AIAE RESEARCH PAPER 5

On the Determinants of Energy Poverty in Sub-Saharan Africa

AFRICAN INSTITUTE FOR APPLIED ECONOMICS

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Published by:

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First Published, April 2010

ISSN 079-4187

Abstract

This paper sheds light on the determinants of electricity access in developing countries and pays particular attention to why sub-Saharan African countries have been comparatively unsuccessful in providing electricity to its population, despite reforms in the electricity sector. We find that some factors underlying electricity access in developing countries have a different impact in sub-Saharan Africa (SSA). Specifically, the marginal benefit from increased gross domestic savings, which commonly constitutes the bulk of capital used to finance energy projects, is less in SSA than in non-SSA developing countries, while a SSA country, with the same percentage of rural population, has, on average, a lower electrification rate than a non-SSA country. Our results support the importance of institutional quality and we suggest for policy makers to encourage an adequate portion of savings to be channelled towards the electricity sector. Furthermore , they highlight the importance of reforms with a strong focus on providing electricity access to the rural poor.

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1.1 INTRODUCTION

Africa's long term economic growth and competitiveness fundamentally depend on reliable access to energy. However, despite reforms and other measures to scale up electricity access, sub-Saharan Africa (SSA) in particular has not succeeded in expanding access to electricity. In the past decade, SSA has lagged behind globally not only in terms of Gross Domestic Product (GDP), but also in terms of electricity consumption. Africa's total primary energy production is about 7.6 percent of the world's total output yet the inhabitants of the continent consume the least amount of energy per capita, accounting for 3.1 percent of world commercial primary energy consumption (EIA). The population of Sub-Saharan African countries have the least access to electricity compared to developing countries from other regions (See Table 1). The OECD, as well as transition economies, enjoys an electrification rate of over 99 percent, while the average rates in the Middle East, North Africa, East Asia/China and Latin America are all above 90 percent. South Asia and sub-Saharan Africa rank lowest, with rates of 60.2 percent and 28.5 percent[1] respectively. Even though Africa is well endowed with energy resources such as fossil fuels and renewable resources, they are not adequately distributed and their full potential remains largely unexploited, which is one contributing factor in making the continent the lowest consumer of energy worldwide. Table 2 depicts electricity consumption and access rates for selected SSA countries. Generally, energy demand and energy investment are chronically mismatched in the SSA region. Consequently Africa's energy sector is characterized by deficiencies such as low access and insufficient capacity, poor reliability as well as extremely high costs (World Bank, 2009). These and other shortcomings in the power sector threaten Africa's long term economic growth and competitiveness.

Energy poverty is a quite complex problem. Since the electricity sector is the most capital intensive of all major industrial sectors (IEA, 2003), it could easily be concluded that energy poverty is merely a question of insufficient investment and/or limited ability to afford electricity. However, energy poverty is probably due to a multitude of factors, considering the difference in performance among developing countries. As of 2008, 1.46 billion people – roughly 25 percent of the world population - have no access to electricity (EIA), more than 80% of which are located in South Asia and sub-Saharan Africa, among the poorest regions in the world. Therefore it is not surprising that there is a strong correlation between the lack of electricity and the number of people living below

[1] These are roughly 21 and 6 percentage changes respectively over the year 2000.

Table 1 Electricity Access in 2008 – Regional Aggregates

	Electrification Rate (%)	Population without Electricity (million)	Rural Electrification Rate (%)	Urban Electrification Rate (%)
World	**78.2**	**1456**	**63.2**	**93.4**
Developing Countries	**72**	**1453**	**58.4**	**90**
Africa	40	589	22.7	66.8
Sub-Saharan Africa	28.5	587	11.9	57.5
Developing Asia	77.2	809	67.2	93.5
Latin America	92.7	34	70.2	98.7
Middle East	89.1	21	70.6	98.5
Transition economies & OECD*	**99.8**	**3**	**99.5**	**100**

Source: IEA, 2009b.

* OECD figures aggregate some important regional variations. The electrification rate for Turkey and Mexico is about 95%. All other Member countries have 100% electrification.

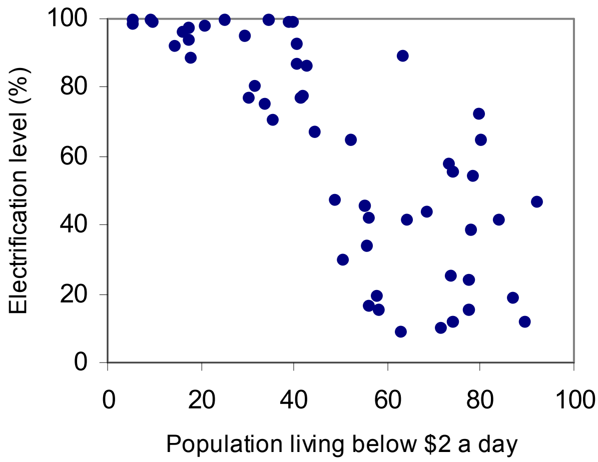
Table 2 Electricity Access and per capita Consumption Rates of Selected SSA Countries

Country	Access to Electricity (percentage), 2008	Per capita electric power consumption (kWh per capita), 2005
Benin	24.8	69
Botswana	45.4	1406
Cote d'Ivoire	47.3	170
Gabon	36.7	999
Ghana	54.0	266
Kenya	15.0	138
Mozambique	11.7	450
Nigeria	46.8	127
Senegal	42.0	151
South Africa	75.0	4847
Tanzania	11.5	61
Zimbabwe	41.5	953

Source: IEA, 2009b and World Bank 2008a.

$2 per day (IEA, 2002) (See Figure 1). Income, however, is not the only determinant of electricity access. As of 2000, China, for instance, with 56 percent of its people still poor, had managed to supply electricity to more than 98 percent of its population (IEA, 2002). China's success in developing its power infrastructure is characterized by structural reforms opening up new sources for capital and, maybe even more importantly, high domestic savings (IEA, 2002). What, however, are the factors characterising sub-Saharan Africa's particularly *poor* performance in terms of electricity provision to its population?

Figure 1 Access to Electricity and Poverty



Source: IEA, 2009b and World Bank 2008a.

The objective of this paper is to empirically analyze the problem of energy poverty in developing countries in general and in SSA countries in particular. In doing so, we identify major variables, and analyze their potential contribution in shaping the level of EP. We undertake this analysis within a South-South framework, which enables us to compare the determinants of EP particular in SSA and other developing regions.

