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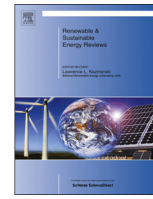

Energy poverty: An overview

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ABSTRACT

In the coming decades the energy sector will have to face three major transformations concerned with climate change, security of supply and energy poverty. The first two have been extensively analysed, but less attention has been paid to the third, even though it has a great influence on the lives of millions of people. This paper presents an overview on energy poverty, different ways of measuring it and its implications. According to the WHO, indoor pollution causes an estimated 1.3 million deaths per annum in low income countries associated with the use of biomass in inadequate cookstoves. Although energy poverty cannot be delinked from the broader, more complex problem of poverty in general, access to energy infrastructures would avoid its most serious consequences and would help to encourage autonomous development. According to the IEA, the cost of providing universal access to energy by 2030 would require annual investment of $35 billion, i.e. much less than the amount provided annually in subsidies to fossil fuels. Finally, the paper argues that energy and energy poverty need to be incorporated into the design of development strategies.

Contents

1. Introduction

In the coming decades the energy sector will have to face three major transformations, concerned with energy security, climate change and energy poverty. The first two have been extensively analysed (see [16,4,18]), but less attention has been paid to the third in terms of both research and its inclusion on political agendas [6]. The UN's Millennium Development Goals [32] – whose objective is to eradicate extreme poverty, improve living conditions and facilitate progress towards sustainable development – do not include any mention of access to energy. Nor qhas this issue been mentioned to date (see [28]) in the context of the United Nations Framework Convention on Climate Change (UNFCCC).

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Table 1
Energy and development indicators, 2010.
Source: World Bank [41].

	HDI	Life expectancy (years)	GDP per capita ($, PPC)	Electricity consumption per capita (kW h)	Energy consumption per capita (tep)	Passenger cars (per 1000 people)	CO_2 per capita (t)
United States	0.92	78.2	46.612	13.394	7.1	632	19.7
Germany	0.92	80	37.652	7.215	4.0	510	9.8
Saudí Arabia	0.78	73.9	22.747	7.967	6.1	139	16.5
Russia	0.78	68.8	19.940	6.452	4.9	233	11.3
Brazil	0.73	73.1	11.180	2.384	1.3	178	1.9
China	0.69	73.3	7.553	2.944	1.8	35	4.4
India	0.55	65.1	3.366	616	0.5	12	1.2
Nigeria	0.47	51.4	2.367	137	0.7	31	0.7
Ethiopia	0.39	58.7	1.033	54	0.4	1	0.1

This paper seeks to provide an overview of the energy-related aspects of poverty, a concept which has come to be known as "energy poverty" (see [14]). There are many different views to be found in the existing literature, but here the problem is approached in a way that at least enables the most significant elements of it to be identified. We analyse the current situation as regards energy poverty, its future prospects and its current impacts. Although energy poverty affects many different economic sectors and hampers environmental protection efforts, its most relevant (and perhaps least known) repercussion is its impact on health: according to the WHO it currently causes more deaths than malaria or tuberculosis. The paper ends with an analysis of the possibilities of providing universal access to energy.

Although it is difficult to separate energy poverty from the broader, more complex problem of poverty in general, this article do not seek to examine the underlying causes and consequences of poverty. Nor is the paper intended to analyse the various technological options available for providing access to energy or indeed to assess ongoing projects [40]. The attention is focused rather on poor[1] countries, and particularly on energy poverty in the sense of a lack of access to energy. The particular features displayed by energy poverty in wealthier countries ("fuel poverty", see [15]) therefore lie outside the scope of the study.

The paper is organised as follows: Section 2 examines the link between energy consumption and economic development. Section 3 defines the concept of energy poverty and outlines the various ways in which it is measured. Section 4 analyses the current situation and trend as regards energy poverty. Section 5 then looks at the impacts of energy poverty on health, the economy and the environment, and Section 6 analyses the cost of providing universal access to energy. Section 7 concludes.

2. Energy and development

Energy consumption and economic development are closely linked (see for example, [20] or [9]). The basic macro-economic indicators of a country generally include energy and electricity consumption, number of vehicles and, lately, per capita CO_2 emissions. Table 1 shows indicators related to development and energy for nine representative countries. Observe that the human development index (HDI), life expectancy at birth and gross domestic product (GDP) per capita are all closely related to energy consumption. For instance, Germany and the USA, which have very similar HDI scores (0.92) and life expectancy levels (80 and 78 years, respectively), also have high per capita energy consumption

[1] The UN distinguishes between less economically developed countries (LEDCs) and more economically developed countries (MEDCs). We use "poor countries" to refer to LEDCs countries.

