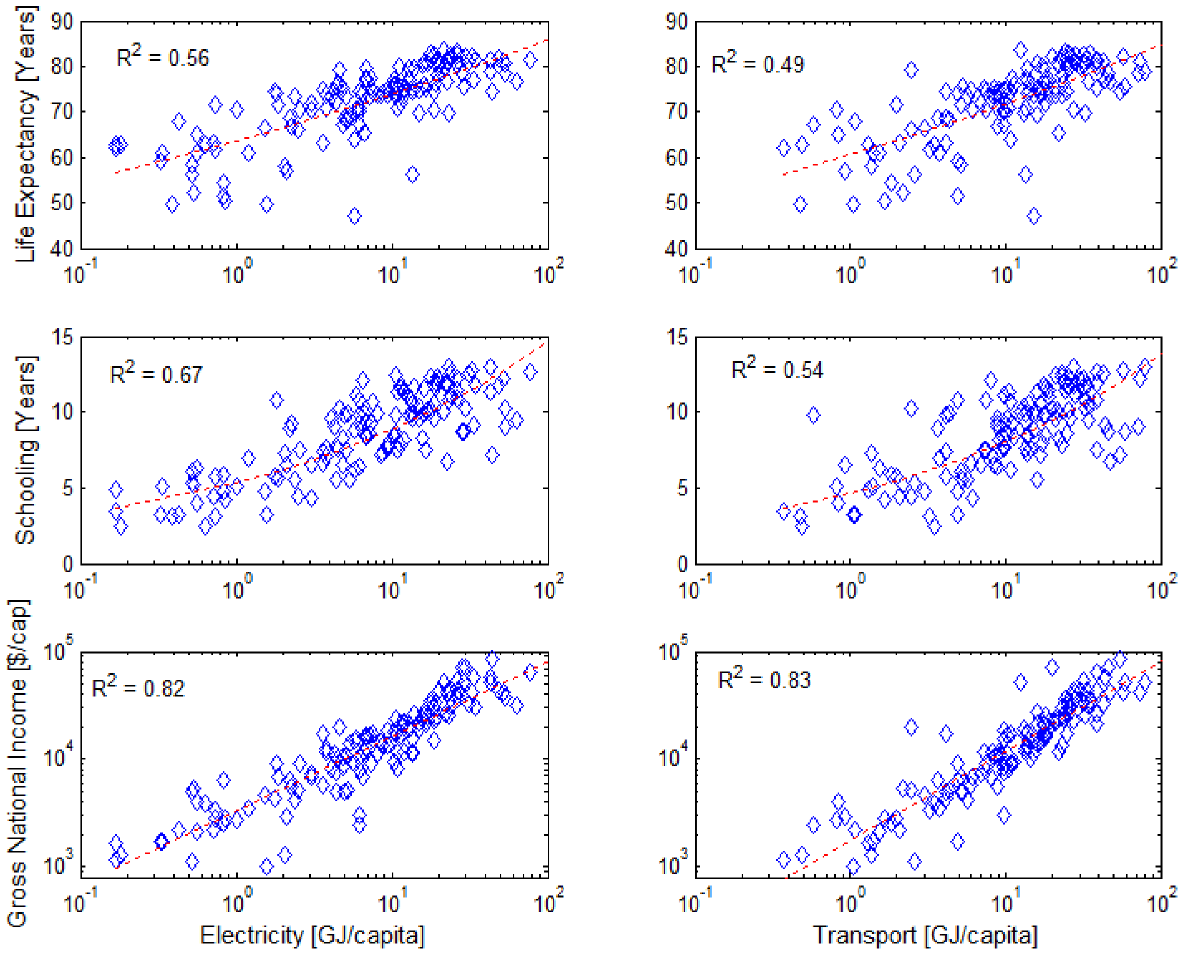

Figure 6. Human development vs. final energy fit log-log fit curves.
Goodness-of-fit (R^2) shown can be interpreted as "the fit curves explain R^2 % of the variation in the data".

