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Energy and quality of life

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HIGHLIGHTS

- ► Energy consumption is inherently coupled to quality of life and population growth.
- ► Limiting overconsumption can keep 2040 energy consumption at 2010 levels.
- ► Restricting population growth has a minor effect on future energy demand.
- ► Social inequality reduction increases quality of life with a minor energy use.
- ► Increasing energy-for-life efficiency can keep 2040 energy use at 2010 levels.

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ABSTRACT

Energy is required to sustain life. A human-centered analysis of the worldwide energy situation is conducted in terms of quality of life-related variables that are affected, but not directly determined, by energy consumption. Data since 1980 show a continuous global increase in both energy consumption and quality of life, and lower population growth in countries with higher quality of life. Based on these trends, we advance non-linear energy consumption predictions and identify various plausible scenarios to optimally steer future energy demands, in order to maximize quality of life. The scenarios consider the coupling between energy consumption rate per capita, quality of life, population growth, social inequality, and governments' energy-for-life efficiency. The results show the energy cost of increasing quality of life in the developing world, energy savings that can be realized by limiting overconsumption without impacting quality of life, and the role of governments on increasing energy-for-life efficiency and reducing social inequality.

1. Introduction

Energy is required to sustain and improve quality of life. The dramatic societal changes and the six-fold population growth since the industrial revolution have required vast amounts of energy provided mainly by coal and petroleum (Hall et al., 2003). In the near future, further population growth and improvements in quality of life will increase the demand for non-renewable fossil fuels and intensify the associated environmental implications (IPCC, 2007; Lee, 2011).

In the meantime, the high rate of fossil fuel consumption accelerates their depletion (Bentley et al., 2007—note: two-thirds of the world's oil-producing countries are already past their production peak), technological readiness and economic return on investment hinders the development of non-conventional fossil fuel sources (Arent et al., 2011; Resch et al., 2008), the hydroelectric capacity is almost saturated (EIA, 2010), renewed concerns affects investment in nuclear energy (Glaser, 2011), and renewables grow fast but starting from a small base (REN21, 2011). In this context, improvements in efficiency and conservation must remain important components in the global energy strategy (Herring, 2006).

Other aggravating conditions add further concerns to the present situation. The spatial mismatch between resource and demand strains international affairs (Colgan, 2010). Trade balance and technological differences imply disparities in energy and carbon dioxide embodied in global transactions (Machado et al., 2001; Peters and Hertwich, 2008). Finally, the contrast in the time scale between the political cycle (∼4 years), industrial investments (∼40 years), and natural processes (millennia) delays determined decision-making.

Abbreviations: QL, Quality of life index [–]; WA, Improved water access [–]; LE, Life expectancy at birth [years]; IM, Infant mortality rate [deaths/1000 live births]; MYS, Mean years of schooling [years]; EL, Electrification level [–]; GNI, Gross national income [US$/person]; ECR, Energy consumption rate per capita [kW/person]

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The purpose of this study is to anticipate energy needs and to explore alternative scenarios from a quality of life perspective. First, we identify the most meaningful quality of life-related indicators and combine them to define the simplest quality of life index *QL* that best predicts the energy consumption rate per capita. Then, we use the new index to trace global energy consumption trends and to explore the relationship between quality of life and population growth. Finally, we anticipate future energy demands based on current trends and explore the effects of various realizable scenarios.

2. New quality of life index in view of energy needs

Several indices, such as the human development index of the United Nations (UNDP, 2010), the human welfare index of Meadows and Randers (Meadows et al., 2004), and the quality of life index of the Economist Intelligence Unit (EIU, 2007) have been proposed to compare societies and to quantify their improvements. All these indices consider income, which inherently biases the indices to show a high correlation with energy consumption, as will be discussed later on.

2.1. Quality of life variables

An alternative quality of life indicator is explored herein in terms of quantifiable quality of life-related variables that are not directly determined by energy consumption. We place emphasis on variables that are available for most countries over several decades. Based on these considerations, we identify the following four variables:

- *Improved Water Access WA* [–]: Proportion of the population using improved drinking-water sources, such as public tap, tube well, and protected springs (UN, 2011b).
- *Life Expectancy at Birth LE* [years]: The number of years a newborn infant would live if the mortality patterns at the time of birth prevail throughout the individual's life (WB, 2011).
- *Infant Mortality Rate IM* [deaths/1000 live births]: The number of infants that die before reaching one year of age, per 1000 live births in a given year (WB, 2011).
- *Mean Years of Schooling MYS* [years]: Lifetime number of years of education received by individuals ages 25 and older (Barro and Lee, 2010; UN, 2011a; WB, 2011).