With its main focus on SSA countries, this analysis deserves a considerable amount of attention for various reasons. First, energy poverty seems to be somewhat under researched in Africa in the sense that it is difficult to come across an *empirical* study on energy poverty that focuses particularly on African countries. This is quite surprising, since energy supply is crucial to the region's much needed economic development. According to the Economic Report on Africa [ERA] 2008, currently only a few, and mainly northern African, countries are well on track to meeting an important number of Millennium Development Goals [MDGs]. In this respect the report singles out 'the poor state of infrastructure in Africa' as one of the major impediments to 'domestic market and regional integration, to equitable access to social services, and therefore to growth'. In the case of energy, clean and available (modern) services in this sector are indispensable to the escape from poverty (IEA, 2002). In fact, "modern energy can directly reduce poverty by raising a poor country's productivity and extending the quality and range of its products – thereby putting more wages in the pockets of the deprived" (IEA, 2002, p 366).

Second, positive developments in the energy sector can affect the impact of climate change, whose mitigation plays a major role in making progress towards the MDGs. Taking a closer look at the 8 Goals and 18 Targets from the Millennium Declaration, it quickly becomes obvious that energy is indispensable to meeting virtually all of them, from the eradication of extreme poverty and hunger and the promotion of gender equally and empowerment of women to environmental sustainability.[2]

Third, drastic cutbacks in energy investment as a result of the global economic and financial downturn will impede access to electricity and other forms of modern energy by poor households (IEA, 2009a). At the same time financial problems limit the ability of utilities to connect new customers. A better understanding of the underlying factors will help policy makers in the energy sector respond better to the effects of the financial crisis on the electricity sector in developing countries.

Given the importance of the infrastructural facility 'energy' to the socio-economic well-being of a country, we seek to expand our understanding of the factors underlying countries' performance in the energy/electricity sector. This study is important because although relatively plenty of research has been done on energy and economic performance etc., it is difficult to find an analysis of the factors characterizing energy poor countries in a systematic way. This paper will contribute in filling this void.

The empirical results can be summarized as follows: They confirm that, among other factors, poverty, savings rates as well as the percentage of rural population play major roles in determining the pattern of electricity access across developing countries. In addition, the factors underlying electricity access in developing countries have a different impact in SSA countries than in other developing regions. This may be the result of the quality of previous reforms in the electricity sector and consequently of the opportunities the institutional framework in a country offers.

The rest of the paper proceeds as follows: Section II, revisits the existing literature on energy poverty in developing countries. Section III, explores the determinants of energy poverty and take a look at supporting facts and figures. Section IV presents the research design and the variables used in the analysis. Section V presents and discusses the results. Section VI concludes with policy implications.

[2] See Annex (Table ii. *Linking Development to Electricity*).

2.1 LITERATURE REVIEW

This section provides a brief look into selected examples of the existing literature on 'energy poverty'.

Even though it is not the aim of this study to analyze the relationship between energy and poverty/economic output, it is nevertheless important for our study to appreciate the significance of the relationship. The link between energy and growth is well documented in the literature and has been found to flow in both directions. A recent paper examining the causal relationship between energy consumption and economic growth for eleven SSA countries, for example, found that while there is a strong causal relationship between energy consumption and economic growth, the direction of causality is not the same across countries (Akinlo, 2008), suggesting that the same factors probably operate differently in different countries. Other studies have come up with energy-based economic growth models where energy has been explicitly included as factor of production, one of the reasons being that economic output is explicitly derived from energy consumption (Nel and Zyl, 2010), with results demonstrating the vital importance of energy security. Based on the extant literature, and without going into more detail about this relationship, we assume that energy poverty severely hampers economic growth and human development. Before embarking upon the relevant literature on energy poverty, we briefly present its definition.

Although the term "energy poverty" is widely used in literature dealing with energy/electricity, particularly in developing countries, one hardly comes across a clear definition. In general, the term is most often employed to describe the disastrous situation of the majority of people in the developing world and stands for the lack of access to various forms of energy. There are several ways of looking at it. People can be "energy poor" when the required infrastructure is not in place for energy supply or when they do not possess the means to acquire (improved) energy services, even if they have access to them (high costs, low income) (Uche, 2008). Energy poverty equally refers to the situation of rampant power outages where access to electricity is available. The term can be summarized as 'the lack of sufficient choice that would give access to adequate, affordable, effective, and environmentally sustainable energy services that could support economic and human development' (EAC). In our study we identify energy poverty as constrained access to modern energy services, in other words the larger the share of the population without access to electricity, the higher the level of energy poverty in a country.

Following our definition, we choose to present the existing literature on energy poverty as divided into two main groups: 'inadequate supply' and 'no access'. The former focuses on inadequate electricity supply and its various consequences, while the latter addresses various issues concerning the complete lack of electricity access, referring to the situation of the predominantly poor inhabitants of remote, rural areas not connected to the national grid.

Obviously most studies and publications in the 'inadequate supply' group conclude on a negative impact of inadequate electricity service. Among others, Tyler (2002), for example, stresses the effects of inappropriate public as well as private provision on manufacturing competitiveness in Nigeria. In response to this particular infrastructural deficiency, businesses mostly take on various mitigating strategies such as relocation, factor substitution, output reduction, private provision or even production substitution. Some of these responses tend to throw the demand-supply equilibrium off track. Production substitution for one has as a consequence that the products manufactured are less influenced by their demand but rather by the power supply and their robustness to it's irregularities. Others adjust their mode of production in favour of inputs that are less electricity-intensive. Again others make do with huge losses from output reduction due to poor provision of electricity. As at 2002, in Nigeria, for instance, ninety-seven percent of businesses had to pay for the public and private provision of electricity in parallel. This is all the more frustrating as many businesses have to operate their private provision utilities even when public supply is available in order to avoid detrimental waste of input/output losses. This example demonstrates that the comparatively high production costs in developing countries, and in SSA countries in particular, is in large part owed to the deficiency in public provision of electricity. This puts SSA at a competitive disadvantage not only globally but also compared to developing countries in other regions.

Another result of inadequate energy supply mentioned in the literature is 'information poverty' (AfDB). This term is "linked to the incapacity to communicate with the wider world due to the lack of electric power (…) [which] limit people's participation in national, regional and global activities, including trade." (AfDB). Equally at the individual level, inadequate electricity supply implies the loss of potentially productive or leisure time. The African Development Bank, for example, describes energy poverty as being "associated with deprivation of adequate light to facilitate evening and night-time chores and leisure activities" (AfDB). Both 'information poverty' as well as 'time poverty' prevent the development of human capital to its full potential.