An application of the fit curve method to the same human development and final energy indicators as in 3.2.1 and 3.2.2 above is shown in Figure 6 below. The fit curves are done linear in log-log space, which means that the curves for life expectancy and schooling years tend to overshoot at high energy values (for life expectancy, at least, a saturation curve may be preferred (16)). In all cases, human development indicators show a strong correlation with energy use levels – but this correlation is strongest by far for economic performance, rather than health or education. Interestingly, electricity has a significantly better goodness-of-fit R^2 value than transport in all cases except for Gross National Income per capita, where the value is very close. This indicates that electricity may be more important in human development terms than transport.

The estimates of well-being vs. energy use provided by the best-fit curve method are likely to be large over-estimates of the real energy required for human needs. Indeed, because this method also takes into account the “worst” performers, countries or regions who have large energy use but relatively low well-being delivery, it will by necessity tend to higher values than required for well-being delivery, if this well-being were a social priority. This flaw is what the next two methods attempt to remedy.

3.2.4. Residuals

The residuals method simply calculates the vertical residuals (well-being dimension) from the fit curve discussed above (see Figure 4 for a schematic representation), and was first introduced in this context by Knight and Rosa (2011) (26) . If a country’s residual value is positive, this shows that it is better at delivering well-being at the level of energy use that they currently have than the world average, whereas if it is negative, it shows that the country is worse. This method is appropriate in order to measure the relative well-being performance of countries along the whole range of energy use. One note of caution: the residual itself, as an indicator, cannot be compared over time, since the fit curve location itself changes over time. It is thus better suited to static analysis at one point in time.

An application of the residual approach is shown for life expectancy, mean years of schooling and Gross National Income per capita versus electricity and transport energy in Figure 7. The results show a range of behaviours: for life expectancy, there is a large spread in residual values (as expected given its relatively low goodness-of-fit with energy), but these are at lower energy use values: at higher energy use, there is a convergence towards low residual values, indicating that high energy use almost always corresponds to high life expectancies. In contrast, the residual spread is relatively even (and large) across the mean schooling years indicator, indicating a lack of convergence: high energy use does not automatically imply high durations of education. The income residuals show the highest values for higher energy use, but this is mainly due to the higher income corresponding to those residuals, since high energy and high incomes are very tightly coupled.

