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Evaluation of Energy Security Situation and Related Policies Using Country Comparative Analysis

: Focus on Ghana

에너지 안보와 국가별 비교분석을 통한 에너지 안보 정책에 대한 평가

: 가나 사례를 중심으로

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Graduate School of Seoul National University

College of Engineering

Technology Management, Economics and Policy

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지도교수 김태유

이 논문을 공학석사학위 논문으로 제출함

2014 년 02 월

서울대학교 대학원

협동과정 기술경영경제정책전공

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의 석사학위 논문을 인준함

2014 년 02 월

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찰스 아쿠아 의 석사학위 논문을 인준함

2014 년 02 월

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논문제목: Evaluation of Energy Security Situation and Related Policies Using Country Comparative Analysis: Focus on Ghana

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Acronyms

ASEAN	Association of Southeast Asian Nations
CIA	Central Intelligence Agency
CO_2	Carbon dioxide
EC	Energy Commission of Ghana
EIA	Energy Information Agency
EISD	Energy Indicators for Sustainable Development
EU	European Union
HEP	Hydroelectric power
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
MoEn	Ministry of Energy, Ghana
WB	World Bank
ESMAP	Energy Sector Management Assistance Program
RFO	Residual fuel oil

Abstract

Evaluation of Energy Security Situation and Related Policies Using Country Comparative Analysis

: Focus on Ghana

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The frantic efforts by successive governments to provide adequate supply of energy to facilitate socioeconomic development are yet to yield the expected results. Ghana continues to suffer from electricity supply outages and shortages in petroleum products as well as in crude oil and gas. The reckless exploitation of the forest continues to deplete the forest cover at an alarming rate. Consequently, this study aimed to assess the energy security situation of Ghana, examine the effectiveness of the policies on energy security, and develop policy recommendations therefor.

This study employed the composite energy security index developed by B. K. Sovacool (2011) to compare Ghana's energy security situation with those of

34 other countries — ASEAN, USA, EU, Japan, South Korea, China., India, Oceania, and 17 African countries — over a 20-year period. These metrics were captured under the categories of availability, affordability, technology development and efficiency, environmental sustainability, and regulation and governance. The top five performers were Brunei (273), Japan (260), New Zealand (254), USA (253), and EU (252) while the five worst performers were (from the bottom) Tunisia (123), Libya (124), Algeria (127), Egypt (128), and Morocco (132). Ghana was 17th, with a score of 185. The best-performing African countries were Congo DR (201), Cameroun (201), Angola (200), Tanzania (199), and Zambia (187). Ghana was the sixth best performer amongst the African countries. Also, the study revealed that a time-bound strategic plan, tax relief, and regulatory instruments have a positive influence on energy security.

The second part of the study assessed the performance of Ghana's energy security indicators between 2001 and 2012, the most eventful period in the energy sector of Ghana. The indictors were selected with recourse to the National Energy Policy of Ghana. Ghana had negative trends for oil intensity, non-carbon fuel portfolio, CO_2 emission, CO_2 emission per capita, and energy import. Consequently, to reverse these trends, it is imperative to review the existing policies with recourse to the international best practices.

Keywords: energy security, assessment, sustainable energy policy, Ghana

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Chapter 1 - Introduction

1.1 Energy Security and Socioeconomic Development

Modern energy services are crucial to human well-being and to a country's economic development, and yet globally, over 1.3 billion people do not have access to electricity, and 2.6 billion people do not have clean cooking facilities. More than 95% of these people are either in sub-Saharan Africa or developing Asia, and 84% are in rural areas (IEA, 2013).

The lack of access to modern energy services is a serious hindrance to economic and social development and must be overcome if the UN Millennium Development Goals are to be achieved.

Energy security, defined as the equitable provision of available, affordable, reliable, efficient, environmentally benign, proactively governed, and socially acceptable energy services to the end users, has grown as a salient policy and political issue of late. (Sovacool*, 2011)

The security of supply and the concentration of energy fuels among countries, the peak oil theories, the rising prices, and energy poverty, to name a few, have all become prominent concerns among policymakers and investors of late, along with energy security's close relationship with sustainable development and economic growth (Sovacool*, 2011).

1.2 Research Problem and Relevance

Ghana's energy security challenge is to ensure the supply of adequate and reliable modern forms of energy for economic development in an environmentally benign manner. The installed generation capacity available for grid supply at the end of 2012 was 2,296 megawatts (MW) (Energy Commission, Ghana, 2013). This available capacity is inadequate for a population of over 25 million, with an access rate of 72%. The obsolete transmission and distribution infrastructure is also a serious challenge. The total power transmission loss in 2012 was 4.3% of the gross transmission, a 0.4 percentage point improvement over the 2011 figure (Energy Commission, Ghana, 2013).

The 1983/84, 1998, and 2007 erratic rainfall patterns, which rendered the HEP dams ineffective with the subsequent power rationing exercises, support the assertion that climate change is negatively impacting the HEP supply in Ghana (Braimah, 2012). HEP's ineffectiveness is compounded by the increasing demand for electricity resulting from the ever-increasing number of consumers thanks to the aggressive National Electrification Program by the Ministry of Energy (Ministry of Energy, Ghana, 2013).

This inadequate power supply as well as petroleum products supply shortages and are limiting the operations of industries, raising the cost of doing business and limiting investments. These cause dire social and economic problems. Despite the efforts being made by successive governments to progressively improve the energy supply security, the challenges of the energy sector persist.

So far, there has been no comprehensive assessment of the existing energy security indicators in a bid to address the challenges. This study sought to fill this void and also to provide a good lead in terms of the best practices to address these challenges.

1.3 Research Questions and Objectives

Three key questions guided the progress of this study towards the attainment of the study's three objectives. The questions are: (1) What is the energy security situation of the Ghanaian economy?; (2) What are the energy security deficiencies and energy security policy limitations of Ghana?; and (3) Which policies can appropriately address the energy security limitations of Ghana towards long-term economic development? With respect to these three key questions, three objectives were identified: (1) to compare the energy security situation of Ghana with that of 34 other countries over a 20-year period; (2) with recourse to the best practices, make appropriate policy recommendations towards ensuring the requisite energy security for sustainable development; and (3) to identify the deficiencies in the current energy security policies of Ghana, and to make appropriate recommendations to address such deficiencies.

1.4 The Study Area

This chapter focuses on the study area, Ghana, and also takes a closer look at such country's energy situation, with emphasis on electricity. It also reviews the current energy security policy of Ghana.

Figure 1. Ghana (Source: Google maps).

Ghana is located in West Africa and is boarded on the west by Cote d' Ivoire, on the east by Togo, on the north by Burkina Faso, and on the south by Gulf of Guinea. It has a total land area of 238,533 sq. km., of which land is 227,533 sq. km. and water is 11,000 sq. km. The total population is 25 million. Ghana's capital city is Accra, located in the South Coast, near the Prime

Meridian. The 2012 GDP estimate was USD38.94 billion, and the GDP growth rate is 7% (2012 estimate). Also, the inflation rate as of 2012 is 9.2%. Its major exports are cocoa, gold, and recently (since 2010), oil.

Ghana is divided into ten regions. The northern part of the country is largely savanna grassland, and the southern part is forest land.

1.5 Methodology

The selection of the energy security index for the performance measurement was based on a maiden research by Benjamin K. Sovacool in 2011 using 20 indicators. This maiden paper provides the appropriate premise for the definition of energy security as well as for the selection of the appropriate indicators constituting the composite index. Prior to the publication of this paper, no composite indicator had been used to compare the energy security situation of countries due the controversy surrounding the definition and scope of energy security. The composite indicator employed in the maiden study was essentially a consensus on the definition. This is because it was the result of a survey questionnaire administered to 74 energy experts working at 35 institutions in Asia, Europe, and North America. This study scales down the number to 13, with recourse to priority and data availability. Research intensity, though highly rated, was not included in the set of 13 indicators for the composite index due to the data limitation for most of the developing nations. To determine which policies are suitable for sustainable development, the energy security indices of the various countries were regressed against a selected number of sustainable energy policies: a time-bound strategic plan, tax relief, and regulatory instruments (IEA, 2014).