As mentioned earlier, literature belonging to the 'no access' group deals with the complete absence of access to electric power, as is mainly the case in rural areas. Because the majority of the poor lack access to modern energy services (electricity and modern fuels) they use mainly human and animal power to perform mechanical tasks like agricultural activities or transportation. For activities requiring lighting or heat they tend to use traditional biomass (wood, crop, residues, and dung). However, wood and other traditional fuels have a number of non negligible disadvantages. Apart from being less efficient economically, they often constitute a major health hazard. Burning these types of fuels in enclosed or poorly ventilated spaces is a cause of serious respiratory diseases. The usage of biomass also often has negative consequences on the surrounding environment. Among them deforestation, soil erosion as well as reduced soil fertility, just to name a few. Finally, the usage of biomass as an alternative source of energy greatly reduces time for productive activities and thus, once more, perpetuates poverty (Barnes et. al., 1997)

One of the main reasons why rural areas tend to lack access to electricity is the dispersed character and the low commercial energy consumption of rural populations, which leads to poor capacity utilisation of transmission and distribution utilities and other energy infrastructure involved (Goldemberg, 2001). This is mainly due to low population, low densities and demand levels, peaky demand profiles as well as the tendency of high line losses. According to the World Bank, the extension of the electric grid to the rural setting can engender energy costs of up to seven times the cost of supplying electricity in an urban setting (Goldemberg, 2001) Also, in the process of the long distance transmission a substantial amount of energy is lost, resulting in huge transmission losses. It is because of these problems of supplying rural areas with grid electricity that decentralised electricity generation has become more popular. And as conventional ways of extending energy infrastructure to rural areas are economically inefficient for public as well as private providers, governments tend to give low priority to energy problems of rural populations. The explosive growth of cities, as the second half of the twentieth century has witnessed a strong urbanisation trend in most developing countries (Goldemberg, 2001). The irony is that among the reasons why people leave the rural setting for urban areas is precisely the lack of energy supply in rural areas.

The way out of energy poverty is to make modern energy services more accessible to the population, physically as well as financially. 'Energy ladder' is the term often encountered in the literature referring to the array of existing energy products and services from the least to the most efficient, electricity being at the top of the ladder. Poor people, mostly in rural areas, only have access to the lowest rungs, however the past has shown that when alternatives are available and affordable, people generally switch over to more modern energy carriers that are more efficient, convenient and cleaner. In other words, they "move up the energy ladder" (Goldemberg, 2001) and out of energy poverty. It is the goal of our study to better understand the factors affecting this 'movement up the energy ladder' by large parts of the populations.

The literature reviewed is predominantly descriptive in nature rather than empirical. Furthermore, none of the studies reviewed explicitly explored the factors affecting energy poverty/electricity access in developing countries, talk less of SSA, which is the main aim of this study. In the following section we present a few stylized facts on electricity access in developing countries, which motivated the choice of variables included in our model; we also present the theory underlying this study.

I. FACTORS AFFECTING ENERGY POVERTY

First, an important aspect of energy poverty is the energy sector's capital intensity. Due to the fact that they involve large initial investment before production/supply can even begin, energy projects are normally the most capital-intensive compared to projects in other industries. The electricity sector, for example, requires up to three times the investment needed by the manufacturing sector (IEA, 2003). We can divide the sources of funding for investment in the energy sector into two groups: *internal* and *external* finance.

In most countries, the majority of capital used for infrastructure projects comes from domestic savings (internal finance). According to data on *energy-investment needs* (projected averages from 2001-2030, IEA, 2003) the total amount of capital available worldwide for investment in energy projects is about twenty times larger than the actual energy-investment need. However, the ratio of domestic savings to energy investment varies considerably among regions and since other economic sectors are equally competing to attract investment, it can prove difficult to attract the necessary amount to the energy sector. OECD countries, for example, have an average domestic savings rate of 23 percent of GDP, about 40 times higher than their actual energy investment needs (IEA, 2003. Countries of Asia, East Asia in particular, have high domestic savings rates. China, for example, which sticks out with a particularly high savings rate of 40 percent, has an investment need of 2.4 percent, while India has a relatively high investment need of 2.2 percent and an average domestic savings rate of 20 percent. However, domestic savings in transition economies and Latin America are below average, while domestic capital is most scarce in Africa , where the energy-investment need alone makes up almost half of total savings.

Taking a look at the balance between total domestic investment (financial resources for *all* types of investment in the economy) and domestic savings we learn that domestic savings are lower than total domestic investment in many, if not most, developing countries and transition economies. While the average investment-savings (IS) gap is over 2 percentage points in transition economies and close to 7 percentage points in Latin America (excluding Brazil), domestic savings constitute on average less than half of total domestic investment in Africa, where the need to expand access to modern energy is most urgent. In all of these regions it is the electricity sector that accounts for the majority of energy investment needs.

It is this shortfall between investment requirements and domestic savings in some developing and transition economies, that gives rise to the need to resort to foreign capital flows (external finance). While foreign capital flows often reduce the cost of capital and provide longer debt maturity and a larger base of investors and lenders due to better organized international financial markets, over-dependence on external finance comes with the risk of volatile capital inflows as well as exchange rate risk, both of which can destabilize an economy. This situation is most often worsened by underdeveloped financial markets, which make it difficult for companies to have access to the financial services they need. The few instruments available make it tricky to mitigate the various refinancing and foreign exchange rate risks associated with energy investment. The World Energy Investment Outlook [WEIO] 2003 points out that in terms of constraints in financing energy investment, the lack of appropriate mechanisms in domestic financial markets adapted to the needs of energy projects is perhaps even more important than the availability of funds itself. Financial resources and the capital structure of companies are strongly affected by the stage of development of a country's financial market. Without going into details about various financial products and their advantages it is safe to say that less developed financial markets in developing and transition economies translate into lower quality financial services to energy investors.

Second, like all other sectors, the electricity sector is subjected to the institutional quality of a country. North (1994) explains that institutional quality shapes economic performance because organizations that emerge (political, social, economic or educational bodies) reflect the opportunities provided within the institutional framework. As such, if the latter encourages unproductive activities, organizations that engage in unproductive scheming will come into existence just as the reward of productive activities will stimulate the emergence of productive organizations. In other words if the institutional framework does not effectively punish unproductive activities and/or even impedes the exertion of productive activities, this will have a negative impact on the economic performance. A country with a weak law enforcement mechanism, for instance, is less capable of successfully reinvesting revenues in a productive and socially efficient manner. Rather, those revenues tend to be diverted towards less productive activities.