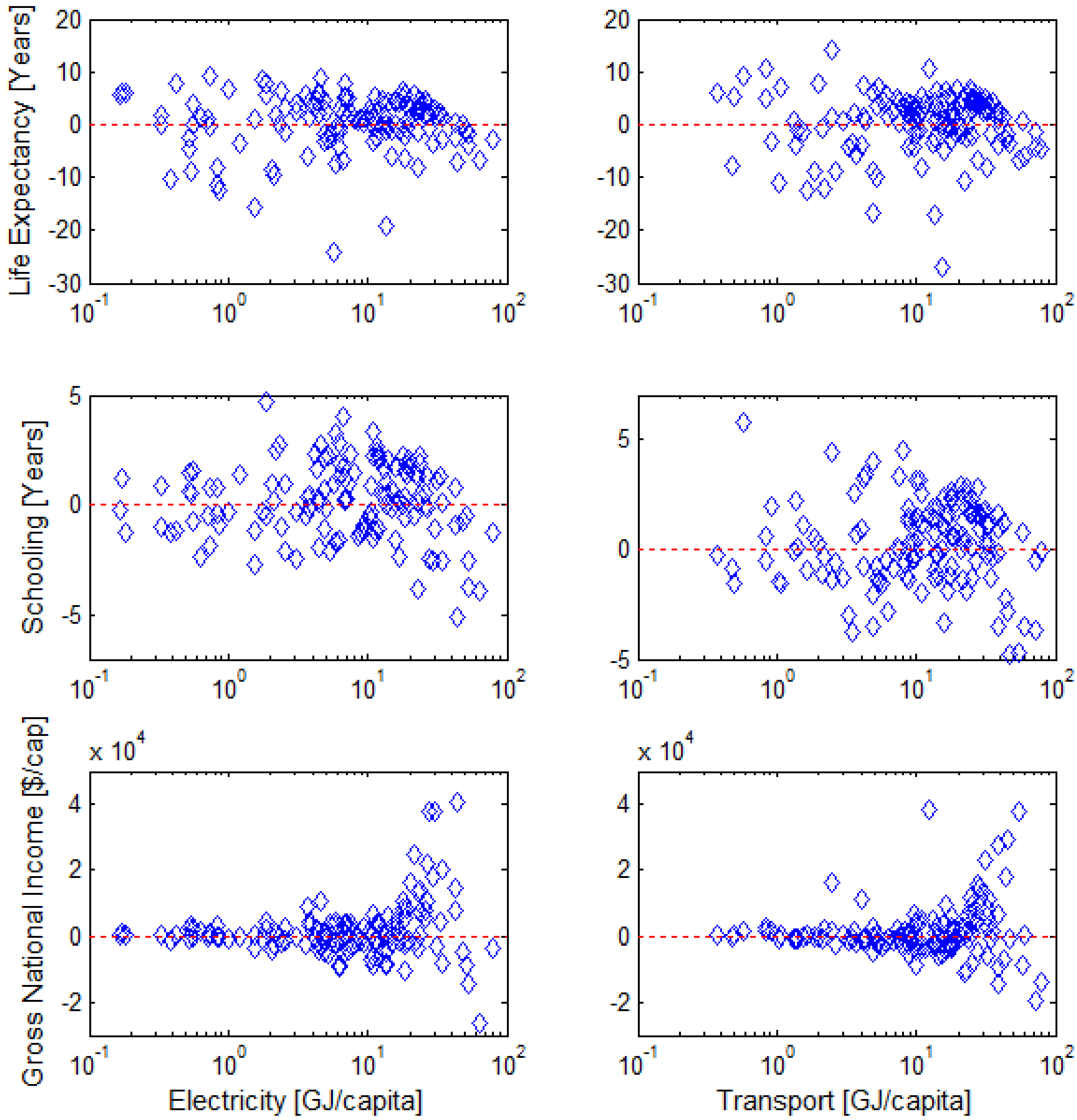

Figure 7. Residuals of the fit curves shown in Figure 6.

3.2.5. Well-being and energy boxplot

This method seeks to estimate a statistically robust low range of energy use at a given level of well-being performance. Instead of targeting the average performance, as a fit curve does, this method selects countries or regions within a narrow band around a given well-being level, and analyses the distribution of energy use, using a simple boxplot or similar descriptive statistics tool (curve fitting of the distribution could also be considered), Figure 8. Whereas some data points at very low energy could be considered outliers (extraordinary cases, not representative of prevalent international conditions, or even simply having faulty data), the first quartile is likely to be a more robust estimate of the lower range of energy at which that well-being level can be attained. This method is as yet largely unexplored in the literature, but could prove to be quite interesting.