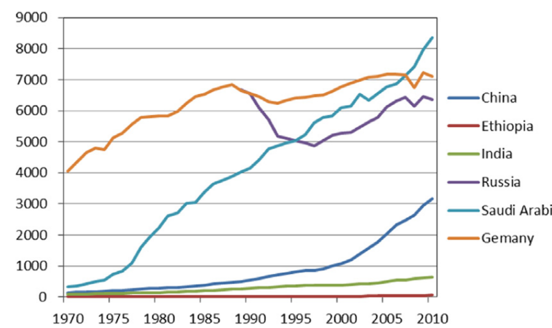

Fig. 1. Electricity consumption, 1960–2010, kW h per capita. .
Source: World Bank [41]

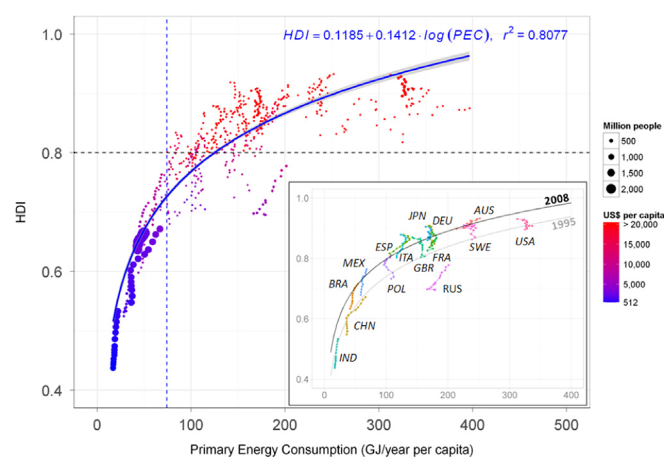

Fig. 2. Human development index and energy consumption, 1995–2008.
Notes:

(1) HDI: human development index; PEC: primary energy consumption.
(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 vertical blue dotted line represents the threshold of the minimum energy to achieve a HDI > 0.8 for the set of countries and years analysed (i.e. Malta 2000, with PEC 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.
(4) GDP per capita in US$, constant prices of 2008.

Source: Arto et al. [2]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

levels (in excess of 4 t of oil equivalent (toe) per person per annum). By contrast, India, Nigeria and Ethiopia, whose HDI scores (0.55, 0.47 and 0.39, respectively) and life expectancy (below 65 years) are much lower, also have low levels of energy consumption (below 0.7 toe).

As countries progress their energy consumption increases. Fig. 1 shows the trends in electricity consumption from 1970 to 2010 for a number of countries. One of the most spectacular increases is that of China, where the figure rose from 150 kW h per capita in 1970 to 3000 in 2010, i.e. 20 times more. However, in some African countries where there has been little or no economic progress energy consumption has hardly increased at all: for instance in Ethiopia consumption is up from 18 kW h per person in 1970 to 58 in 2010. Per capita electricity consumption in Ethiopia is currently 250 times lower than in the United States. The economic inequalities that exist around the world are reflected in similar inequalities in energy consumption. It is worth pointing out that the link between energy consumption and development also works in the opposite direction: energy consumption tends to decrease at times of economic recession. This can be seen easily in Fig. 1 in the case of Russia during its transition to a market economy: GDP dropped by almost 30%, and energy consumption decreased accordingly.

Fig. 2 shows the statistical link between development and energy. Each point represents the HDI and the energy consumption of a country. The size of the point indicates the relative size of the population. In general, almost all the countries with high or very high HDI scores also have high energy consumption levels. However, it is also possible to have a high HDI with very different levels of energy consumption, as shown by the broad horizontal spread found in the data. Moreover, beyond a certain level of consumption the link seems to curve, indicating that there is a threshold beyond which HDI and energy consumption are no longer linked.

Although a strong link has been seen to exist between energy consumption and development, two important nuances must be noted. The first is that in energy exporting countries the link may be highly distorted as a result of high levels of subsidies on energy, especially on energy from fossil fuels. For instance in Saudi Arabia and in Russia, electricity consumption per capita is higher than in Germany even though standards of living are lower (see Table 1). The second is that government policies have a considerable impact on levels of energy consumption. For instance, in the USA energy and electricity consumption per capita is almost twice as high as in Germany. This difference cannot be explained in terms of economic structure or indeed geographical or climate-related factors, but for the policies implemented, especially energy and urban policies [21].

In conclusion, energy consumption is necessary, but not sufficient in itself, for development. Moreover, as from a certain level of development the policies implemented are decisive in determining whether standards of well-being can be increased or maintained without increasing energy consumption. In any event, the clearest way of understanding the importance of energy consumption is to analyse the implications of energy poverty.

3. What is energy poverty?

There are many different definitions and visions of energy poverty, but they all refer to a level of energy consumption that is insufficient to meet certain basic needs. According to Reddy [26], energy poverty can be defined as "the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development". This definition is selected here because it incorporates a number of interesting elements and nuances (see also [3]).

First of all, it refers to the absence of choice. According to Sen [29], development is not so much a question of achieving a certain level of income (or energy per capita in our case) as, first and foremost, not being excluded from those options that enable us to choose and obtain welfare in its broadest sense. Not having access to energy may mean being deprived not only of basic services such as cooking and home heating, for instance, but also other elements which are fundamental for individual and collective development, such as access to education, health, information and participation in politics. A lack of capability or choice may, as can be seen, affect elements that are essential for participation in and control of institutions, and when they do not serve the general interest there is unlikely to be genuine development [1].

Second, the definition stresses the idea of meeting demand for "energy services". Although it may seem obvious, it is worth recalling that the goal is not energy consumption per se but rather the provision of energy services from the various sources of energy. Primary energy sources (coal, oil, gas, biomass, etc.) are processed, and energy is stored and distributed via various energy "vectors" (heat, electricity and solid, liquid or gaseous fuel) to provide the various energy services that are really need: cooking, heating, cooling, lighting, transportation, work and access to information and communication technologies ("connectivity"). The make-up of the primary energy sources and energy vectors used may vary widely depending on geographical characteristics and on the energy policy implemented in a given country, but the energy services demanded are very similar all over the world.

