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The energy requirements of a developed world

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ABSTRACT

Through history, special attention has been paid to the study of the relationship between the energy use of a country and its level of development. While the interest of this research area is unquestionable, the energy indicators commonly used (e.g. total primary energy) are problematic. In the current context of globalization, the energy used by a country is not anymore a suitable indicator for measuring the total energy requirements associated with its level of development; the significant variable is the energy consumed worldwide to produce the goods and services demanded by that country, i.e. its energy footprint. In this study, we compare the human development index of 40 countries with their total primary energy demand and total primary energy footprint for the period 1995–2008. The results show that the total primary energy demand underestimates the energy required to maintain a high level of development, since a significant part of the energy used by emerging countries is being increasingly devoted to sustain the welfare of developed countries by means of international trade. We also find that the minimum total primary energy footprint per capita to achieve a high level of development is 33% higher than current world's per capita energy use.

Introduction

An adequate energy supply has been identified as a key prerequisite for economic, cultural and social development in complex societies (White, 1943; Cottrell, 1955; Tainter, 1990). The United Nations General Assembly adopted in 1986 its “Declaration on the Right to Development” (UN, 1986), which established the right to development ‘as an universal and inalienable right and an integral part of fundamental human rights’, setting out a catalog of objectives for ‘equality of opportunity for all in their access to basic resources, education, health services, food, housing, employment and the fair distribution of income’. Ultimately, energy, in its different forms, is essential to provide all these goods and services linked to the achievement of human development targets, playing a key role for overcoming poverty (Najam and Cleveland, 2003; Karekezi et al., 2012).

A number of authors have investigated the relation between the degree of development of a country and its energy use (Cottrell, 1955; Mazur and Rosa, 1974; Olsen, 1992; Suárez, 1995; Rosa, 1997; Alam et al., 1998; Pasternak, 2000; WBGU, 2003; Smil, 2005; Dias et al., 2006; Martínez and Ebenhack, 2008; Steinberger and Roberts, 2010; Lambert et al., 2014). Most studies have found strong correlations between energy use and living standards at lower energy use levels (“developing countries”), and decoupling at higher levels (“developed countries”). This can be seen when comparing the relation between the per capita total primary energy demand (TPED)[1] and the human development index (HDI).[2]

Fig. 1 shows the relation between the per capita TPED and the HDI of a selected group of countries for the period 1995–2008. While in highly developed countries variations in the use of energy barely affect the

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[1] The TPED includes the consumption of the energy sector, the losses during transformation (for example, from coal or gas into electricity) and distribution of energy, and the final consumption by end users. This indicator is also referred to as the gross inland energy consumption and represents the quantity of all energy necessary to satisfy inland consumption. The TPED is equivalent to the total primary energy supply (TPES), which is calculated as the production plus imports, minus exports, minus international marine bunkers plus/minus stock changes.

[2] The HDI is an indicator developed by the United Nations Environment Program of the average achievement of each country in three basic areas of human development: life expectancy at birth, adult literacy and school enrolment, and standard of living as measured by the Gross National Product per capita. The HDI uses a scale from zero to one where zero would indicate the lowest level of human development and one the highest level of human development (see (Klugman et al., 2011) for further information on the HDI). In this paper we refer to “highly developed countries” to those with a HDI > 0.8, where the advanced industrialized countries currently stand (i.e. European Union, Japan, USA, etc.), and represents the level of material well-being that most countries want to achieve or, in other words, the level of development that most countries aspire to converge with.

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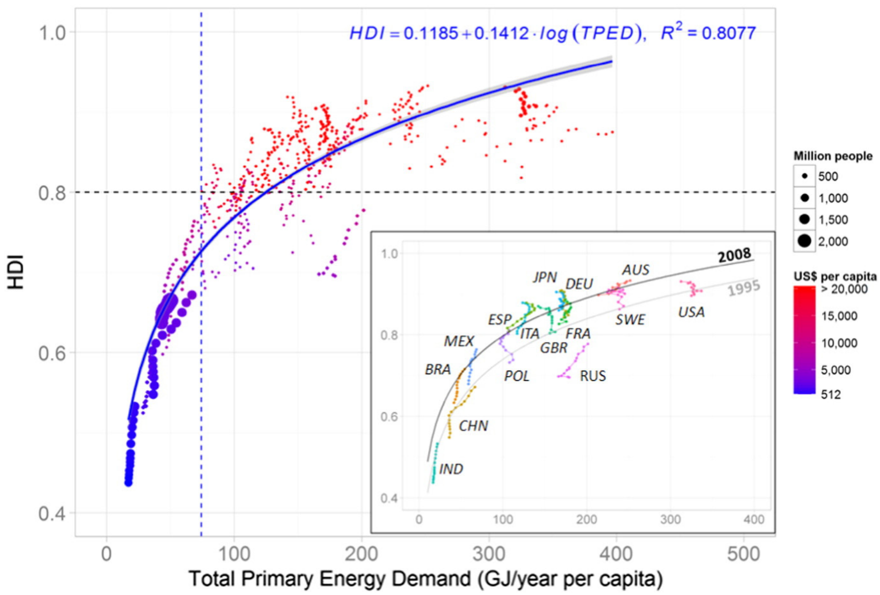