If we apply North's explanation to the problem of electricity access we can conclude that countries, which have been unable to supply electricity to large parts of their population, probably have institutions in place that do not (effectively) encourage productive

Table 3 Percentage of Rural Population – Regional Aggregates

Region	Average Rural Population 2008 (% of Total Population)	Percentage of Countries with >50% Rural Population per Region*
East Asia and the Pacific	58	75
Latin America and the Caribbeans	22	29
Sub-Saharan Africa	64	81

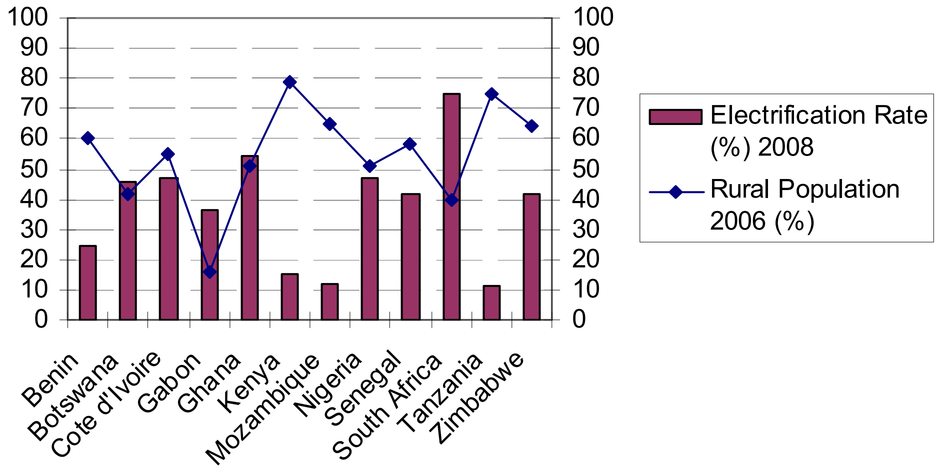
Source: World Bank 2008a.

* In the Region Asia and Pacific, 15 out of 20 countries; In Latin America and the Caribbeans, 4 out of 14 and in the sub-Saharan African region, 34 out of 42 countries had over 50% of rural population.

activities in the area of electricity provision. In order to explore this possibility we try to establish a link between the extent to which the rule of law in a country is enforced and the percentage of population having access to electricity. This link is further suggested by the rampant corruption and the restrictive bureaucratic bottlenecks electricity sectors (like most other sectors) in developing countries are often subjected to. Being responsible for the suspension of vital projects, such counterproductive behaviour has inflicted (and continues to inflict) major damage upon the electricity sector. While investors, lenders as well as project developers can reduce economic risks, political and legal risks, which are receiving more and more attention, are often outside their control. The same applies to the uncertainty about market reforms, such as changes in subsidies and taxes as well as the unbundling and privatisation of state companies. Investors' doubts about whether they will compete on a level, competitive playing-field impose an additional risk for energy investment. These are examples of how the institutional quality of a country can influence investment in the energy sector. Here we seek to investigate the widely accepted connection between weak institutional quality and the tendency of (severe) crises in the context of energy/electricity.

Third, statistics show that four out of five people without electricity live in rural areas of the developing world, mainly in South Asia and sub-Saharan Africa. Table 3 presents some aggregate data on rural population in different regions. Even though, as a proportion of the world's population, the share of unelectrified people has fallen from

Figure 2 Electrification Rate and Rural Population, selected SSA countries



Source: WDI 2008, 2009

51 percent in 1970 to 22 percent in 2008 (EIA), the number of people without electricity worldwide is still 1.46 billion, 99 percent of which live in developing countries (EIA). About 80% of the unelectrified population in developing countries live in rural areas. Figure 2 shows the relationship between electrification rate and the size of the rural population in selected SSA countries.

Finally, a glance at Figure 1 reveals that the lack of electricity is strongly correlated to the number of people living below $2 per day. Since more than 80 percent of people without access to electricity are located in South Asia and sub-Saharan Africa, among the poorest regions in the world, it is safe to assume that there is a strong correlation between the lack of electricity and the number of people living below $2 per day (IEA, 2002) (See Figure 1). Income, however, is not the only determinant of electricity access and it is the aim of our study to identify the major determinants and potential differences in their relative importance between different regions. In other words, after accounting for other relevant factors, is there still a significant unaccounted for regional difference in the pattern of electricity access? This question is based on the observation that developing countries from other regions tend to outperform SSA countries in the energy/power sector. By analysing differences among regions in terms of underlying factors, we seek to better understand why only a relative low share of SSA countries' populations have access to electricity.

From the literature review and the stylized facts presented in this chapter we have put together a reasonable theoretical framework on which our model is based. We divide the postulated determinants of electricity access into three major groups: (1) availability of funds, (2) characteristics of the population, and (3) institutional quality. Group (1) contains indicators of savings, GDP per capita and poverty. These three variables give us an indication of the potential ability of a country to invest in the energy sector: the lower the percentage of poor and the higher the annual economic output, the higher the potential share that can be channelled towards savings and the more finance available for investment in the energy sector. This suggests a positive relationship. Group (2) is made up of population growth, the share of rural population as well as population density. These three indicators are meant to give us an idea of the prevailing level of difficulties associated with providing electricity access to the population. The rate at which electricity access is being scaled up should ideally keep pace with population growth rates. Therefore, fast growing populations make it difficult to even keep electrification levels constant, let alone improve them. This explains why some countries end up having lower electrification levels than in preceding years. Furthermore, it is technically and financially inefficient to connect remote rural households to the national grid, which suggests a negative relationship between electrification levels and the size of the rural population in a country. The same principle applies to the density of a population: the cost of extending networks is raised by a low population density, thus a higher population density facilitates the provision of electricity access. This suggests a positive relationship. Finally, the regulatory quality index of a country indicates the quality of the institutions in place, the effectiveness of government as well of the respect of prevailing rules and the law. These factors all have an enormous influence on the risk dimension of investments, on how efficiently funds can be allocated as well as on the productivity of investments. This suggests a positive relationship.

We propose to explore cross-sectional data of 53 developing countries from different regions[3] to answer the following questions: (i) What factors might explain differences in levels of energy poverty across developing countries and are these factors equally relevant to EP in SSA? (ii) How relevant is institutional quality in explaining levels of EP across developing countries? And, (iii) based on our analysis, what policy options lead to improved energy services in SSA countries in particular?

The analysis in the following chapter is an attempt to test the validity of our theory and comes up with interesting results, which will be discussed in the final chapter.

[3] See Annex C for a detailed list of countries included in the dataset.