The second part of the research was an evaluation of the energy security situation of Ghana using 16 indicators. These indicators were selected with recourse to the priority areas of Ghana as per the National Energy Policy. Particular emphasis was placed on the transportation and electricity generation sectors because of their importance in the Ghanaian economy (Ghana Statistical Services, 2013).

1.6 Structure and Scope of the Study

The study was divided into two parts. The first part compared the energy security situation of Ghana with those of 34 other countries. Following this was an analysis of the performance of Ghana with those of the top five as well as the top five African countries. This aspect of the study aimed at determining in which metrics of the composite index these countries outperformed Ghana. After that, a selected number of sustainable development policies were regressed against the energy security indices to determine their effect on energy security, using a panel data model. The purpose of this panel data analysis was to determine which policies are worth pursuing to ensure sustainable development.

Phase two used 16 selected energy security indicators (selection based on Ghana's energy security policies) to assess the economy-wide energy security situation in Ghana. The second part of the study took a queue from a research done to assess the energy security situation of Thailand (Martchamadol, 2012). This study focused on the performances of Ghana’s energy security indicators from 2001 to 2012. This period was used because it was arguably the most eventful period in the country’s energy sector because it followed the implementation of major policies (Energy Commission, Ghana, 2013).

Chapter 2 - Literature Review

2.1 Background of Energy Security Issues

The critical role of energy in the development of all economies worldwide has made the issue of energy security a global concern of late. This awareness gained prominence in the wake of the first oil crisis in the 1970s, which catapulted the oil prices. Oil-importing countries were caught off guard and struggled to manage their economies amid these high oil prices. Diverse policies were adopted to ameliorate the situation. The fear of natural gas supply shortages only heightened this apprehension (Bhattacharyya, 2011).

As a result of the low oil prices of the mid-1980s and the focus shift on market reform and restructuring, very little attention was paid to energy security issues until the phenomenon of peak oil and the need to develop the supply capacity to match the growing demand emerged. The sustained high oil prices made the issue of energy security resurface.

2.2 Concept of Energy Security

Energy security is commonly defined as the reliable and adequate supply of energy at reasonable prices (Bielecki, 2002; Bhattacharyya, 2011). Reliable and adequate supply denotes the uninterrupted supply of energy to meet the global demand. Supply adequacy and reliability go beyond external dependency. The internal sources of supply in many countries could be equally challenging. The focus of much of the literature, however, is the external supply because the control over the external supply has a myriad of limitations.

Reasonable price, on the other hand, is more difficult to define because there it has no unanimously accepted benchmark. In economic terms, it would mean the market-clearing price in a competitive market where there is a demand-supply balance. Energy security involves externalities, however, which requires internalization to ensure efficient resource allocation.

The definition of the term *energy security* is related to the priority of the respective users, giving it geopolitical, military, technical, and economic dimensions (Bielecki, 2002; Bhattacharyya, 2011). It also has a time dimension; thus, in the short term, the main concerns are related to the risks of disruption of the existing supplies primarily due to an act of God. The long-term concern is basically the future energy supply risk.

As with most other concepts, it is evolving. Initially, the focus was on oil and oil products, but now, it entails all energies and various types of risks to reliable and adequate supplies (including accidents, terrorist activities, and underinvestment). The geopolitical, internal, and temporal aspects of the issue require a multidimensional-policy approach to deal with the problem.

2.3 Contextual Interpretation of Energy Security Indicators

Most of the social and environmental indicators of energy security are unambiguous pointers of progress. For example, a lower level of ambient concentration of air pollutants in urban areas compared to before is certainly a sign of progress and an indication that the policies in this area most likely contributed to such.

In the case of the economic indicators, the situation is different. For example, an increase in agricultural energy intensity might be because of a higher degree of mechanization or a structural change in agriculture, such as a shift to growing crops that require more energy for growing, harvesting, and processing. In this regard, the changes in the indicator values must be considered in the context of the respective conditions of the country. When analyzed as prescribed, however, they show the effects of policy decisions and are useful for evaluating such decisions and for making future policy decisions.

It is imperative that the analysis and interpretation of energy indicators for sustainable development be performed within the context of each country's energy and sustainable development priorities. Each country has its peculiar conditions; hence, the results from one country should not necessarily be taken as a standard for comparison with another country that has different conditions (IAEA, 2005).

2.4 Priorities and Approaches for Individual Countries

The fact that every country is unique presupposes that each country will have its own approach to EISD and will employ them with respect to its priorities. It is the responsibility of every country to determine which indicators within the recommended EISD core set are relevant to its needs. A country may even develop other indicators to cater to its own special energy supply and demand circumstances. The recommended approach follows this sequence. First, identify the major priority areas, which are usually enshrined in the national energy policy plans and programs. These national plans, however, could constitute a possible point of departure from the initial application of EISD. These vulnerabilities in the national energy structure or the known financial, environmental, or social pressures related to energy can inspire ideas on the critical areas to cover.

Next is to select indicators from the EISD core set that are relevant for addressing these priority areas. New indicators can also be defined and structured if need be. An appropriate monitoring and evaluation regime should then be defined for these indicators. The complied time series data can then be analyzed, and its implications can be deduced. The progress in the priority areas should then be evaluated. The effectiveness of the past and present energy policies can be subsequently assessed. Following this, it will be necessary to consider different policies for the future, as well as their possible effects, using models for different scenarios. This will enable a country to learn the lessons of the past while exploring options for the future.

2.5 Composite Energy Security Indicators for Sustainable Development

As mentioned earlier, energy security is defined as the equitable provision of available, affordable, reliable, efficient, environmentally benign, proactively governed, and socially acceptable energy services to the end users. The definition of energy security has become a salient policy and political issue in most countries of late. The security of supply and the concentration of energy fuels among countries, the oil peak theories, the rising prices, and energy poverty, to name a few, have all become critical issues of concern among policymakers and investors, along with energy security's close relationship with sustainable development and economic growth (Sovacool*, 2011).

These notwithstanding, the variegated nature of energy security vulnerabilities has led to attempts to develop a concise rather than elusive definition of the concept. Consequently, policymakers and experts have struggled to devise the appropriate and acceptable metrics to measure national energy security performance. Proponents of a composite energy security index have argued that measuring energy security using single metrics in isolation, such as energy intensity, the electrification rate, or the electricity consumption per capita, provides an incomplete and possibly misleading assessment. Most of IAEA's energy security indicators for sustainable development point to the fact that most of these indicators do not say much when considered in isolation, suggesting that the results of several indicators have to be deliberated on to provide meaningful and useful information (IAEA, 2005).

In this regard, considerable efforts have been made to create individual indicators for transport, forestry, agriculture, energy efficiency, energy production, environmental sustainability, and energy use, but these have yet to be synthesized into a common usable framework (Sovacool*, 2011).

Furthermore, many studies rely on incomplete or inconsistent definitions of energy security, which focus on technical and economic aspects such as the security of fossil fuel supply or end user prices but not including social and political elements such as stewardship or good governance. In addition, many energy security studies focus only on a particular sector (e.g., industrial energy intensity), an individual country (e.g., USA), or a specific technology (e.g., “nuclear security” or “oil security”). Hitherto, not much effort has been invested into trying to measure, track, or quantify energy security, and few attempts have been made to compare energy security dimensions, or the relative strength and weaknesses of different national approaches to energy security. Presumably, this was due to a lack of consensus on how best to capture these elements. This seeming void was filled with the first attempt by the research on 18 countries (USA, EU, Australia, New Zealand, China, India, Japan, South Korea, Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) using a comprehensive energy security index. Much work went into developing this indicator, which was subsequently used to assess the energy security performance of these selected countries. The whole process was grouped into four phases: (1) conceptualizing energy security; (2) devising metrics to measure it; (2) collecting data; and (4) scoring the results.