In general, wealthier countries tend to have various sources available, while in poorer countries (and particularly in rural areas within those countries) there may be few alternatives or indeed none at all. The most widely used primary energy source in poorer countries tends to be wood. Bailis [3] shows the various energy sources used for cooking in different African countries, divided according to wealth quintiles. In the cases of Burkina Faso and the Central African Republic the only choice is between burning wood or charcoal. Elsewhere, e.g. in Kenya and South Africa, gas and electricity are more widely available. There are also fewer options for poorer people (the first quintile), who generally live in rural areas, than for the wealthier, generally urban-dwelling population (the fifth quintile).

Third, the definition identifies certain desirable characteristics of the technologies used to access energy services. Those technologies need to be "adequate", i.e. suited to the geographical characteristics, knowledge base and culture of each area. It is well-known that development aid projects may fail if they simply try to replicate the use of the same technologies in different locations without taking the particular features of each region or community into account.

Technologies must also be "affordable", i.e. as cheap as possible compared to the alternatives available. In general, as average household income levels rise fuel sources such as biomass tend to be replaced by sources such as kerosene, oil and, ultimately, electricity (see table), which is the cleanest, most versatile energy vector of all. This is known as the "energy ladder" theory [36], and it posits that low-quality fuels are displaced by higher-quality, more versatile fuels as income increases.

One major caveat that must be taken into account in energy ladder theory is that low-quality fuels are not (as generally believed) always the cheapest: all too often they are simply the only option. A study conducted in Guatemala [13] has shown that sometimes, especially if what is measured is the cost per unit of energy service and if the opportunity costs involved in collecting wood are taken into account traditional fuel sources may even be more expensive. The lack of alternatives means that poor people consume energy that is not only of lower quality but also more expensive.

Finally, insofar as possible, technologies need to be "reliable", i.e. not subject to continual breaks in service (in many countries power cuts lasting for several hours a day are commonplace) and "safe", i.e.

Table 2
Energy poverty by physical threshold.
Source: Adapted from [7].

Thresholds	Energy consumption (cap year)	Energy consumption (GJ/cap year)	Population (% total)
Basic human needs	100 kW h +150 l (≅ 5 GJ)	< 5 GJ	1800 (27%)
Productive uses	750 kW h +220 l (≅ 10 GJ)	5–10 GJ	1600 (24%)
Modern Society	2000 kW h +550 l (≅ 25 GJ)	10–25 GJ	1500 (22%)
European Union	Average UE (≅ 75 GJ)	25–75 GJ	1300 (19%)
United States	Average USA (≅ 150 GJ)	> 75 GJ	600 (7%)

not liable to endanger health. The definition also mentions that technologies should be "environmentally benign", i.e. that they should not compromise future generations. It is important for technological solutions intended to reduce energy poverty to take into account impacts on climate change and on the environment so that development can be maintained in the future. Moreover, as indicated in the definition, the purpose of energy use is "to support economic and human development", so the mere fact that energy resources exist and that there is economic activity associated with their extraction does not guarantee that there will be development in general or indeed energy development.

3.1. Measurements of energy poverty

Energy poverty can be measured using three alternative but complementary approaches (see [24]). These approaches focus on access to energy according to a technological, physical or economic threshold:

- *Technological threshold*: this approach is based on the idea that energy poverty is first and foremost a problem in accessing "modern" energy services. This term is considered to mean electricity and sources other than biomass for cooking and home heating. Traditional energy sources, as shown, limit or hamper access to many basic energy services. From this viewpoint, energy poverty is measured by counting the population with no access to such services. According to the IEA, in 2012 there were 1.3 billion people with no access to electricity, and 2.7 billion who depended on biomass for cooking. The main limitation of this indicator is that it provides no information on levels of consumption.
- *Physical threshold*: this approach estimates minimum energy consumption associated with basic necessities. Anyone found to be below that threshold is considered to be suffering from energy poverty. This is similar to the approach used by the World Bank to estimate absolute poverty levels[2]. The problem lies in the difficulty of defining just what a "basic necessity" is, and in whether or not energy used for production is included. If the threshold for basic necessities (see Table 2) is set at 100 kW h in terms of electricity consumption and 150 l of gasoline per person per annum (equivalent to 5 GJ), then 1.8 billion people were unable to cover their basic energy consumption requirements in 2009 (27% of the world's population). A further 1.6 billion (24% of the population) consumed double that amount (10 GJ), but were still well below the consumption levels of emerging societies (25 GJ) and the average consumption, for instance, in the European Union (75 GJ).
- *Economic threshold*: this approach seeks to establish the maximum percentage of income that it is reasonable to earmark for energy spending. It is similar to the approach used by developed countries to measure relative poverty in general. This is the most widely used system for measuring energy poverty in developed countries, where the problem is concerned more with purchasing power, energy prices and the difficulty of maintaining adequate temperature levels in the home, especially in winter ("fuel poverty"). The UK, a pioneer in such studies, where official statistics have existed since 1996, sets a percentage of 10% of available income. In 2010 there were 4.7 million homes in the UK [15] below this threshold (19% of the population). The problem with such thresholds is that they are relative in nature, which makes it difficult to draw comparisons between countries with different economic situations.