II. METHODOLOGY

We identify factors that determine the different levels of electricity access based on the analysis of the factors underlying electricity poverty in developing countries. The dependent variable is the percentage of population with access to electricity. Our choice of independent variables was constrained by data availability. For instance, data on important factors such as *domestic investment* or indicators for *reforms in the electricity sector* are not readily available for most developing countries, especially for countries in SSA. Therefore we are unable to test the impact of important factors, such as the finance gap and structures of the electricity sector on access to electricity. Furthermore, the often poor availability of data, particularly in many SSA countries, severely constrains the number of observations in our regressions.

A. RESEARCH DESIGN

Let *ACCESS* denote the percentage of population with access to electricity and consider the following function as our basic model to explain electricity access in terms of the following factors:

$$ACCESS = f(POV, GDP, SAVE, RURAL, DENSITY, POPULATIONGROWTH, REGQUAL)$$

where *POV* is the percentage of population living below $2 a day, *GDP* is Gross Domestic Product per capita, *SAVE* is Gross Domestic Saving as a percentage of GDP, *RURAL* is the percentage of rural population, *DENSITY* is the number of people per square kilometre, *POPULATIONGROWTH* is the annual population growth rate and *REGQUAL* stands for regulatory quality. Our theoretical framework does not suggest any particular functional form.

We use OLS for all estimations with cross sectional data for 53 developing countries from three regions (Sub-Saharan Africa, East Asia and the Pacific and Central America and the Caribbean) in order to examine the extent to which these variables are able to explain the variation in electricity access for our sample. In addition, we employ interaction terms and a regional dummy variable in order to capture potential regional differences in terms of determinants of electricity access. Since we are interested in testing whether there is any difference between regions, we must allow for a model where the intercept and all slopes can be different across regional groups. However, before we embark on the empirical analysis we first take a closer look at the data involved.

B. DATA AND VARIABLES

(1) Description of Explanatory Variables

Poverty (POV) - we use the percentage of population living below $2 a day as a measure of poverty in a country. On account of data difficulties the variable *POV* is based on data from different years (ranging from the 1985 to 2005) for different countries. Since poverty levels are not likely to change significantly in the short run it is not expected to drastically distort our results. Our assumption: the poorer the population, the lesser the percentage of people with access to electricity. Population below $2 a day is defined as the percentage of the population living on less than $2.15 a day at 1993 international prices (World Bank, 2008a).

Gross Domestic Product per Capita (*GDP*) *[averaged over the period 2000-2006]* – Gross Domestic Product divided by midyear population (World Bank, 2008a).

Savings (SAVE) [averaged over the period 2000-2006] - Gross Domestic Savings as a percentage of GDP are calculated as GDP less total consumption (World Bank, 2008a). Since the majority of energy projects are financed by domestic savings, electricity access and domestic savings are expected to be positively related.

Rural Population (RURAL) [averaged over the period 2000-2006] – Percentage of rural population is calculated as the difference between the total population and the urban population (World Bank, 2008a). Due to the difficulties associated with supplying the rural areas with grid electricity (discussed in Chapter 2) and given that 4 out 5 of people without electricity live in rural areas, we have sufficient reason to assume that the larger the percentage of rural population, the larger the percentage of people without access to electricity.

Population Growth (POPULATIONGROWTH) [averaged over the period 2000-2006] – measures the annual population growth rate of a population (World Bank, 2008a). We anticipate a negative relationship between population growth and electrification level.

Table 4 Summary Statistics for the Full Sample

	Mean	Max	Min	Standard Deviation
Access to Electricity (%)	57.93	100.00	9.00	32.63
Population living below $2 a day %)	49695	92.40	5.60	24.57
Regulatory Quality	-0.38	0.74	-2.29	1.76
Rural Population (%)	53.13	88.30	0.00	22.68
Gross Domestic Savings (% GDP)	17.31	55.70	-38.10	17.31
GDP per capita	2320.56	24103	85	3952.20
Population growth (%)	1.84	4.00	0	0.84
Population Density (mllions/sqkm)	212.54	6204	2	786.00

Population Density (DENSITY) [averaged over the period 2000-2006] - is midyear population divided by land area in square kilometres (World Bank, 2008a), which suggested to be inversely related to electricity access levels.

Regulatory Quality (REGQUAL)[2006 data] – measuring perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development (World Bank, 2008b). Institutional quality is expected to affect the percentage of population with electricity access in a country positively.

Table 5 Differences between Sub-Saharan Africa and Other Developing Countries (Mean of Selected Variables)

	SSA	Non-SSA
Access to Electricity	30.80	77.93
Population living below $2 a day	65.58	40.81
Regulatory Quality	-0.58	-0.23
Rural Population	62.01	46.22
Gross Domestic Savings (% GDP)	14.27	19.61
GDP per capita	944.36	4933.30

Table 6 Correlation Matrix

	ACCESS	*POV*	*RURAL*	*GDP*	*SAVE*	*REGQUAL*	*DENSITY*	*POPGROWTH*
ACCESS	1.000							
POV	-0.777	1.000						
RURAL	-0.664	0.661	1.000					
GDP	0.832	-0.827	-0.701	1.000				
SAVE	0.471	-0.289	-0.286	0.505	1.000			
REGQUAL	0.377	-0.520	-0.225	0.543	0.274	1.000		
DENSITY	0.081	0.167	0.372	-0.185	-0.116	-0.044	1.000	
POPGROWTH	-0.629	0.460	0.312	-0.636	-0.334	-0.283	0.040	1.000

(2) Description of the Data

As mentioned before, most of our data was obtained from the World Bank's *World Development Indicators*. Table 4 presents summary statistics of the full sample, the mean selected variables for SSA and non-SSA countries are compared in Table 5 , while Table 6 reports the correlation matrix of our main variables. Our dataset confirms that SSA countries are, on average, performing worse than developing countries from other regions. According to our sample, SSA countries' level of electricity access is less than half of what non-SSA countries enjoy. Additionally, the percentage of population living on less than 2$ a day and the relative size of the rural population is, on average, higher in SSA countries, while their average annual saving rates are lower than in non-SSA countries.

III. RESULTS AND ROBUSTNESS CHECKS

A. EMPIRICAL RESULTS

We begin our analysis by determining variables that are relevant in explaining the variation in electricity access. Results from cross-country regressions are reported in Table 7, columns (1)-(5). They indicate that a large share (roughly 90 percent) of the variation in *ACCESS* can be explained by a relatively small number of factors: it is a positive function of *GDP, SAVE,* and *DENSITY* and is inversely related to *POV, RURAL, REGQUAL* and *POPULATION GROWTH*. In general, the results are consistent with the dynamics of factors influencing electricity access discussed in Chapter 3.