2.6 Composite Index Development

In developing this index, 18 countries were selected for analysis. USA and EU were chosen because they are two of the world's most advanced energy producers and consumers; China, India, Japan, and South Korea because they are Asia's four largest energy consumers; the ten ASEAN countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) because these economies are on a fast ascendency; and Australia and New Zealand because they represent a diverse mix of energy importers and exporters and also have close proximity to the ASEAN countries. It was imperative to develop an index that reflects the unique energy security realities of the respective regions stemming from the range of political systems and geographic priorities as well as the levels of governance and energy markets of the different countries. The next steps involved the four-phase process involving, first, breaking down energy security into its constituent parts, then devising an index based on these parts (correlating them with specific metrics), collecting and consolidating data on these metrics into an index, and finally, scoring the performance within the index for 1990-2010.

2.6.1 Conceptualizing Energy Security Components

To find the appropriate definition of energy security, the researchers relied on semi-structured research interviews, a survey instrument, and a workshop with energy experts. The survey gathered responses from energy experts from acclaimed institutions such as International Energy Agency (IEA), U.S. Department of Energy, United Nations Environment Program, Energy Information Administration, World Bank Group, Nuclear Energy Agency, and International Atomic Energy Agency. The survey questions are shown below.

- Which dimensions of energy security are most important?
- What metrics best capture these dimensions?
- How might these metrics be used to create a common index or scorecard to measure the national performance on energy security?

2.6.2 Choosing Metrics and Creating an Energy Security Index

Data were collected from the interviews, survey, and workshop, and the dimensions, components, and metrics of energy security most commonly identified by the respondents were outlined. According to most of the respondents, energy security is almost synonymous with energy sustainability and is constituted by five overlapping dimensions and 20 final metrics.

These 20 metrics in aggregate demonstrate the necessity of having a multidimensional and comprehensive index. To some, the metrics may look disjointed and unrelated to one another or too closely related to energy or environmental sustainability. Nonetheless, each metric is tied to a particular dimension and component of energy security derived from the interviews, survey, and/or workshop. It is also intuitive why one needs a broad set of indicators rather than a few utilized in isolation. Relying on the total primary energy supply per capita by itself, for example, does nothing to measure how efficiently energy is used within a country or how clean or equitably distributed it is. Reserve-to-production ratios by themselves do not account for the global trade issues (think how much coal Indonesia produces that it never uses, or how much oil Singapore refines but does not consume and instead exports globally), self-sufficiency says nothing about how clean or sustainable that sufficiency is, and diversification to renewable energy resources does not say how reliable or intermittent they are or how much that diversification might cost in terms of reduced reliability or increased tariffs for the customers. Furthermore, electricity price volatility and the affordability of petroleum can be tied more to the introduction of new subsidies or to trends in the international markets than to the individual actions within a country; high prices can also be good if they reflect other things, like the inclusion of externalities into energy prices or the cross-subsidization of energy efficiency programs and mandates. A country's electrification rate, in isolation, reveals nothing about the quantity (hours of availability in a day), quality (rated voltage and frequency), or household use of electricity (a light bulb's wide range of end uses). The percentage of households dependent on traditional fuels such as biomass also does not describe how much that fuel costs them in terms of money, time, or debilitating health disorders, and will also differ by latitude, with high-latitude locations needing more fuel for heating. Moreover, high biomass consumption by itself can signify affluence as well as poverty, with larger and wealthier homes using more of it. Electricity is not always a substitute for traditional fuels, with many homes in developing countries, including those in Asia, reliant on both, which is why an index including both biomass and electrification is essential. The research intensity figures for some developing countries may not account for the percentage of revenues lost to graft and corruption, which is also why having a metric associated with corruption (the worldwide governance rating incorporated in this matrix) is necessary. The point is that utilizing these 20 metrics as part of a consolidated index is instrumental in ensuring that as many dimensions and complexities of energy security as possible will be captured (Sovacool*, 2011).

2.6.3 Collecting and Synthesizing Data

In the penultimate phase, data for the 20 metrics were collected for the period 1990-2010 in five-year increments. Data for these metrics were gathered primarily from International Energy Agency, U.S. Energy Information Administration, World Health Organization, World Bank, and United Nations. The data gaps were filled with reliance on academic papers and on the energy ministries of the respective countries.

After the exhaustive data collection exercise, which ended in March 2011, the next step was to make all the 20 metrics in the index unidirectional so that higher values would correspond with better energy security scores (the idea being that this would make it easier to identify common trends). Thus, eight of the metrics — price stability, households dependent on traditional fuels, retail prices, energy intensity, grid inefficiency, per-capita CO_2 and SO_2 emissions, and per-capita energy subsidies — were inverted or transformed (Sovacool*, 2011).

2.6.4 Scoring Country Performance

The final phase of the research focused on scoring country performance among the 20 metrics over the 20-year period. The study avoided measuring performance using some type of abstract or absolute method by adopting a scoring system that is empirical and relative — empirical in that the scores were based on the real-world performances of the countries observed within a particular metric for a given year, and relative in that the best and worst scores for those countries were taken and used to create a range of scoring points. This involved converting all the data points to a score between 0 and 100.

Specifically, a scoring range was created for each metric point for a given year by subtracting the minimum value (the worst performer) from the maximum value (the best performer). The negative values were discarded and converted to zero. The next step was to take each data point and subtract the minimum value from it, and divide it by the range. The result was a score for each country anywhere between 0 and 100. The idea was to avoid scoring based on arbitrary judgments and to instead rely on one based on actual performance.

Due to the sliding and comparative nature of the scoring system, sometimes, the best and worst performances are related not with improvement but with the overall range deterioration in some metrics (Sovacool*, 2011).

2.7 Prioritization of Energy Security Indicators

The study investigated how energy users from government, industry, civil society, and academia perceive energy security challenges (Sovacool*, 2011). It also investigated the influence of demographic characteristics such as perceptions as well as how geography, economic structure, and modes of domestic energy production dictate energy security priorities. The data for the analysis were obtained from the accomplished copies of a four-part survey questionnaire distributed in seven languages (English, Mandarin, Portuguese, Russian, Arabic, German, and Japanese) to 2,167 respondents in Brazil, China, Germany, India, Kazakhstan, Japan, Papua New Guinea, Saudi Arabia, Singapore, and USA. These countries were selected because they represent a mix of urban and rural populations, developed and developing economies, import- and export-oriented energy trading flows, communist and capitalist societies, liberalized and state-owned energy markets, and small and large geographic sizes. The survey results were used to test four propositions about energy security related to the education, age, occupation, and gender of the respondents, as well five propositions about national energy priorities and the interconnected attributes of security of supply, energy efficiency, energy research and development, energy trade, diversification and decentralization, affordability, environmental quality, climate change, and energy governance.

As per Table 1 below, the "ratings" derived from the five-point Likert scale show a convergence of answers ranging from a mean of 4.02 for the decentralization of energy systems at the bottom to a high of 4.72 for preserving the integrity of water supplies.

Table 1: Rating the Importance of the 16 Energy Security Dimensions - Summary of Ratings (n=2167)

Energy Security Dimension	Mean
To provide available and clean water	4.72
To minimize air pollution	4.71
To conduct research and development on new and innovative energy technologies	4.71
To maximize the destruction of forests and the degradation of land and soil	4.66
To reduce greenhouse gas emissions (i.e., migration)	4.58
To have a secure supply of coal, gas, oil and/or uranium	4.50
To minimize the impact of climate change (i.e., adaptation)	4.47
To assure equitable access to energy services to all of its citizens	4.44
To inform the consumers and promote social and community education about energy issues	4.42
To have low energy intensity (unit of energy required per unit of economic output)	4.41
To have stable, predictable, and clear price signals	4.38
To have affordably priced energy services	4.37
To minimize the depletion of the domestically available energy fuels	4.33
To ensure transparency and participation in energy permitting, siting, and decision-making	4.32
To promote trade in energy products, technologies, and exports	4.27
To have small-scale, decentralized energy systems	4.02

Source: Sovacool*, 2011.