[2] In 2008 there were 2.47 billion people living below the poverty line (on less than two dollars per day) and 1.29 billion living below the extreme poverty line (on less than $1.25 per day).[7]

4. Current situation and trend in energy poverty

4.1. Access to modern energy services

As indicated, in 2010 there were almost 1.3 billion people with no access to electricity, and around 2.6 billion who used biomass to meet their basic energy needs. 95% of those with no access to electricity live in Asia and sub-Saharan Africa, as can be seen in Table 3. In terms of numbers there are more people with no access in Asia, because of the size of the population, but the level of access is generally lower in sub-Saharan Africa. There are also areas without access to these services elsewhere, e.g. Latin America, the Middle East and North Africa, but in comparative terms the size of the population affected is small and access levels in general are higher. Everywhere else access is almost universal, except in remote, rural areas.

It is striking to note that just 10 countries, four of them in Asia (India, Bangladesh, Pakistan and Indonesia) and six in Africa (Nigeria, Ethiopia, the Democratic Republic of the Congo, Tanzania, Kenya and Uganda) account between them for 63% of all the people with no access to electricity (see the right-hand side of Fig. 3). The largest number can be found in India, with 293 million, followed by Bangladesh with 88 million and Nigeria with 79 million. However, the lowest levels of access to electricity are found in countries such as Malawi (9% of the population), Uganda (9%), the Democratic Republic of the Congo (11%), Mozambique (11%), Myanmar (13%) and Afghanistan (15%). In Latin America, the level of 38% found in Haiti is far lower than in the second worse case, which is Nicaragua with 72%. Most countries in North Africa and the Middle East have universal access, e.g. the United Arab Emirates, Kuwait, Lebanon and Jordania.

Just three countries – India, China and Bangladesh – account for half of all the people of the world with no access to modern cooking facilities (see Fig. 4). If Pakistan, Indonesia, Vietnam and the Philippines in Asia, along with Nigeria and the Democratic Republic of the Congo in Africa are added to the equation the figure rises to 75%. Once again, the numbers are greater in Asia but it is in sub-Saharan Africa where the level of access is lowest. Levels of access to modern cooking facilities are close to zero in Liberia, Zambia, Malawi, Namibia, the Democratic Republic of the Congo, Myanmar, Nepal and Bhutan. In Latin America the lowest levels of access are found in Nicaragua (3%), Honduras (4%) and Haiti (5%). Access is almost universal, however, in northern African

Table 3
Number of people without access to "modern" energy access, 2009 (millions).
Source: [16].

	Lacking access to electricity		Relying on the traditional use of biomass for cooking	
	Population	(% Total)	Population	(% Total)
Asia	628	18%	1814	51%
Sub-Saharan Africa	590	57%	698	68%
Latin America	29	6%	65	14%
Middle East	18	9%	10	5%
North of Africa	1	1%	2	1%
Total	**1267**	**19%**	**2588**	**38%**

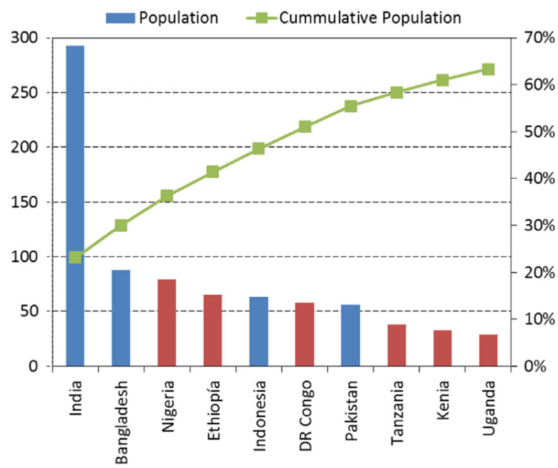

Fig. 3. Population lacking access to electricity, 2009 (millions). .
Source: [16]

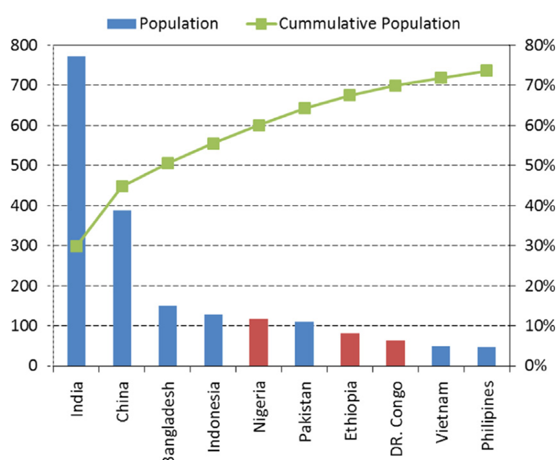

Fig. 4. Relying on the traditional use of biomass for cooking, 2009 (million). .
Source: [16]

and Middle Eastern countries such as Iran (100%), Jordan (99%) and Algeria (98%).

These figures do not reflect the differences that exist within countries, particularly between urban and rural areas. Eight out of every ten people with no access to modern energy services live in rural areas. Geographical barriers and scattered populations are determinant factors when it comes to providing access to basic energy services in rural areas. Major gaps may also exist at provincial level. In India, for instance, there are notable differences: 85% of the homes in Odisha have no access to modern cooking facilities, compared with 40% in Punjab.