The coefficients on *SAVE, POV* and *RURAL* as well as *DENSITY* and *POPULATION GROWTH* always appear statistically significant, each of them having the expected sign. Interestingly, the regional dummy variable (*SSA*) is negative and statistically significant. R^2 increases notably with *SSA*, indicating the importance of the regional effect. The coefficient of the Africa dummy is interesting because it measures the average difference of *ACCESS* between SSA and non-SSA countries with same levels of *GDP, SAVE, REGQUAL, POV,* DENSITY, POPULATION GROWTH and *RURAL,* suggesting the existence of an unaccounted for "Africa" effect. *GDP* appears statistically significant in the specifications of columns (1) and (2), however adding the variables describing the characteristics of the population renders its coefficient insignificant, which is why we decided to drop it in the specifications of columns (4) and (5).

We next test whether the impact of poverty, percentage of rural population and savings rates on electricity access is the same for SSA and non-SSA countries. To find this out, we interact each variable with the SSA dummy. The regression results are reported in column (5). Except for *RURAL*, all variables remain significant, which indicates their importance in explaining different levels of electricity access across non-SSA countries. Interestingly, the dummy alone no longer appears statistically significant as we add these interaction terms, implying that the specification (5) has left no space for the mere fact of being a SSA country to explain the variation of electrification levels across developing countries. Table 8 reports the estimated partial coefficients of *POV*, *RURAL* and *SAVE* for SSA and non-SSA countries. The table shows that, except for RURAL, which only

Table 7 OLS Regression of Access to Electricity (Dependent Variable is *Access to Electricity (% of Total Population)*, 2000.

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Intercept	*23.19* *(24.04)*	*17.59* *(23.39)*	*63.64** *(31.70)*	*98.47**** *(7.43)*	*99.21**** *(5.92)*
POV	*-0.33*** *(0.12)*	*-0.35*** *(0.13)*	*-0.37**** *(0.12)*	*-0.43**** *(0.12)*	*-0.57**** *(0.12)*
GDP	*8.74**** *(2.87)*	*9.51**** *(2.84)*	*3.91* *(3.51)*		
SAVE	*0.32** *(0.18)*	*0.33** *(0.18)*	*0.39*** *(0.15)*	*0.45**** *(0.13)*	*0.49*** *(0.20)*
SSA	*-29.82**** *(5.09)*	*-29.17**** *(4.98)*	*-21.04**** *(6.00)*	*-21.10**** *(5.94)*	*18.56* *(24.66)*
REGQUAL		*-4.12* *(3.14)*	*-2.23* *(3.29)*	*-1.10* *(2.98)*	
RURAL			*-0.34*** *(0.15)*	*-0.39**** *(0.12)*	*-0.12* *(0.12)*
DENSITY			*4.35*** *(1.61)*	*4.41**** *(1.54)*	
POPULATION GROWTH			*-5.59** *(2.81)*	*-7.02**** *(2.32)*	
SSA×POV					*0.40** *(0.21)*
SSA×RURAL					*-1.03**** *(0.30)*
SSA×SAVE					*-0.61*** *(0.28)*
Observations	*52*	*52*	*51*	*51*	*52*
R^2	*0.8677*	*0.8715*	*0.9024*	*0.8998*	*0.8940*

Notes: All regressions are estimated by OLS with White's correction of heteroskedasticity. Standard errors are in parentheses denoting ***1%, **5% and *10% significance.

appears significant for countries in the SSA region, the variables have a significant impact in both SSA and non-SSA countries. The significance of the coefficients follows from the fact that we can reject the hypothesis that the sum of the coefficients for *POV* and *POV*SSA* is equal to zero (same applies to *RURAL* and *SAVE* and their respective interaction terms). The results indicate that the marginal impact of the proportion of

Table 8 Partial Effect of Selected Variables

Variable	**SSA**	**Non-SSA**
POV	-0.171*** (0.002)	-0.567*** (0.000)
RURAL	-1.151** (0.015)	-0.117 (0.315)
SAVE	-0.124** (0.018)	18.56** (0.019)

Significant at the ***1% and **5% level, *P*-values in parentheses.
The null hypothesis that *ACCESS* follows the same model for SSA and Non-SSA countries is stated as $H_0 = \beta_{SSA} = \beta_{SSA\times POV} = \beta_{SSA\times RURAL} = \beta_{SSA\times SAVE} = 0$. We soundly reject this null with an *F* statistic of 25.52 and a *p*-value of 0.0000.

population living in rural areas is much stronger in SSA than in non-SSA countries. On the other hand, the sign of the marginal benefit from increased domestic savings appears to be different for the two regional groups. Specifically, a 1 percent increase in savings leads to a 0.489 percent increase in electricity access for a non-SSA country, compared to a 0.124 percent *decrease* for an equivalent country in SSA. Finally, the coefficients for *POV*, reflect the intuitive relationship between poverty and electricity access in both cases. In other words, a large number of people living below $2 a day seems to have a stronger impact on electrification levels in non-SSA countries than in the SSA region. All results reported in Table 2 are significant at least at the 5 percent level.

As discussed earlier, the measures of *POV* and *RURAL* are on average higher in SSA countries, while the measure of *SAVE* is on average much lower, compared to non-SSA countries. We therefore consider the possibility that the differential impact of these variables can actually be explained by a "threshold" effect rather than a "regional" effect. This hypothesis is tested by adding quadratic terms of the three variables. Their estimated coefficients, however, are not statistically significant, suggesting that there is no second-order effect (results not reported).

Inspecting the performance of *REGQUAL*, we observe that its coefficient is statistically insignificant (columns (2), (3) and (4)) and appears with the 'wrong' sign. In addition, R^2 remains nearly unchanged when adding/removing *REGQUAL*. Table 7 takes a closer look at changes in terms of significance and sign of its coefficient when combined with different variables in a regression. We discover that *REGQUAL* appears statistically significant only in combination with *RURAL* and/or *SAVE*. However, when run alongside *POV* and/or *GDP* it loses its significance. In other words, when *POV* or *GDP* are being accounted for in the model, *REGQUAL* does not add value in explaining variations in the data on the variable *ACCESS*. The coefficients reported in Table 7 are those of the z-scores of the variables in question, thus allowing us to measure effects in standard deviation units, instead of the original units of the various variables. This makes the scale of the regressors irrelevant, since this equation puts the explanatory variables on equal footing. Thus, merely comparing the magnitudes of coefficients allows us to conclude that the largest coefficient is "the most important". For example, looking at column (2), we can see that if *RURAL* increases by one standard deviation, then *ACCESS* changes by -0.488 standard deviations, while it increases by 0.383 standard deviations if *REGQUAL* increases by one standard deviation. Consequently the