This indicates that in aggregate, the respondents rated all the dimensions as falling within the range of important to extremely important. It is also important to note that when asked the final open-ended question at the end of the survey about which dimensions may have been missed, the most dominant response was “renewable energy development,” followed by “reducing consumption.” This presumably places equal importance on both renewable energy and energy efficiency.

2.8 Energy Security Policy Options for Developing Countries

Energy security issues have been the priority of most governments of late. The term, however, has diverse meanings. From the perspective of developing economies, policies to improve energy security essentially focus on the need to secure a low-cost and reliable supply of fossil fuel for electricity generation and transport. For the OECD countries that are increasingly reliant on imported oil, natural gas, and coal, on the other hand, the fundamental objective is how is to diversify these supplies of imported energy in their bid to reduce the risk of shortage.

Although the foregoing is of equal importance to developing countries, energy security is also about meeting the basic needs of the citizenry at the household level, where the consumption per capita and the quality of supply are far lower than in the OECD countries. The energy security policy options for developing countries should therefore have a connection between the national and household levels. The key policy recommendations should focus on the need to expand the supply of renewable energy with simultaneous efforts being made to manage the demand growth through energy efficiency measures (GNESD, UNEP, 2010).

To improve energy security, it is essential to consider policies that reduce the risks from both the supply and demand sides. Towards this end, the governments of developing countries are advised to diversify their sources of imported energy while seeking to reduce their reliance on imported energy (especially oil) over the longer term. On the demand side, policies aimed at increasing energy efficiency are often the easiest and lowest-cost means to achieve greater energy security. This is particularly the case in countries with diminishing marginal reserve capacities in the electricity generation sectors, where short-term demand-side management is often quicker and cheaper than building new supply capacity (GNESD, UNEP, 2010).

In countries that have high net energy imports, there is a greater need and justification for expanding the role of the domestic renewable energy sources. The barriers to expanding the supply of renewable energy are often the same across countries, principally a lack of financial subsidization or incentives and limited access to appropriate technologies. To encourage large-scale and sustained private investment in renewable energy, a combination of R&D-push and demand-pull measures is crucial to achieve cost competitiveness.

Examples from the GNESD country studies show that it is necessary for governments to establish dedicated and authorized agencies responsible for promoting, initiating, and financing renewable energy projects and programs. Clearly set government targets are fundamental in giving confidence to private investors seeking to develop renewable energy projects. The success of the Brazilian biofuel program was mainly due to the clear and consistent policies and targets as well as the government subsidies set at an early stage.

2.9 Panel Data Models

The panel data model provides information on individual behavior, both across individuals and over time; thus, they have both cross-sectional and time series dimensions. The variable is therefore represented by x_{it}, where i represents the individual and t represents the time dimension.

The panel data include the number of individuals (N) observed at T regular time periods. The variation for the dependent variables and regressors included the following: overall variation or variation over time and individuals; between variation or variation between individuals; and within variation or variation within individuals (over time) (Katchova, 2014).

The pooled OLS model specifies the constant coefficients, the usual assumptions for cross-sectional analysis. Here,

$$y_{it} = \alpha + \acute{x}_{it}\beta + u_{it}.$$

This model is the most restrictive of the panel data models and hence is not used much in the literature.

The individual specific-effects model assumes that there is unobserved heterogeneity across the individuals captured by α_i. The next step is to determine whether the individual specific effects α_i are correlated with the regressors. If they are correlated, it is a fixed effects model, and if they are not correlated, it is random effects model.

The fixed effects model allows the individual specific effects α_i to be correlated with the regressors (x). Here, α_i is included as intercepts. Each individual has a different intercept term and the same slope parameters.

$$y_{it} = \alpha_i + x'_{it}\,\beta + u_{it}$$

The individual specific effects can be recovered after estimation as follows:

$$\hat{\alpha}_i = \bar{y}_i - \bar{x}'_i\,\hat{\beta}\,.$$

Put in a different way, the individual specific effects are the leftover variation in the dependent variable that cannot be explained by the regressors.

The random effects model, on the other hand, assumes that the individual specific effects α_i are distributed independently of the regressors. Here, α_i is included in the error term. Each individual has the same slope parameters and a composite error term ($\varepsilon_{it} = \alpha_i + e_{it}$).

$$y_{it} = x'_{it}\beta + (\alpha_i + e_{it})$$

Here, $var(\varepsilon_{it}) = \sigma_\alpha^2 + \sigma_e^2$ and $cov(\varepsilon_{it}, \varepsilon_{is}) = \sigma_\alpha^2$.

Therefore, $\rho_\varepsilon = cov(\varepsilon_{it}, \varepsilon_{is}) = \sigma_\alpha^2/(\sigma_\alpha^2 + \sigma_e^2)$.

Rho is the interclass correlation of the error and is defined as the fraction of the variance in the error due to the individual specific effects. It approaches 1 if the individual effects dominate the idiosyncratic error (Katchova, 2014).

Chapter 3 - Energy Situation and Policy of Ghana

3.1 Energy Situation of Ghana

Figure 2 below shows the trends of the population, GDP, and TPES in Ghana from 2001 to 2012. These figures give a good impression of how these important factors have changed over this period, especially against the backdrop of the unprecedented developments that took place prior to and during this period, making such period very important and historical in the energy sector of Ghana.

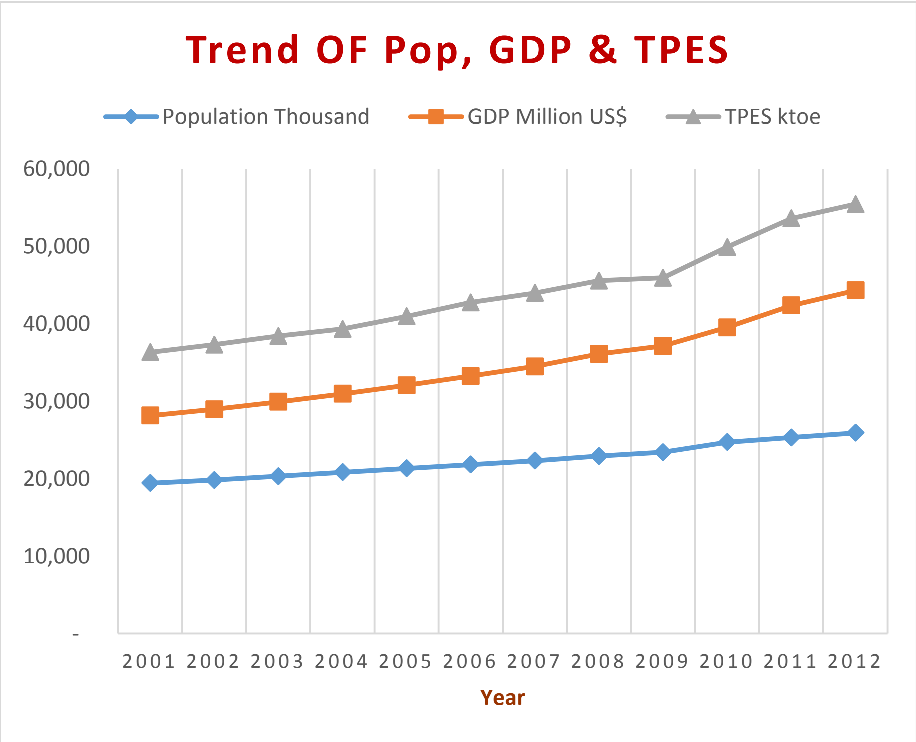

Figure 2 Source: Author's own elaboration using data from IEA and World Bank

These policy initiatives include but are not limited to the following:

- the establishment of the Energy Commission of Ghana on December 31, 1997 and the Public Utilities Regulatory Commission on October 16, 1997 to regulate and oversee the provision of utility services by public utilities to the consumers, and to provide for related matters;
- the development of the Strategic National Energy Plan in 2005 and the National Energy Policy and Strategy in 2009, and the diversification of the generation mix to include light crude oil in 1997, diesel in 2007, and gas in 2010;
- the commencement of the power sector reforms in 1997;
- the commencement of the deregulation of the petroleum sector in 1996; and
- the discovery of commercial quantities of oil and gas in Ghana in July 2007.