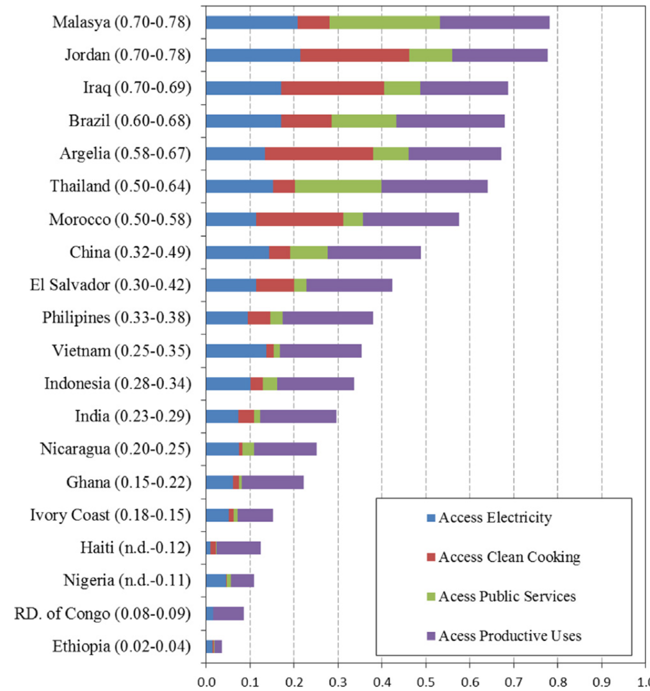

Fig. 5. IDE for 20 selected countries, 2002–2008. .
Source: [16]

4.2. Energy development indicator

The energy development indicator (EDI) combines data on access to and consumption of energy in a single index, covering the period from 2002 to 2010. The EDI has its limitations (see [22]) but its coverage is broad (80 countries). It is measured on a scale from 0 to 1, where 0 is the minimum level of energy development and 1 is the maximum. It is broken down into four sub-indicators[3]: (1) access to electricity; (2) access to modern fuel for cooking; (3) access to energy for public services; and (4) access to energy for production services. Each sub-indicator covers a specific aspect of energy development, and between them they provide a general indication of the energy development level of a country.

Fig. 5 shows the results broken down by sub-indicators for a selection[4] of 20 countries in 2010. Just as energy poverty is found to be concentrated mostly in sub-Saharan Africa and in Asia, this graph shows that energy development is located mainly in Latin America and the Middle East, especially in countries with energy resources. Most Latin American countries have medium to high EDI levels, with the exception of Haiti, Nicaragua and Guatemala. However, with the exception of South Africa, most countries in sub-Saharan Africa have low or very low EDI levels.

Fig. 5 shows the EDI obtained for 2002 and for 2010 beside the name of each country, thus enabling trends to be analysed. These data show that global energy development improved over this period, as the overall EDI rose from 0.392 0.43. In fact, EDI levels improved over the period in all countries except Iraq and Cote d'Ivoire. Four of the 10 countries with the biggest improvements are located in Asia (China, Thailand, Vietnam and Malaysia), three in Latin America (El Salvador, Argentina and Uruguay), one in the Middle East (Jordan) and two in North Africa (Algeria and Morocco).

[3] These sub-indicators in turn combine data on access to and consumption of energy. For instance, the "access to electricity" sub-indicator gives a weighted figure for access to electricity and electricity consumption per capita. The overall EDI is obtained as the arithmetic mean of the four sub-indicators.

[4] We have selected the countries to have a good representation of different regions. In any case, the full list can be found in the IEA database.

One of the biggest increases in IDE took place in China, thanks to improvements in access to electricity. Access to electricity in China is now practically universal, and various programmes have resulted in the installation of more than 40 million bio-gas cookers in rural areas. According to the IEA, most of the improvement in Thailand is attributable to growth in public investment. There was also a significant improvement in Vietnam thanks to various electrification programs in rural areas, which increased the electrification level to 98%. Latin American countries such as El Salvador, Brazil and Ecuador also made substantial progress. Finally, although in percentage terms the progress made was less, in India millions of people gained access to electricity over the course of the 10 year period studied, especially in urban areas. In Ghana access to electricity improved considerably, and the country has set a target of attaining universal access to electricity by 2020. However, around 40% of homes currently still use wood for cooking.

In spite of the general improvement observed, many countries with low EDI levels made little or no progress. Ethiopia, for instance, continues to have the lowest EDI of all (up from 0.02 to 0.04). Moreover, although some oil and gas-rich countries show generally high EDI levels (e.g. Venezuela and Iran) the same cannot be said for most African countries (e.g. Angola, Chad and Sudan).

5. Consequences of energy poverty

5.1. Impacts on health

As mentioned previously, energy use in many homes in poor countries is characterised by the use of biomass (wood, coal, dung and waste material) for cooking and heating. These fuels are normally burned directly in the home in clay, brick or metal cookers. Lighting requirements are also met largely by the use of candles and, to a lesser extent, kerosene lamps.

This type of energy use has substantial effects on health, as it is associated with high levels of pollution due to inefficient combustion and poor ventilation in homes. Indoor air pollution is characterised by higher than advisable levels of carbon monoxide, aromatic compounds and suspended particles. The suspended particles tend to comprise ash, soot and metal elements, and tend to be extremely fine. Particles with diameters of less than 10 μm are referred to as PM_{10}, and those with diameters of less than 2.5 μm as $PM_{2.5}$. When inhaled, PM_{10} easily penetrate the respiratory system, causing damage to health, particularly if the compounds are formed by toxic elements such as heavy metals. Moreover, $PM_{2.5}$ can be deposited in the deepest parts of the respiratory system, where their effects may be even more severe.