Table 9 Significance of Regulatory Quality (OLS Regression of Electricity Access)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Intercept	*0.128* *(0.085)*	*-0.004* *(0.092)*	*0.039* *(0.078)*	*-0.001* *(0.105)*	*-0.003* *(0.093)*
POV	*-0.770**** *(0.093)*				
RURAL		*-0.488**** *(0.125)*			*-0.468**** *(0.123)*
GDP			*0.834**** *(0.101)*		
SAVE				*0.238** *(0.128)*	*0.057* *(0.128)*
REGQUAL	*-0.062* *(0.11)*	*0.383**** *(0.117)*	*-0.045* *(0.102)*	*0.438**** *(0.112)*	*0.364**** *(0.121)*
Observations	*53*	*64*	*63*	*65*	*64*
R^2	*0.6027*	*0.4825*	*0.6435*	*0.3158*	*0.4848*

Notes: All regressions are estimated by OLS with White's correction of heteroskedasticity. Standard errors are in parentheses denoting ***1%, **5% and *10% significance.

percentage of rural population has greater explanatory power than regulatory quality for the variation of electrification levels across countries. Apart from not even appearing statistically significant, the β-coefficients on *REGQUAL* are very small in columns (1) and (3). However they appear more important in columns (2), (4) and (5), where they are also statistically significant. We conclude that regulatory quality is important in explaining variations in *ACCESS* only in isolation with *RURAL* and/or *SAVE*.

B. DISCUSSION OF RESULTS

(i) There is a regional difference in the effect of percentage of poverty, rural population and saving rates on electricity access.

The effect of *RURAL* seems to be dampened in developing countries outside the SSA region. In other words, the effect of rural population on the national electrification level is stronger in SSA countries. This implies that, ceteris paribus, remote, rural areas in other developing regions enjoy on average higher electrification rates than those in SSA. This result could be explained by government's different approaches, towards appropriate reforms in the electricity sector. To be more specific, we could interpret this result as that governments in SSA are less dedicated to putting in place adequate off-grid solutions that would give the mainly poor, rural population increased access to electricity. This interpretation stems from, amongst others, a study by GNESD (Global Network on Energy for Sustainable Development, UNEP). It provides empirical evidence suggesting that when implementing reforms, governments have hardly shown any devotion to increased electricity access to the poor, and that without such devotion, reforms have rather been detrimental to the poor than beneficial. According to case studies (GNESD, 2004), reforms have had damaging effects on electricity access to the poor in parts of East and West Africa, amongst others. The reason given for very low electrification in Western Africa, for instance, is that the objectives of the reforms were clearly related to technical (improvement of the quality of electricity, restoration and extension of the grid, etc.), financial or management aspects of the sector. Little attention was paid to the expansion of services to low-income and rural groups. On the contrary, countries like China, Thailand, Bangladesh and Vietnam have been more successful in increasing electrification levels and electricity consumption thanks mainly to their efforts in extending grid connections and various tariff reforms in the poorest areas of their countries. The main conclusion is that it is inappropriate to introduce market-led reforms into countries with a large proportion of the market consisting of very poor people living in mostly rural areas. This is mainly due to the fact that they put the financial health of electricity utilities first rather than targeting rural areas in particular.

The importance of institutional quality and government's willingness can equally be linked to the result showing that the impact of *SAVE* is positive in non-SSA and negative in SSA countries. Specifically, with the same level of savings, SSA countries have on average less access to electricity than non-SSA countries. It follows that non-SSA countries are more willing (able?) to channel their savings, which make up the bulk of finance in the electricity sector, towards the improvement of electricity access.

Interestingly, our results suggest that the level of poverty in the population has comparatively less impact on electrification levels in SSA countries. This outcome is probably a reflection of the overall failure by SSA countries' governments to scale up electricity access. According to our results, the number of people living below $2 a day plays a less determining role in explaining electrification levels among SSA countries, which strongly points towards particularly weak institutional settings, which, nearly independent from the poverty level, have adverse impacts on the power sector. We discuss the importance of the institutional framework in more detail in the following.

(ii) Importance of Institutional Quality in the Electricity Sector.

Our results show that *REGQUAL* appears significant only in combination with *SAVE* and/or *RURAL*. As mentioned above, poverty as well as GDP levels are assumed to incorporate the level of institutional quality in a country. The ability and willingness of a government to promote private sector development is generally reflected in a healthier social and economic environment with lower levels of poverty and higher GDP levels. This is in line with our results, suggesting that at fixed levels of GDP/poverty, the quality of institutions in place does not play any role in explaining variations in the access of electricity across countries.

However, at fixed levels of rural population and savings, it does remain statistically significant. This is in accordance with our previous result, implying that having controlled only for savings, there is still room for institutional quality to make a positive impact on electricity access. Same applies to the percentage of rural population. If only the percentage of rural population and/or saving rates are taken into account, the government's influence plays a decisive role in determining the level of electrification in a country. At given levels of poverty/GDP, however, there is a limitation to the impact government's power can have on the rate of access to electricity.

Nevertheless, we identify the government's willingness to put in effect appropriate reforms in the electricity sector and/or provide the necessary funding for it to be crucial aspects of the electrification process. Both can be regarded as weaknesses of the institutional framework, which should be accepted as being a main determinant of electricity access. This is because, whether or not energy projects can be financed lies, to a great extent, in the hands of governments, even if they play no direct role in the financing. This is due to the fact that they set out the conditions which determine the magnitude of economic, political and legal risks[4]. Less well-developed institutional and organisational structures lead to greater risks when investing in energy projects in developing countries compared to OECD countries. Unclear and non-transparent energy, legal and regulatory frameworks as well as poorer economic and political management are examples of such structures.

[4] See Annex: Table ii: Risks in Energy Investment.

IV. CONCLUSION AND POLICY IMPLICATIONS

This paper has analyzed the determinants of electricity access in developing countries and, particularly, examined why sub-Saharan Africa has been relatively unsuccessful in providing electricity to its population, despite reforms in the electricity sector. The results indicate that the factors underlying electricity access in developing countries have a different impact in sub-Saharan Africa. Specifically, the marginal benefit from increased gross domestic savings is less in SSA – suggesting that a higher savings rate will lead to higher levels of electrification in non-SSA than SSA countries. We equally find that the percentage of rural population in a country is another important factor underlying electricity access in developing countries, though our results suggest that it plays a more important role in SSA countries than in non-SSA developing countries. This entails that a SSA country will, on average, have a lower level of electrification, than a non-SSA counterpart with the same percentage of rural population, whose remote location makes it difficult to provide access to the national grid. Finally we identify the percentage of the population living below $2 a day as another important factor determining the level of electricity access, since, electricity access is generally a function of income. However, this factor appears less significant in SSA countries.