Figure 2 shows that the trends of the changes in the three factors (population, GDP, and TPES) have been fairly coordinated over the period, which was expected. This notwithstanding, the TPES of about 11,129 ktoe for a population of over 25 million is woefully inadequate for economic and social development. It is also important to note the composition of the TPES. Strong social and economic development thrives when there are modern forms of reliable and adequate energy supply. Despite the steady increase in TPES, the changes in composition to include the requisite quantities of modern forms of energy have not been very impressive.

As shown in Figure 3, the TPES consisted of wood fuel, oil, and hydropower until 2009, where gas was included in the energy supply mix. Wood fuel continues to be the most dominant source of fuel supply, as indicated in Figure 3.

As can be seen in Figure 4, the percentage of wood fuel in the TPES changed from 77 to 55% in 2012, raising a number of social, economic, and environmental concerns.

The electricity supply situation in Ghana somewhat evolved over the past decade from and near total reliance on hydropower to a mix that now includes diesel, gas, and light crude oil.

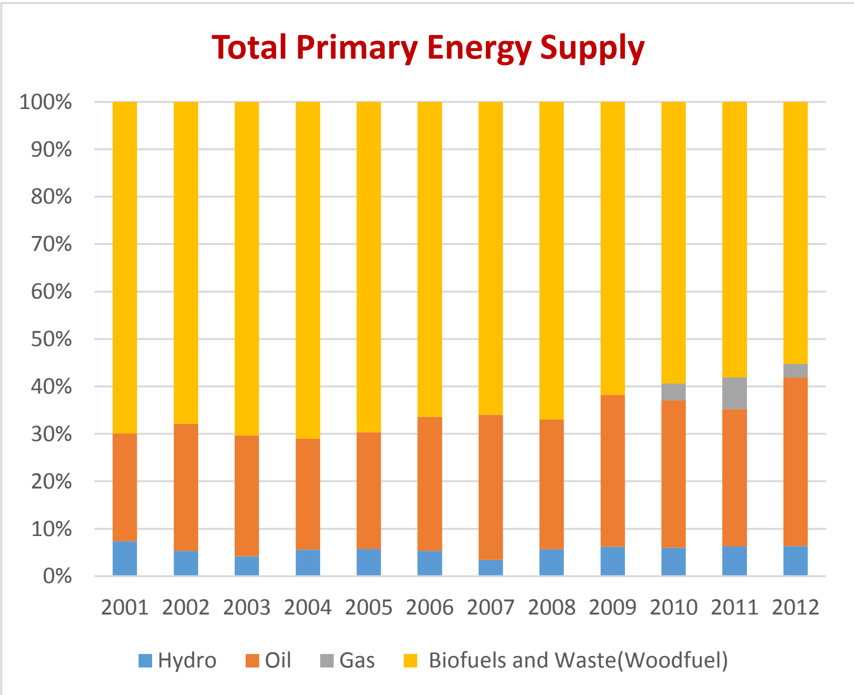

Figure 3. Source: Author's own elaboration using data from IEA.

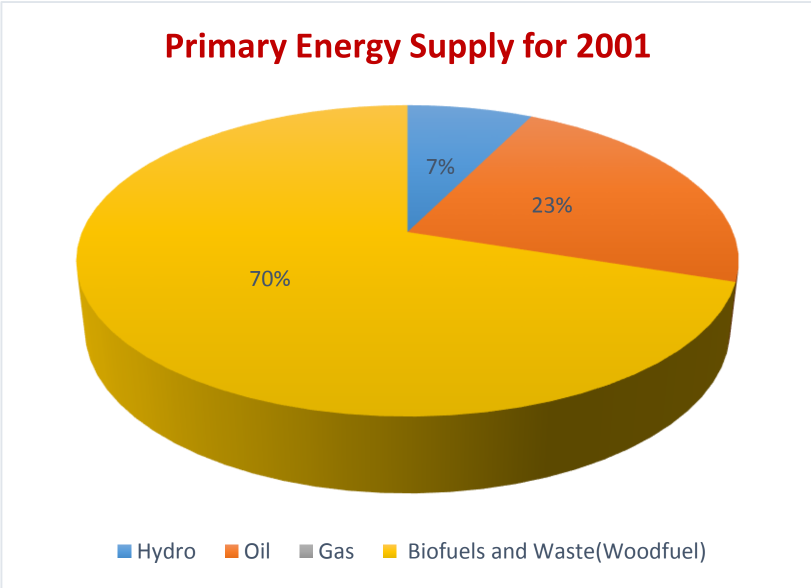

Figure 4. Source: Author's elaboration using data from IEA and the Energy Commission of Ghana.

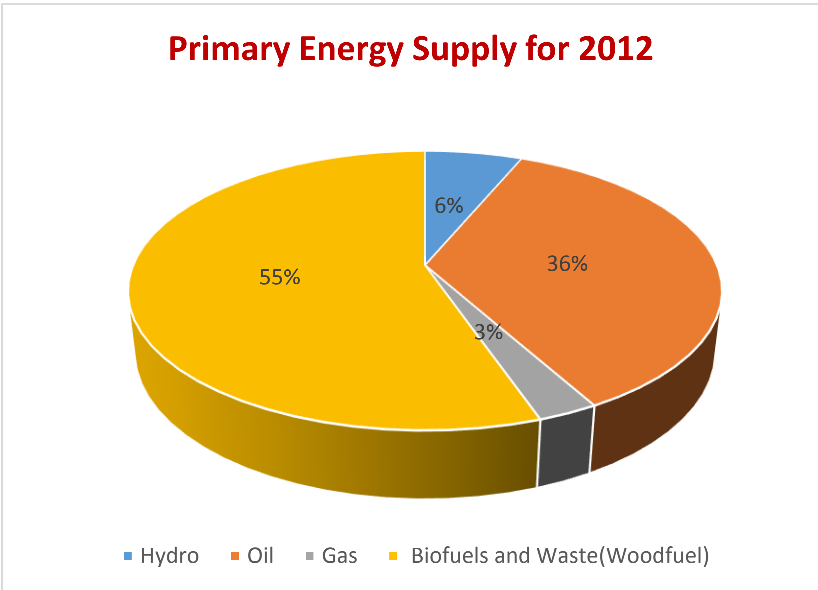

Figure 5. Source: Author's elaboration using data from IEA and the Energy Commission of Ghana.

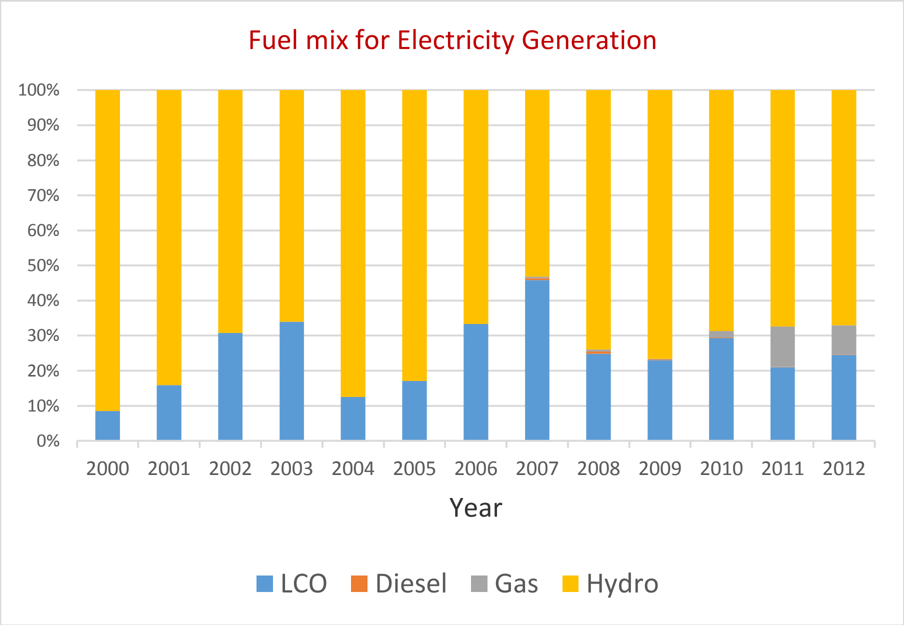

Figure 6. Source: Author's own elaboration using data from the Energy Commission of Ghana.