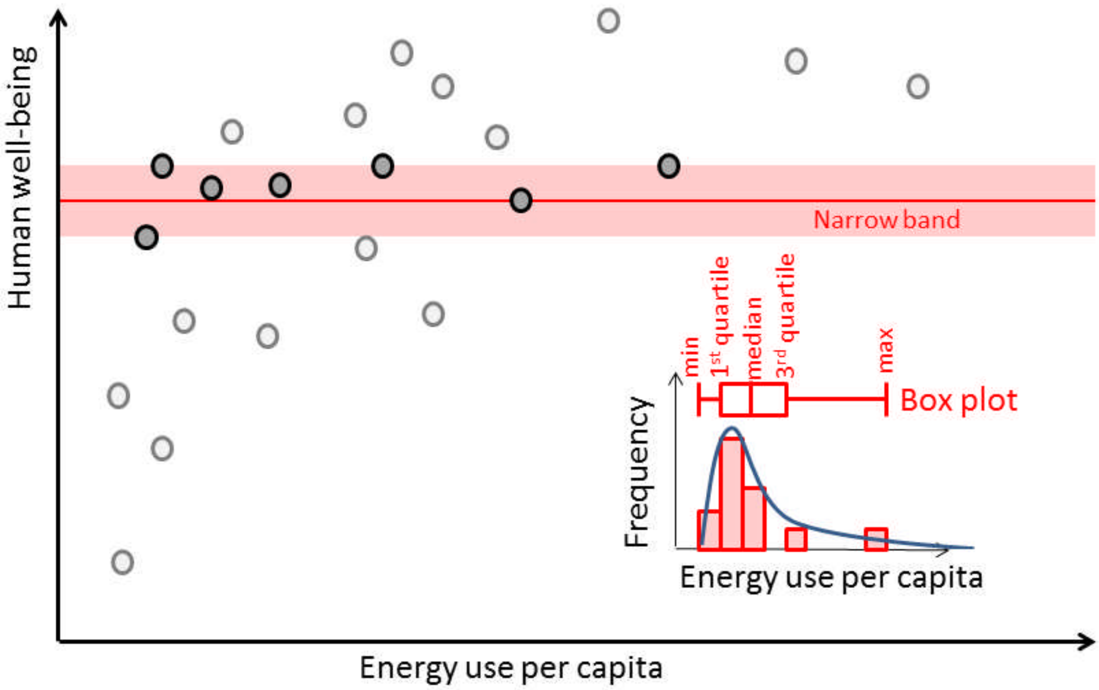

Figure 8. Schematic showing the "boxplot" method for estimating a robust minimum energy required for a achieving desired level of well-being

An application of the boxplot approach is shown in Figure 9 below, again for life expectancy, mean years of schooling and Gross National Income versus electricity and transport energy. The range was chosen to include roughly 20 countries (out of 135 in the total sample) in each case, and corresponds to 70 years +/- 2 years for life expectancy, 8 years +/- 0.5 years for schooling, and 5'000 +/- 1'500 $/capita for income. Countries within these ranges had electricity use values of roughly half the transport values, in general. The interesting differences here are mainly between the human development indicators. Life expectancy has the lowest energy range, and the boxplots and histograms show a concentration of countries at the low energy end, whereas schooling starts from higher energy values and has a flatter distribution. The countries with income within the range are distributed towards the extreme lower of electricity use, but seem almost normally distributed around a low value (5 GJ/cap) of transport energy. It is clear from this quick initial trial that this method may yield significant results when trying to estimate thresholds and distribution patterns of well-being and energy use.