Our results strongly point towards the importance of the institutional quality, in the sense that

(i) government has the power to channel an adequate portion of savings in the electricity sector;

(ii) government has the power to guide reforms towards targeting marginalised customers – the rural, mainly poor, population.

As far as policy implications are concerned, our results inspire a few suggestions.

First, the importance of renewable energy technologies cannot be overemphasized. Energy from solar, wind and micro-hydropower technologies is an attractive option, particularly in SSA countries, which are richly endowed with the necessary resources. Most attempts to expand the existing grid networks are inappropriate for the vast majority of people in SSA, in particular for those living in rural areas. Therefore, decentralised electricity generation using clean, renewable energy systems is perceived to be one of the most suitable solutions to meet Africa's rural electrification needs.

Nevertheless, many of these technologies that are theoretically best suited for the provision of energy services to those areas have high initial capital costs as well as maintenance and replacement costs. In addition, the diffusion of information on renewable energy sources is a necessary condition for the success of their installation, since populations without electricity are scattered in very remote areas where information on such systems are not available. For these reasons, governments are advised to introduce policy reforms to make capital resources more readily available for small-scale rural energy investments so that the barriers of lack of information as well as high initial capital costs for such systems could be more easily overcome. This would help make renewable energy affordable to small rural consumers.

Second, it is thus essential to encourage the mobilization of the necessary capital to make available adequate finance, which is one of the main challenges developing countries are facing in meeting their current and future energy demand. Apart from governments, current sources of energy finance in developing countries include multilateral institutions, ODA as well as private investors (Postnote, 2002). The public sector alone will hardly be able to meet up with the finance requirements to satisfy growing energy demands, consequently the responsibility to ensure adequate energy supplies lies to a large extent with the private sector. However, clearly, it has proven difficult to secure the amount of investment needed, which can be attributed not only to various barriers faced by private as well as foreign investors in many developing countries but also to the common association of relatively low rates of return with energy investments. African countries in particular are perceived to be overly risky, which is one of the greatest hindrances to investment in African countries. Thus, governments should encourage domestic resource mobilization as well as improve negative perceptions about their countries by highlighting positive aspects.

Finally, we wish to stress, once again, the importance of effective reforms. Prior to reforms, the electricity sector in developing countries was typically owned, operated and regulated by the government. In recent years, however, this model has been challenged in most countries and has been most commonly replaced by a market-led model, involving measures from the unbundling of utilities (separating their different functions) to complete private ownership. This was to enable countries to keep up with the financial pressure of the new generating capacity resulting from economic growth and the ensuing increased energy demand (GNESD, 2004). However, this privatisation of the power sector has had detrimental consequences to the poor due to the government's lack of commitment to improving the mostly poor, rural population's access to electricity. Studies have shown that the one thing those countries, that have been successful in improving electrification levels for their marginalized citizens have in common is their focus on rural electrification (GNESD, 2004). Therefore countries whose reforms have not yet developed to an advanced stage are advised to make provision for increased rural electrification before embarking on large scale privatisation.

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ANNEX A

Table I Risks in Energy Investment

	Type of risk	**Examples**
Economic risk	Market risk	• Inadequate price and/or demand to cover investment and production costs • Increase in input cost
	Construction risk	• Cost overruns • Project completion delays
	Operation risk	• Insufficient reserves • Unsatisfactory plant performance • Lack of capacity of operating entities • Cost in inflation and interest rates
	Macroeconomic risk	• Abrupt depreciation or appreciation of exchange rates • Changes in inflation and interest rates
Political risk	Regulatory risk	• Changes in price controls and environmental obligations • Cumbersome administrative procedures
	Transfer-of-profit risk	• Foreign exchange convertibility • Restrictions on transferring funds
	Expropriation/nationalisation risk	• Changing title of ownership of the assets
Legal risk	Documentation/contract risk	• Terms and validity of contracts, such as purchase/supply, credit facilities, lending agreements and security/collateral agreements
	Jurisdictional risk	• Choice of jurisdiction • Enforcement risk • Lack of a dispute-settlement mechanism
Force majeure risk		• Natural disaster • Civil unrest/war • Strikes

Source: World Energy Investment Outlook 2003, p. 67, *International Energy Agency*.

ANNEX B

Table II Linking Development to Electricity

MDG Targets	Benefits from modern energy services
Goal 1: Eradicate extreme poverty and hunger	• Energy for local enterprises, lighting to facilitate income generation, employment opportunities.
Goal 2: Achieve universal primary education	• Reduce time spent by children on energy provision, lighting for reading, energy for educational media.
Goal 3: Promote gender equality and empowerment of women	• Modern energy services free girl's and women's time spent on energy provision.
Goal 4: Reduce child mortality	• Energy supply for health clinics, reduced air pollution from traditional fuels.
Goal 5: Improved maternal health	• Energy supply for health clinics, reduced air pollution from traditional fuels.
Goal 6: Combat HIV/AIDS, Malaria and other diseases	• Energy supply for health clinics, cooling of vaccines and medicines.
Goal 7: Ensure environmental sustainability	• Afforestation/reforestation, substitution of non-renewal biomass, waste management.

Source: Matazum M.B. (2008).

ANNEX C

Table III Countries Grouped by Region*

South East Asia & Pacific (12)	Central America & Caribbean (20)	Sub-Saharan Africa (21)
Bangladesh	Argentina	Angola
Cambodia	Bolivia	Benin
China	Brazil	Botswana
India	Chile	Burkina Faso
Indonesia	Columbia	Cameroon
Iran	Costa Rica	Côte d'Ivoire
Nepal	Dominican Republic	Ethiopia
Pakistan	Ecuador	Ghana
Philippines	El Salvador	Kenya
Sri Lanka	Guatemala	Lesotho
Thailand	Haiti	Madagascar
Vietnam	Honduras	Malawi
	Jamaica	Malaysia
	Nicaragua	Mozambique
	Panama	Namibia
	Paraguay	Nigeria
	Peru	Senegal
	Trinidad and Tobago	South Africa
	Uruguay	Tanzania
	Venezuela	Zambia
		Zimbabwe

* Classification according to the Human Development Report 2004, *The World Bank*.