The World Health Organisation (WHO) estimates that PM_{10} concentrations in these homes may vary from day to day between 303 and 3000 $\mu g/m^3$, and may on occasion be as high as 10,000 $\mu g/m^3$. These levels are extremely high in comparison to the maximum levels permitted for outdoor air pollution. For instance the European Union has set an average annual limit figure of 40 $\mu g/m^3$. Indoor pollution is thus far higher than outdoor pollution in the world's most highly polluted cities [37]. Moreover, those exposed to it are mostly women, children, the elderly and the infirm, as they spend more hours per day in the home.

Table 4
Risk factor causes of death for low income countries, 2004.
Source: WHO [38].

	Risk factor	Deaths (millions)	Percentage of total
1	Childhood underweight	2.0	7.8
2	High blood pressure	2.0	7.5
3	Unsafe sex	1.7	6.6
4	Unsafe water, sanitation, hygiene	1.6	6.1
5	High blood glucose	1.3	4.9
6	Indoor smoke from solid fuels	1.3	4.8
7	Tobacco use	1.0	3.9
8	Physical inactivity	1.0	3.8
9	Suboptimal breastfeeding	1.0	3.7
10	High cholesterol	0.9	3.4

Medical studies have spent decades analysing the effects on health of high, prolonged exposure to indoor pollution. It is now known that fine particles are responsible for numerous respiratory and cardiovascular diseases and cases of lung cancer. The WHO [38] considers that indoor air pollution doubles the risk of pneumonia and other acute infections of the respiratory system in children under five. Women are three times more likely to suffer obstructive pulmonary diseases such as chronic bronchitis and emphysema, and twice as likely to suffer lung cancer.

In its latest Global Health Risk report [38], the WHO calculates the number of deaths and the loss of disability-adjusted life years (morbidity) attributable to 22 risk factors. In poor countries (see Table 4) indoor pollution is estimated to cause 1.3 million deaths per year, making it the sixth highest risk factor. It is ranked well behind factors such as infant malnutrition (2 million deaths per year) and the lack of drinking water and drainage (1.7 million), but it is well ahead of other causes of death. At global level, indoor pollution results in 2 million deaths per year, but is only the ninth highest risk factor because in high-income countries its incidence is zero. In terms of disability-adjusted life years (DALYs[5]), indoor pollution is the fifth highest risk factor, because its impact is especially prolonged: it affects younger people and gives rise to chronic illnesses. It is estimated that indoor pollution causes the loss of 33 million DALYs, making its impact greater than that of vitamin A deficiency (20 million) and zinc deficiency (14 million), which mainly affect the early stages of infant development.

Finally, Fig. 6 compares the number of deaths caused by various diseases with those caused by indoor pollution. The results show that more people die from indoor pollution than from malaria and tuberculosis. In fact indoor pollution is second only to HIV/AIDS. The OECD also expects the number of deaths from indoor pollution to increase slightly, so that they may actually overtake deaths from HIV/AIDS in the not too distant future (see [23]). The expectation is that income and the use of modern energy services will both increase in many countries, but that improvement will be insufficient to offset the increase in population unless specific measures are taken.

5.2. Impacts on the economy

Energy poverty affects all production sectors and limits potential for development. For instance in agriculture, a highly important sector, the energy input in poor countries is very low and comes mainly from animal and human labour. By contrast, in rich countries there are high levels of direct energy input (machinery and fuel) as well as indirect inputs (chemicals and fertilisers). In the USA, for instance, nitrogen-based fertilisers account for 45% of all the energy input in the process of producing corn, while physical labour accounts for just 3% [12]. According to the FAO, low levels of fertiliser use are one of the reasons for low crop yield, which means that poor countries find it harder to progress along this economic development path.

[5] DALY is the acronym for "Disability—Adjusted Life Year" and measures the years of 'healthy' life lost due to death or disease, measured as the difference between the actual health status and the ideal situation (where "ideal" is understood as if everyone would live until the global life expectancy free of disease and disability).

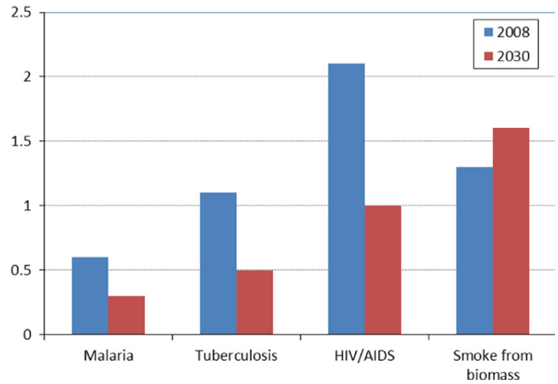

Fig. 6. Premature annual deaths (millions) from household air pollution and other diseases. .
Source: [23]

On the other hand, even slight improvements in access to and consumption of energy may have a substantial impact. In education, for instance, statistics show that populations with higher levels of access to electricity and better street lighting have higher literacy rates, lower drop-out rates and devote more time to reading and studying (see [19]). In the field of health, the availability of transport is often a determining factor in the provision of effective medical treatment in good time. And although the idea may seem like wishful thinking for poorer countries, access to information and communication technologies could encourage the formation of micro-businesses, enable people to access high-quality training courses free of charge online and encourage empowerment in society. It is hard to measure the impact of energy infrastructures on development, but it is clear that in their absence it is not possible to take advantage of the potential offered by energy in combination with new technologies.