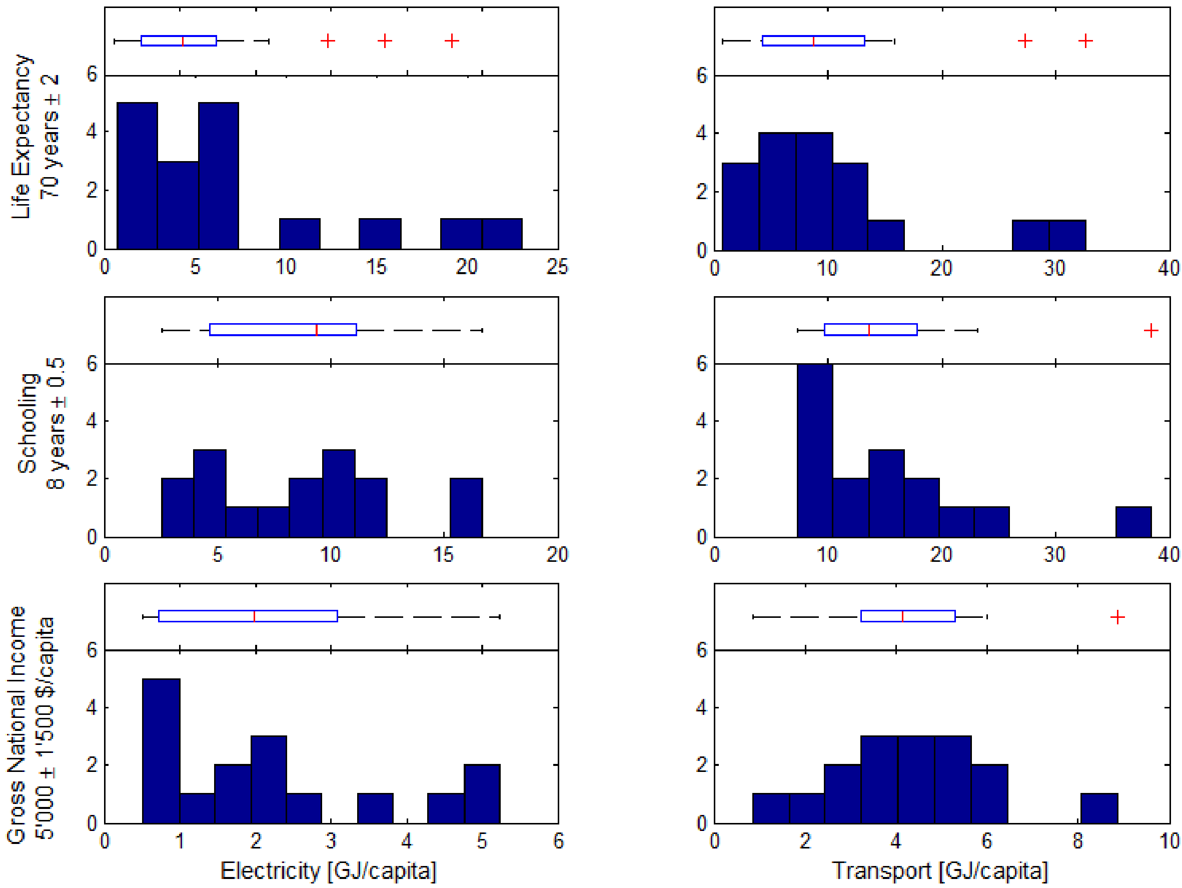

Figure 9. Schematic showing the "boxplot" method for estimating a robust minimum energy required for a achieving desired level of well-being

3.2.6. Parametric frontier method

Parametric frontier approaches are widely used in business economics to determine the productivity "frontier" of firms under different conditions of factors of production. This method was applied to life expectancy and the ecological footprint by Dietz et al. (2009) (27), but to our knowledge not replicated or used more widely. More recently, the method has been used in relation to economy-wide energy efficiency (Zhou et al., 2012) (28), and this will hopefully revive interest in this approach.

3.3. Consumption-based accounts of human well-being

This methodology uses as a starting point the establishment of a bundle of minimum goods and services to achieve human well-being. The energy and carbon emissions embodied with that bundle are then estimated, thus finding an energy threshold or carbon entitlements. Rao and Baer (2012) (29) propose to use Input-Output data to implement this methodology. The authors construct their bundle based on the "basic goods" work of Reinert (2011) (30), which they describe as being consistent with the capabilities approach and also subjective approaches. This means that the bundles must be country-specific, which implies a departure from more internationally-comparable accounts of well-being.

We classify this approach as neither top-down or bottom-up, since it relies on Environmentally-Extended Input-Output as its work-horse: EE-IO is by nature a bridging approach, connecting macro-level energy use and emissions with final demand of consumers. It is likely called upon to play a key role in this emerging research, connecting needs requirements with national-level (or even international-level, including Multi-Regional Input-Output) supply chains in a comprehensive and consistent way.

4. Concluding remarks and future research

This paper mainly sought to describe and apply some proposed methods for quantitatively characterising the international links between human well-being (in this case mostly measured as dimensions of human development) and energy use. Although this paper was not able to attain the goal of comparing human need satisfaction with energy service delivery, mainly due to a lack of internationally available data for both of these, future research in this direction would clearly yield important insights. Hopefully the summary of methods contained above can serve as a guide to such future research.