  Two additional variables, electrification level and income, are compared in this section. They are defined as follows:
- *Electrification Level EL* [–]: Proportion of the population with access to electricity (DM, 2011; Elvidge et al., 2011; IEA, 2010).
- *Gross National Income per Capita GNI* [US$/person]: Sum of value added by all resident producers in the economy divided by the mid-year population. It is expressed in purchasing power parity in US$ (UN, 2011a).

However, these two variables are not included in the definition of the new quality of life index because they would systematically bias the correlation between the index and the energy consumption: electrification, a critical infrastructure to quality of life, is inherently correlated with primary energy use, and income is the monetary dimension of energy.

Fig. 1 shows a plot of the selected variables for 118 countries versus the energy consumption rate per capita *ECR* [kW/person], which is computed as the annual rate of primary energy use divided by the country's population (EIA, 2011). Primary energy includes petroleum, natural gas, coal, hydroelectricity, and renewable energy (i.e., wind, solar, and geothermal). Embodied energy in food, the direct use of biomass, and other renewable energy sources, such as solar energy for heating, are not considered.

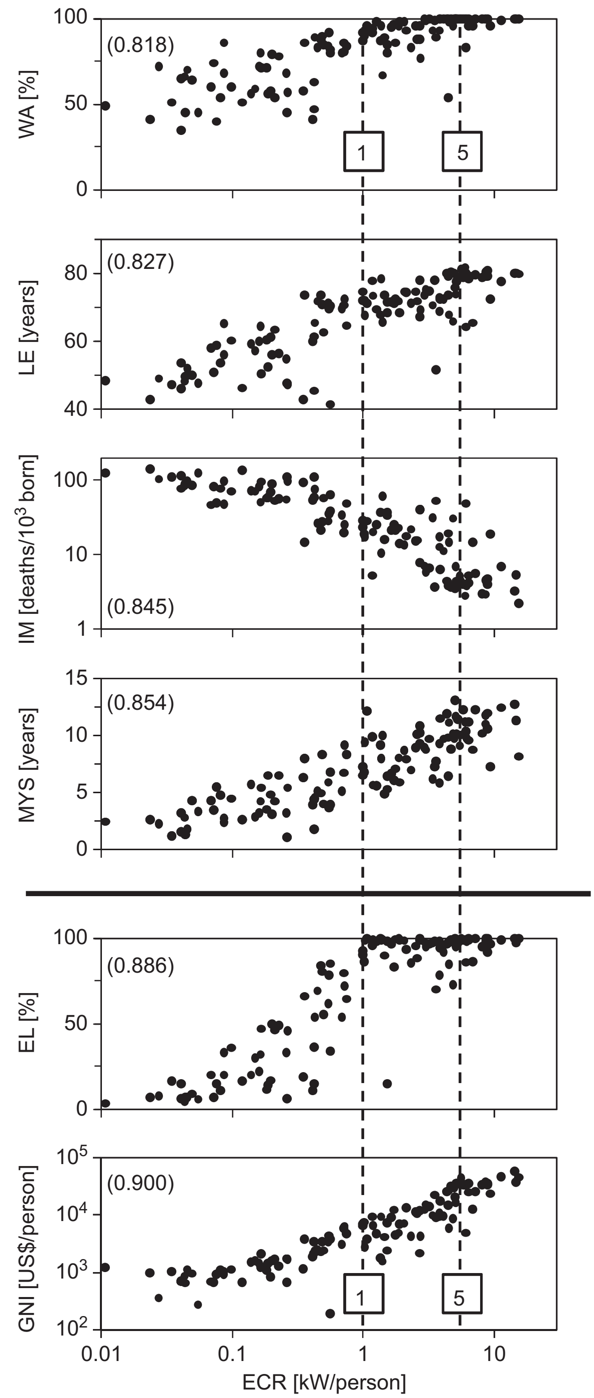

Fig. 1. Quality-of-life-related variables and energy consumption rate per capita *ECR*: Improved water access *WA*, life expectancy *LE*, infant mortality *IM*, mean years of schooling *MYS*, electrification level *EL*, and gross national income *GNI*. Correlation coefficient in parentheses (infant mortality and gross national income are considered in logarithmic scale). Note: Data for 118 countries with populations larger than four million in 2005 (data sources: Barro and Lee, 2010; DM, 2011; EIA, 2011; Elvidge et al., 2011; IEA, 2010; UN, 2011a, b; WB, 2011).

Although countries with high energy consumption rates collapse in the figure, the logarithmic scale helps us to differentiate countries with low consumption and highlights the three orders of magnitude difference between countries with low and high energy consumption. Water access, life expectancy, mean years of schooling, electrification level, and gross national income increase