Finally, it is important not to confuse the existence of energy resources and a powerful extraction and exporting industry with the reduction of poverty and energy poverty. Indeed, in most countries an abundance of resources has historically been linked to low levels of growth, in what is known as the "natural resource curse" (see [27]). Between 1970 and 1993 economic growth in countries without natural resources was, on average, four times greater than in resource-rich countries, even though public revenue was twice as high in the latter. In some oil-producing countries, e.g. Iran and Venezuela, public sector revenue has been used to encourage energy consumption[6]. However, it is not clear whether the subsidies provided really reach the poorest sectors of society, or whether they can be maintained over time. The situation in the oil-exporting countries of sub-Saharan Africa is clearly worse: high levels of income from oil and gas exports coexist with extreme levels of poverty in general and energy poverty. For instance, Angola has been drilling for oil since the 1970s, and oil revenue accounts for a high percentage of the country's GDP, but even so there has been very little progress for most people. Currently, 91% of the population of Angola are dependent on biomass, and only 9% of the rural population have access to electricity. Even in countries such as Gabon, whose per capita GDP and HDI levels are among the highest in Africa, levels of access to modern energy sources remain very low compared to developed countries.

5.3. Impacts on the environment

Energy poverty and the environment are linked mainly through land use change. As indicated above, traditional biomass provides the main source of energy for the poorest people, and its overexploitation increases deforestation, desertification and land-degradation. However, detailed studies in many areas around the world have documented that the main cause of deforestation is not the consumption of traditional biomass, as sometimes is assumed, but the expansion of farmland for crops and livestock and illegal logging. According to a recent assessment traditional biomass o fuelwood collection only account for around 6% of global deforestation [31].

Therefore, and although it is true that energy poverty can affect negatively the environment in reality the causality goes more in the other direction; so a lack of policies to protect woodland may also endanger the only energy source available to the poor, thus exacerbating their existing energy poverty [11]. Moreover, the loss of woodland has significant implications for the populations in question: not only do they lose firewood but many of the services provided by the relevant ecosystems will vanish with them, including sources of food and water, thus forcing populations to migrate.

The same happens with climate change. Although from a global viewpoint the loss of forest will reduces CO_2 absorption capacity and will exacerbate the climate change, the impact of this problem will be felt first and hardest in the poorest, most vulnerable countries, which have not contributed almost at all historically to this problem [25].

6. Cost of universal access to energy

According to the International Energy Agency ([16], *Energy for All*), universal access to modern sources of energy could be achieved by 2030 for a total investment of around $979 billion, which works out at an average annual investment of between $30 and 35 billion from 2010 to 2030. Actual global investment in 2010 was just $9 billion.

An idea of the economic effort entailed by these investments can be obtained by comparing the relevant figures with macroeconomic variables, with figures for the energy sector itself or with official aid for development. The annual investment required to finance universal access to energy is equivalent (according to 2012 data) to 0.05% of the world's GDP, or to 0.08% of the GDP of the OECD countries. This investment represents an average contribution of around €5 per person per annum at global level, or €25 per person per annum if it is funded entirely by OECD countries.

A look at the energy sector reveals that the investment required amounts to around 3% of the sum invested by the sector globally each year. According to the IEA this is equivalent to an increase of approximately 2% in electricity bills in OECD countries. The IEA also indicates that worldwide subsidies awarded to fossil fuels in 2012 totalled $544 billion[7], of which 68 billion corresponded to wealthy countries. This comparison is significant because at the G 20 summit in Pittsburgh in 2009 wealthy and emerging countries alike undertook to reduce those subsidies in line with the goals of energy efficiency, security of supply and mitigation of climate change. Moreover, the subsidies do not generally filter down to poorer homes and tend to be regressive. According to the International Monetary Fund [17], only 7% of subsidies in developing countries actually reach the poorest 20% of the population, while 43% end up in the hands of the richest 20%. However, as shown in Fig. 7, subsidies have increased considerably since 2009, driven by rising fossil-fuel prices and social pressure in Middle Eastern and North African countries. Some authors (see [28]) propose as an alternative that a fund for energy poverty should be set up based

[6] EDI in 2010: Venezuela (0.84), Iran (0.76).

[7] According to the IMF the impact of subsidies is much greater if losses in public revenue are taken into account. Including tax losses, the overall amount may be as much as $2 trillion, 8% of the public sector budget.

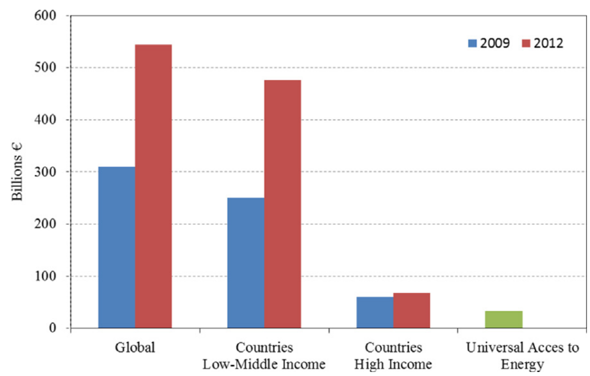

Fig. 7. Fossil fuel subsidies compared to the investments needed for universal access to energy (Billions $).
Source: [16].

on the introduction of a tax on oil by OPEC countries, which would transfer the cost of the programme to the countries which consume most energy, generally the wealthiest countries.