The electricity generation and consumption situation, as shown in Figure 5, has an interesting look. Ghana was a net exporter until 2005, and the imports have increased progressively from 2006, showing the clear inadequacy of the domestic production.

The installed generation capacity available for grid supply as of the end of 2012 was 2,296 megawatts (MW). The total electricity that was made available for gross transmission in 2012 was 12,164 GWh. The 2012 generation consisted of 8,071 GWh (67%) hydropower and 3,639 GWh (33%) thermal power (Energy Commission, Ghana, 2013).

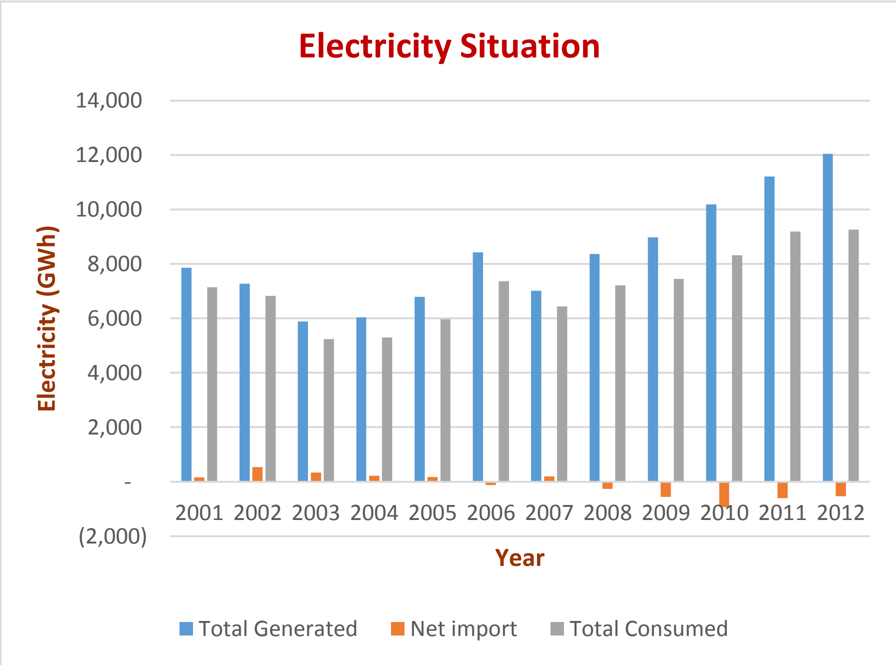

Figure 7. Source*:* Author's elaboration using data from the Energy Commission of Ghana.

Figure 7 above shows the import dependency of Ghana's electricity. Ghana was a net exporter of electricity up until 2005. The year 2007 reported a net export and the country was a net importer until 2012. This clearly shows that Ghana's electricity dependency has been rather significant and consistent from 2009 to 2012.

3.2 Energy Policy Framework of Ghana

The National Energy Policy of Ghana indicates that the country has a huge potential to grow and transform its economy via industrialization, with a view to creating jobs and ensuring equitable distribution of wealth. This is towards the fundamental goal of the government to achieve macroeconomic stability and to grow the economy to a middle-income one by 2020. Currently, Ghana is a lower-middle-income economy with a GDP per capita (PPP) of USD3400 (2012 est.). A significant increase in the country's energy supply is required to ensure that this development objective is met (CIA World Fact Book, 2013).

The energy sector vision is to develop an energy economy that would ensure a secure and reliable supply of high-quality energy services for all the sectors of the economy, and that would become a net exporter of oil and power (Ministry of Energy, Ghana, 2010). The challenges facing the energy sector are an inadequate infrastructure requiring huge investments, inadequate access to energy services, high cost of fuel and electricity generation, inadequate regulatory capacity and enforcement, operational and management difficulties in utility companies, vulnerability to climate and environmental impacts, and inefficiencies in the production, transport, and use of energy. Within the context of the energy sector vision, the goal of the energy sector is to make energy services universally accessible and readily available in an environmentally sustainable manner. Consequently, the following objectives have been outlined to achieve this goal:

i. to secure long-term fuel supplies for the thermal power plants;

ii. to reduce the technical and commercial losses in the power supply;
iii. to support the modernization and expansion of the energy infrastructure to meet the growing demands and to ensure reliability;
iv. to increase the access to modern forms of energy;
v. to improve the overall management, regulatory environment, and operation of the energy sector;
vi. to minimize the environmental impacts of energy supply and consumption through the increased production and use of renewable energy, and to make energy delivery efficient;
vii. to ensure cost recovery for energy supply and delivery;
viii. to ensure the productive and efficient use of energy;
ix. to promote and encourage private sector participation in the energy sector; and
x. to diversify the national energy mix by promoting renewable sources, nuclear energy, and coal. (Ministry of Energy, Ghana, 2010)

Chapter 4 - Methodology

4.1 Country Comparative Analysis

The methodology for the country comparative analysis essentially involved scaling down the number of indicators from 20 to 13, data collection, synthesis, and scoring country performance among the 13 metrics over a 20-year period. The analysis of the performance of the overall top five performers and top five African performers relative to the performance of Ghana was followed by the regression of the energy security indices with a selected number of sustainable development policies.

The composite index used by Sovacool consisted of 20 metrics under the five dimensions. The availability dimension of energy security included four metrics: total primary energy supply per capita, average reserve-to-production ratios, self-sufficiency, and share of national renewable energy supply. Affordability relied on the four metrics of stability of electricity prices, percentage of population with access to the electricity grid, households dependent on traditional fuels, and the retail price of gasoline. Technology development and efficiency was reflected by the four metrics of research intensity, energy intensity, grid efficiency, and energy stockpiles. In terms of environmental sustainability, the four metrics were forest cover, water availability, per-capita energy-related CO_2 emissions, and per-capita SO_2 emissions. Lastly, to reflect regulation and governance, the index employed worldwide governance ratings, energy exports, per-capita energy subsidies, and quality of energy information. These metrics were scaled down to 13 with respect to priority and data availability. This prioritization of the indicators was based on a research by Benjamin K. Sovacool et al. (Sovacool*, 2011).

Ultimately, the 13 indicators were classified under the thematic areas of availability, affordability, technology development and efficiency, environmental sustainability, and regulation and governance as per the adopted definition of energy security. Tables 6 to 9 in Appendix A elaborate this classification. The selected metrics include total primary energy supply per capita, average reserve-to-production ratio for natural gas and oil, self-sufficiency, share of renewable energy in the total primary energy supply, percentage of population with high connections to the electricity grid, retail price of gasoline/petrol, energy intensity, grid inefficiency, forest cover, water availability, per-capita energy-related CO_2 emissions, worldwide governance rating, and quality of energy information. Tables 16 to 25 in Appendix C show the energy security data for the 35 countries.