5. References

1. Doyal L, Gough I (1991) *A Theory of Human Need* (Macmillan).
2. Max-Neef M (1991) *Human scale development : conception, application and further reflections* (The Apex Press).
3. Guillen-Royo M (2016) *Sustainability and Wellbeing: Human-Scale Development in Practice* (Routledge).
4. Cullen JM, Allwood JM (2010) The efficient use of energy: Tracing the global flow of energy from fuel to service. *Energy Policy* 38(1):75-81.
5. Knoeri C, Steinberger JK, Roelich K (2015) End-user centred infrastructure operation: towards integrated end-use service delivery. *Journal of Cleaner Production* In Press.
6. Mattioli G (2016) Transport needs in a climate-constrained world. A novel framework to reconcile social and environmental sustainability in transport. *Energy Research and Social Science* Accepted.
7. Bayliss K, Fine B, Robertson M (2013) From Financialisation to Consumption: The Systems of Provision Approach Applied to Housing and Water. (FESSUD Working Paper 2).
8. Fine B, Leopold E (1993) *The world of consumption* (Routledge London).
9. Fuchs D*, et al.* (2015) Power: The missing element in sustainable consumption and absolute reductions research and action. *Journal of Cleaner Production*.
10. UNDP (2015) Human Development Report 2015: Work for Human Development. (United Nations Development Programme, New York).
11. Goldemberg J, Johansson TB, Reddy AKN, Williams RH (1985) Basic needs and much more with one kilowatt per capita. *Ambio* 14(4-5):190-200.
12. Zhu X, Pan J (2007) Energy requirements for satisfying basic needs: China as a case for illustration. (Chinese Academy of Social Sciences).
13. Jorgenson A (2015) Inequality and the carbon intensity of human well-being. *J Environ Stud Sci* 5(3):277-282.
14. Jorgenson AK (2014) Economic development and the carbon intensity of human well-being. *Nature Clim. Change* 4(3):186-189.
15. Dietz T, Rosa EA, York R (2012) Environmentally efficient well-being: Is there a Kuznets curve? *Applied Geography* 32(1):21-28.
16. Steinberger JK, Roberts JT (2010) From constraint to sufficiency: the decoupling of energy and carbon from human needs, 1975-2005. *Ecological Economics* 70(2):425-433.

17. Raworth K (2012) A safe and just space for humanity: can we live within the doughnut? . in *Oxfam Discussion Papers*, ed Oxfam (Oxfam).
18. Steinberger JK, Roberts JT, Peters GP, Baiocchi G (2012) Pathways of human development and carbon emissions embodied in trade. *Nature Climate Change* 2:81–85.
19. Lamb WF*, et al.* (2014) Transitions in pathways of human development and carbon emissions. *Environmental Research Letters* 9(1):014011.
20. Smil V (2003) *Energy at The Crossroads. Global Perspectives and Uncertainties* (The MIT Press, Cambridge Mass., London, England).
21. Alam MS, Roychowdhury A, Islam KK, Huq AMZ (1998) A revisited model for the physical quality of life (PQL) as a function of electrical energy consumption. *Energy* 23(9):791-801.
22. Dias RA, Mattos CR, Balestieri JAP (2006) The limits of human development and the use of energy and natural resources. *Energy Policy* 34(9):1026-1031.
23. Martinez DM, Ebenhack BW (2008) Understanding the role of energy consumption in human development through the use of saturation phenomena. *Energy Policy* 36(4):1430-1435.
24. Costa L, Rybski D, Kropp JP (2011) A Human Development Framework for CO2 Reductions. *PLoS ONE* 6(12):e29262.
25. Steckel JC, Brecha RJ, Jakob M, Strefler J, Luderer G (2013) Development without energy? Assessing future scenarios of energy consumption in developing countries. *Ecological Economics* 90(0):53-67.
26. Knight KW, Rosa EA (2011) The environmental efficiency of well-being: A cross-national analysis. *Social Science Research* 40(3):931-949.
27. Dietz T, Rosa EA, York R (2009) Environmentally Efficient Well-Being: Rethinking Sustainability as the Relationship between Human Well-being and Environmental Impacts. *Human Ecology Review* 16(1):114-123.
28. Zhou P, Ang BW, Zhou DQ (2012) Measuring economy-wide energy efficiency performance: A parametric frontier approach. *Applied Energy* 90(1):196-200.
29. Rao ND, Baer P (2012) “Decent Living” Emissions: A Conceptual Framework. *Sustainability* 4(4):656-681.
30. Reinert KA (2011) No small hope: The basic goods imperative. *Review of Social Economy* 69(1):55-76.