Fig. 1. Human development index, total primary energy demand per capita, population and GDP per capita of selected countries, 1995–2008.
Notes:

1) HDI: human development index; TPED: total primary energy demand.
2) AUS: Australia; BRA: Brazil; CHN: China; DEU: Germany; ESP: Spain; FRA: France; GBR: United Kingdom; IND: India; ITA: Italy; JPN: Japan; MEX: Mexico; POL: Poland; RUS: Russia; SWE: Sweden; USA: United States of America.
3) The points in the main figure represent the pairs of TPED-HDI for the 40 countries detailed in Fig. 4 and for the period 1995–2008; the regression corresponds to the corresponding 560 observations (i.e. 40 countries times 15 years).
4) The points in the detailed figure represent the pairs of TPED-HDI of a selected group of 15 countries for the period 1995–2008; the two regressions correspond to the observations of the 40 countries for the years 1995 and 2008 respectively.
5) The vertical blue dotted line represents the threshold of the minimum energy to achieve a HDI > 0.8 for the set of countries and years analyzed (i.e. Malta 2000, with TPED of 74 GJ/cap and HDI of 0.801). Countries above the horizontal line are classified as developed countries (i.e. HDI > 0.8), otherwise they are considered as developing countries.
6) GDP per capita in US$, constant prices of 2008. Source: own elaboration from data of the International Energy Agency, United Nations and World Input–Output Database.

level of development, in low and medium developing countries as well as in emerging economies (e.g. BRIIC countries: Brazil, Russia, India, Indonesia, China), changes in the use of energy translate into changes in the degree of development. Similarly, HDI increases with the GDP until a certain level, but further, HDI becomes insensitive to GDP variation. This threshold is identified through a simple screening method in Fig. 1 at around 20,000 US$.[3] This phenomenon is referred in the literature as a "plateau" by (Pasternak, 2000) or "saturation" by (Martínez and Ebenhack, 2008). The observation of paths at the country level reveals that for some high-developed economies (e.g. Germany, Japan, Sweden, the United Kingdom or the United States of America (USA)) there is not a strong positive relation between changes in the HDI and in the TPED, furthermore, in some cases the relation is negative. Moreover, the ability of countries to reach higher development levels with the same amount of TPED has slightly improved between 1995 and 2008 (see detail in Fig. 1). This is the consequence of a combination of factors: the effect of climate and energy efficiency policies, the impact of high energy prices (especially from 2004 onwards), technological progress, changes in the economic structure, and other factors affecting human development such as health improvement. To some extent, this is also reflected in the fact that similar levels of development can be achieved with very different amounts of energy use: for example, in 2008, both USA and Germany had a HDI over 0.9, but the TPED of the USA was 63% higher.

To date, most of the attention has focused on the assessment of the relationship between low levels of development and energy use (WBGU, 2003; Guruswamy, 2011; Kaygusuz, 2011; Bhattacharyya, 2012; Karekezi et al., 2012; Sovacool, 2012). However, although poverty is still a serious and persistent problem, in recent decades many countries have been experiencing relevant progress in terms of development. Between 1990 and 2014 the share of people leaving in less developed countries (with HDI < 0.55) has decreased from 60% to 12%, while the share of people living in developed countries (with HDI > 0.8) has increased from 11% in 1990 to 18% in 2014 (UNDP, 2015). Furthermore, by 2014 more than 50% of world's population was living in countries with a HDI >0.7 (compared to 24% in 1990) (UNDP, 2015). These trends are expected to continue in the future, translating into higher energy requirements to sustain the enhanced living standards.

In this context, a key research question is the identification of the minimum rate of energy use to achieve a certain level of development. This is an important issue in order to support the design and implementation of energy policies linked to the deployment of the infrastructure and technologies required to promote human development. Regarding this research question, it is important to highlight that the minimum per capita energy use in order to reach high development is a normative issue and cannot be globally set due to territorial, climatic, historical and/or cultural differences (WBGU, 2003). For example, the need for heating and the amount of energy used for this purpose depend on local climatic and building conditions which vary between countries. Similarly, although there is a minimum requirement for mobility because schools, medical facilities and markets must be accessible for everyone under acceptable conditions, it also varies substantially (WBGU, 2003). Moreover, basic needs vary not only with climate, region, time, age or sex, but also with personal outlook and expectations (Spreng, 2005). Despite this constraint, several studies have approximated these thresholds or minimum energy use levels following different methodologies.

[3] Note that this is a just a rough approximation for illustrative purposes. This analysis should be done based on regression of HDI vs GDP at several points in time, since the relation is known to by dynamic (Steinberger et al. 2012; Jorgenson et al., 2014).