All the 13 metrics in the index were made unidirectional so that the higher values would correspond with better energy security scores (the idea being that it would be easier to identify common trends). Thus, four of the metrics — retail prices, energy intensity, grid inefficiency, and per-capita CO_2 emissions — were inverted or transformed. Scoring is empirical and relative — empirical in that the scores were based on the real-world performance of the countries observed within a particular metric for a given year, and relative in that the best and worst scores for those countries were taken and used to create a range of scoring points. This was done by converting all the data points to a score between 0 and 100. The scoring range was created by subtracting the minimum value (the worst performer) from the maximum value (the best performer). The negative values were discarded and converted to zero. In the next step, each value was taken, the minimum value was subtracted from it, and the resulting value was divided by the range. The result was a score for each country anywhere from 0 to 100. The absolute score (aggregate of the mean score for each year and metric) was then calculated for each country.

The scoring of the five best overall performers as well as the top five African performers was extensively analyzed alongside that of Ghana. This aspect of the research was to investigate which metrics Ghana needs to improve to be able to improve its energy security situation. The assumption here is that the absolute best performers are the countries that have had very consistent comprehensive energy security policies over the 20-year period and are thus worth emulating.

4.2 Effect of Sustainable Energy Policies on Energy Security

The energy security index is regressed against a select number of sustainable energy policies: tax relief; time-bound strategic plan; research, development, and deployment; and regulatory instruments (IEA, 2014). This was to identify the sustainable development policies worth pursuing to attain a good energy security situation.

Here, data from the years predating 2000-2005 were collected from the IEA Website and were regressed against energy security indices for the years 2000, 2005, and 2010. The assumption here was that it takes four to five years for such policies to yield results and to thus impact energy security. In simple terms, the policies predating 2000 were matched against the 2000 energy security index, the policy data until 2000 were matched against the 2005 energy security index, and finally, the data until 2005 were matched against the 2010 energy security index.

This was done using the panel data model. Following the regression using the simple OLS model, fixed effects model, and random effects model, there was a need to identify the most suitable model for the data. To decide between the fixed and random effects models, a Hausman test was conducted. Following that, a Breusch-Pagan Lagrange multiplier (LM) test was conducted to decide between the simple OLS and random effects models.

Panel Data Estimators

Panel data estimators were used to determine the most suitable model that best describes the given data. The estimators differ based on whether they consider the between or within variation in the data. Their properties (consistency) differ based on which model is appropriate (Katchova, 2014).

The preferred estimators are the consistent and efficient ones; therefore, there is a need to check for consistency first, and then for efficiency.

In terms of consistency, the distribution of $\hat{\beta}_n$ collapses on β as n is large:

$$\rho lim \hat{\beta}_n = \beta$$

The law of large numbers is used to establish consistency. A consistency estimator has more observations providing more precise and accurate estimates.

Efficiency (minimum variance) is usually established relative to the specific classes of estimators (Katchova, 2014). The pooled OLS estimator uses both the between and within variation to estimate the parameters. It is obtained by stacking the data over *i* and *t* into one long regression with NT observations, and by estimating it using OLS, as follows:

$$y_{it} = \alpha + x'_{it}\beta + (\alpha_i - \alpha + e_{it}).$$

If the true model is a pooled model and the regressors are uncorrelated with the error terms, the pooled OLS regressor is consistent. Where the true model is the fixed effects model, the pooled OLS regressor is inconsistent. In such a situation, there is a need for panel-corrected standard errors.

The within estimator uses the within variation (over time). It uses time-demeaned variables (the individual specific deviations of variables from their time-averaged values). It is in fact an OLS estimation of the time-demeaned dependent variable on the time-demeaned regressors.

$$y_{it} - \bar{y}_i = (x_{it} - \bar{x}_i)'\beta + (e_{it} - \bar{e}_i)$$

The within estimator is limited by the fact that time-invariant variables are dropped from the model, and that their coefficients are not identified. The number of observations is *NT* (Katchova, 2014).

The random effects estimator is an OLS estimation of the transformed model, as follows:

$$y_{it} - \hat{\lambda}\bar{y}_i = (1 - \hat{\lambda})\mu + (x_{it} - \hat{\lambda}\bar{x}_i)'\beta + v_{it},$$

$$v_{it} = (1 - \hat{\lambda})\alpha_i + (e_{it} - \hat{\lambda}\bar{e}_i), \text{ and}$$

$$\lambda = 1 - \sigma_e/\sqrt{\sigma_e^2 + \sigma_\alpha^2}.$$

The number of observations is *NT*. The individual specific effects α_i are in the error term. The random effects estimates are weighted averages of the between and within estimates. The random effects estimates are fully efficient under the random effects model (Katchova, 2014).

Table 2 Panel Data Models and Estimators

Estimator/True Model	**Pooled Model**	**Random Effects Model**	**Fixed Effects Model**
Pooled OLS	Consistent	Consistent	Inconsistent
Within or fixed effects	Consistent	Consistent	Consistent
Random effects	Consistent	Consistent	Inconsistent

In summary, the fixed effects model always gives consistent estimates but may not be the most efficient. The random effects estimator is inconsistent if the appropriate model is the fixed effects model. Finally, the random effects estimator is consistent and the most efficient if the appropriate model is the random effects model.

Choosing between Fixed and Random Effects

The Breusch-Pagan Lagrange multiplier test is used to test for random effects based on the OLS residual. The test is whether σ_u^2 or its equivalent, $cor(u_{it}, u_{is})$, is significantly different from zero. If the LM test is significant, the random effects model is used instead of the OLS model.

Following this test, there is a need to test between the fixed and random effects models. This is done using the Hausman test.

The random effects model, being a more efficient ID, is the preferred model if the Hausman test supports it. If not, the fixed effects model is used. Essentially, the Hausman test is used to test if there is a significant difference between the fixed and random effects estimators. The Hausman test statistic can be calculated only for the time-varying regressors, and is represented as:

$$(\hat{\beta}_{RE} - \hat{\beta}_{FE})' \left(V(\hat{\beta}_{RE})\, V(\hat{\beta}_{FE})\right) (\hat{\beta}_{RE} - \hat{\beta}_{FE}) .$$

This is a chi-square distributed with degrees of freedom equal to the number of parameters for the time-varying regressors. If the Hausman test result is insignificant, the random effects model is used, but if it is significant, the fixed effects model is used (Katchova, 2014).

4.3 Economy-wide Energy Security Assessment of Ghana

This part of the paper investigates the energy security situation of the Ghanaian economy based on the country-specific energy security indicators. Tables 10 and 11 in Appendix A outlines the criteria used to define energy security by certain relevant bodies and countries. The criteria assigned to Ghana stems from a review of the country's current national energy policy. The various indicators are categorized under the priority areas below.

- **Energy demand:** Denotes the energy intensity (energy use per GDP), energy use per capita, and related issues. Aside from these, it considers one major energy resource and one sector that is country-dependent: oil and transportation in the case of Ghana.

- **Availability of energy supply resources:** Designated by the resources estimate and the resources-to-production ratio (RPR). The diversification of the energy supply resources is represented by the Shannon-Wiener index (SWI).

- **Non-carbon-intensive fuel portfolio (NCFP) and CO_2 emission:** Used to present the energy consumption and its relation to the environment

- **Energy market:** The parameters are represented by energy import and net energy import dependency (NEID). The various indicators being employed to assess the energy security situation are outlined in Table 12 in Appendix A under the above categories. The corresponding equations for calculating the indicator values are shown in Tables 13, 14 and 15 in Appendix B.

- **Shannon-Wiener Index** of the electricity generation in Ghana

  The next step is to calculate the **Shannon-Wiener Index** for Ghana from 2000 to 2012. This would also help investigate the extent of the risk to the country's electricity associated with the diversity of the fuel supply.

$$\mathrm{SW} = \sum_{i} x_i \ \ln(x_i)$$

Here, x_i is the share of a particular fuel in the electricity generation mix. The change in the indicator values for 2000 and 2012 are compared to see how they change over the study period (Bhattacharyya, 2011).

Lastly, the energy price trend is considered: the electricity tariff from 2001 to 2012 and the monthly prices of the major petroleum products (gasoline, gas oil, kerosene, LPG, and RFO) from 2007 to 2012.