Finally, compared with development aid this investment is high: in 2012 OECD countries gave a total of US$125 billion in official development aid, which means that 30% of the annual amount of that aid would be required to attain the objectives set. This highlights how modest the contribution made by wealthy countries is in relation to the size of their economies. Development aid currently averages 0.29% of gross national income, a long way from the 0.7% agreed at the UN in 1970. That figure is currently only met by the Netherlands, Denmark, Norway, Sweden and Luxembourg.

It is also important to stress that not all the investments required to forestall the worst effects of energy poverty involve technology or the construction of large, expensive infrastructures. Educational programmes to teach people the best way to use biomass in the home may be an effective, inexpensive way of reducing the worst damage to health, and may entail no more than simple actions such as improving combustion in cookers and ventilation in homes. Similarly, micro-funding and/or joint funding programmes have worked well in other areas of development, and could possibly also be applied here. According to Wilkinson et al. [39], a programme to introduce 150 million modern cookers into India in 10 years would reduce emissions of fine particles by a factor of 15 and associated deaths by 2 million. Such a programme would cost $8.2 billion, which works out at less than $10 per annum per home.

7. Conclusions

Poverty is a fact of life for millions of people, and energy poverty is both a cause and consequence of it. Almost 1.3 billion people (a fifth of the world's population) have no access to electricity and almost 2.6 billion use wood as their sole source of energy, particularly in rural areas. Moreover, many more millions who do have access to infrastructures are unable to meet their basic energy needs because they cannot afford to pay for energy. The poverty and inequality in the world is also reflected in high levels of energy poverty and in inequalities in energy consumption. In the past 10 years there has been appreciable progress in energy development, particularly in China, where almost universal access to electricity has been achieved in a very short time, but in many countries in sub-Saharan Africa there has been little or no improvement, and still less than 15% of the population have access to electricity.

Energy poverty has significant implications. First of all, many basic energy needs such as cooking food, boiling water, heating and lighting the home and being able to travel so as to obtain basic medical services are compromised. Other needs, such as participation in society and control of institutions, are often impossible to meet, and this limits potential for personal and collective development. In most countries biomass is the main fuel source used to meet these needs, but it is often not the most suitable, and is certainly not always the cheapest: it is usually just the only option.

Energy poverty has major impacts on health, economic activity and the environment, because it reduces current and future productivity and limits potential for development. One of the biggest (and perhaps least-known) repercussions of energy poverty is its enormous impact on health as a result of the burning of wood and waste. Studies show that indoor air pollution (and especially high concentrations of fine particles) increases the risk of contracting many diseases, especially among women, children and the elderly, who spend more time in the home. According to WHO figures issued in 2010, indoor pollution causes an estimated 1.3 million deaths per annum for low income countries, and is the sixth highest risk factor for early death. It is ranked behind factors such as infant malnutrition and lack of drinking water and sanitation, but ahead of better known causes of death such as tuberculosis and malaria.

Energy consumption is necessary but not a sufficient condition for development. In this sense, there is a danger that energy poverty may be seen merely as a manifestation of poverty in which low income prevents people from consuming energy or investing in infrastructures. This may lead to the idea that efforts should be focused solely on growth and development, and that reducing absolute poverty will do away with energy poverty. However, energy poverty hampers many forms of development and helps to create a vicious circle or poverty trap.

Providing universal access to modern energy sources would require significant investment ($35 billion per year for 20 years), but that figure does not seem so high if it is compared with other macro-economic variables. The investment per annum required is, for instance, considerably lower than the amount granted each year in subsidies on fossil fuels ($544 billion in 2012), mainly in oil-rich countries, which do not generally reach the pockets of the poorest segments of the population.

An issue worth exploring, though it lies outside the scope of this paper, is how poorer countries can benefit from the implementation of new, distributed technologies based on renewable or low-carbon energy sources (see [10,5,8]). Renewables have become considerably cheaper in recent years, and although the initial investment required is high the "fuel" is at least free and can be adapted well to certain needs in rural areas. Distributed (rather than centralised) generation could also enable major savings to be made in resources earmarked for infrastructures, emulating the rapid deployment of mobile telephone systems in many poor countries, where it is thus not necessary to invest the enormous sums associated with landlines. Another area where further research is called for is how to make the eradication of energy poverty compatible with emission reduction to mitigate climate change (see [35,7,30]).

One of the main conclusions of the study is that specific policies and programmes are required to deal with energy poverty, particularly programmes designed to prevent its worst effects on health. Although resources earmarked for such investments have always competed and will always have to compete with urgent needs and other uses, access to energy should be an important component in the design of all-round development programmes. Although energy and energy poverty are not mentioned in the Millennium Development Goals for 2015, the final document produced at the Río +20 Conference in 2012 [33] recognised "the critical role that energy plays in the development process, as access to sustainable modern energy services contributes to poverty eradication, saves lives, improves health and helps to provide for basic human needs". Moreover, although there is still a long way to go, the new proposal for Sustainable Development Goals for 2030 (see [34]), to supersede the Millennium Development Goals for 2015, includes as a specific goal to "Ensure access to affordable, reliable, sustainable and modern energy for all", with interim goals (or "means") by 2030 of ensuring universal access to modern energy services, "substantially" increasing the share of renewable energy in the global energy mix and doubling the global rate of improvement in energy efficiency.

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