Chapter 5 - Results and Analysis

5.1 Country Comparative Analysis

The analysis of the results of the country comparative analysis was done in three parts: analysis of the panel data trend of the metrics, comparative analysis of the performances of the overall five best performers and the best five African performers with the performance of Ghana, and regression of the sustainable energy policies with the energy security indices using the panel data model.

The assumption here is that it is worth pursuing a comprehensive energy security course. This is the very essence of the composite energy security index and also the reason that it is best to learn from the overall best performers. Having said that, it is important to note that different countries have their peculiar conditions and challenges, and as such, it is necessary to investigate these conditions and to juxtapose them on Ghana's situation before adoption and possible adaptation can be recommended. Nonetheless, this aspect would require extensive work and is thus recommended for future studies.

The panel data summary of the metrics, as shown in Table 27, 28, and 29, indicates that all the variables, except "average reserve-to-production ratio," had more between variations than within variations. This means that there is more variation when the individual variables are compared to one another than when an individual variable is compared to its own mean over time.

Conversely, the average reserve-to-production ratio increased consistently over time. This shows that the production reserves increased over the study period.

Generally, the figures show that most of the countries, particularly the developing ones, are heavily reliant on their energy resource endowment, with very limited attention given to the other metrics of the energy security index. The figures from 2005 and 2010 show marginal progress in the other metrics, indicating a progressive improvement in the global energy security situation.

5.1.1 Absolute Best Performers

Figure 46 in Appendix D shows the absolute performance (aggregate of the mean score for each year and metric) of all the 35 countries over a 20-year period. The top five performers were Brunei (273), Japan (260), New Zealand (254), USA (253), and EU (252) while the five worst performers were (from the bottom) Tunisia (123), Libya (124), Algeria (127), Egypt (128), and Morocco (132). No country got a perfect score of 500, indicating that even the best performer has room for improvement in some of the metrics. Again, the relativity of the index shows that the energy security levels of countries are interrelated, and as such, a global effort is required to address the challenges posed by such. Ghana placed 17th, with a score of 185.

All the five worst performers – Morocco (132), Egypt (128), Algeria (127), Libya (124), and Tunisia (123) – are oil- and gas-resource-rich North African nations. Brunei, which is also an oil- and gas-resource-rich country, was the best performer. The other top performers all have good quantities of oil and gas resources. These data show that oil and gas resource wealth per se does not guarantee energy security; it should be accompanied by good policies. It is therefore necessary to investigate which policies the top-performing countries implemented over the study period.

Again, Figure 47 in Appendix D, which shows the comparative performance of the countries over the years, indicates that the top performers sustained their high-level performances over the study period. This presumably indicates the consistent implementation of good policies or possibly effective monitoring and evaluation regimes, which progressively informed better decision-making processes over the study period.

As can be seen in Figure 47 in Appendix D, there were marginal increments in the absolute performances of the top five performers over the five-year intervals, indicating a sustained high performance in most of the metrics. This confirms that these countries sustained high performances in most of the metrics over the study period via the appropriate respective policies.

The comparison of the performance of Ghana in the various metrics with those of the top performers in the year 1990 showed that all the countries performed better in the following metrics: population with high connection to electricity, water availability, forest cover, grid inefficiency, retail prices of unleaded gasoline, average reserve-to-production ratio, and TPES per capita.

Figures 8 to 20 show the situation as of 2010. Here, the five countries performed better than Ghana in governance rating, water availability, forest cover, grid inefficiency, grid connection, and TPES per capita. Again, apart from Brunei, all the top five performers fared better than Ghana in terms of energy intensity. Only New Zealand had a better share of renewable energy than Ghana. It is important to note, however, that Ghana's high share of renewable energy in the TPES was from wood fuel, which is used primarily for rural and peri-urban cooking and heating.

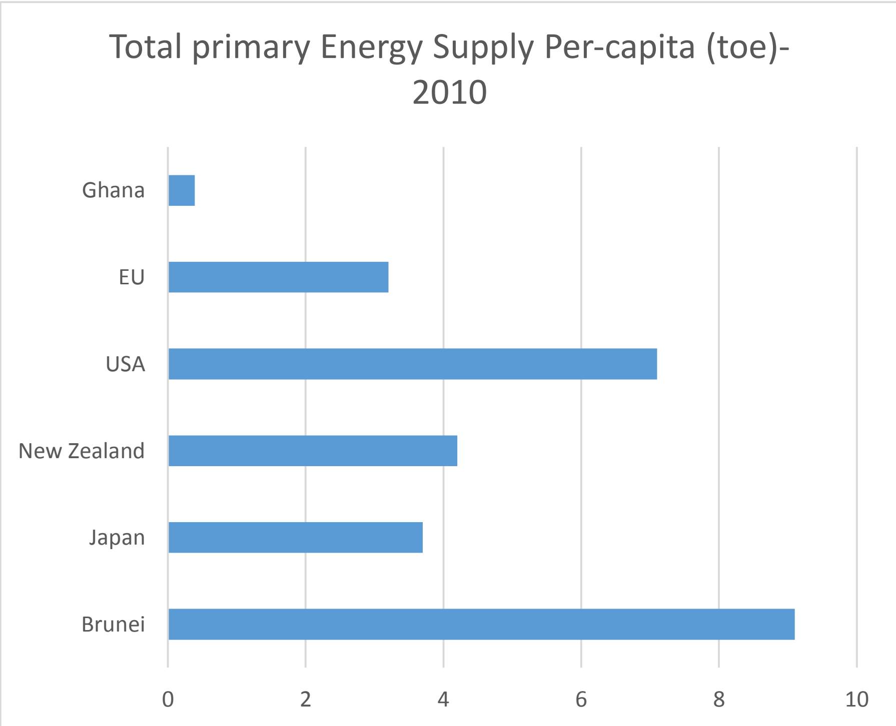

Figure 8. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

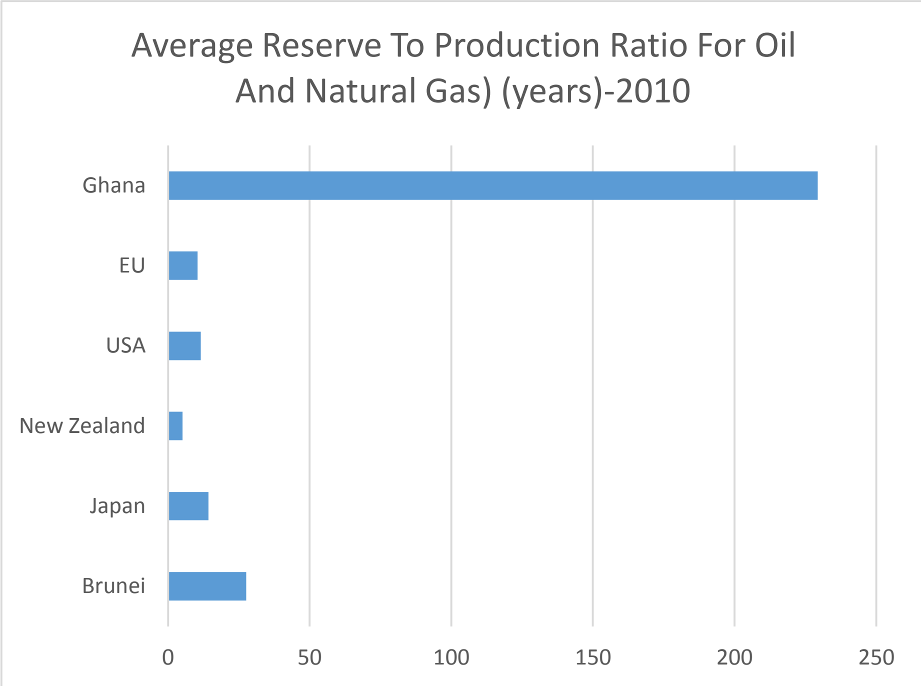

Figure 9. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

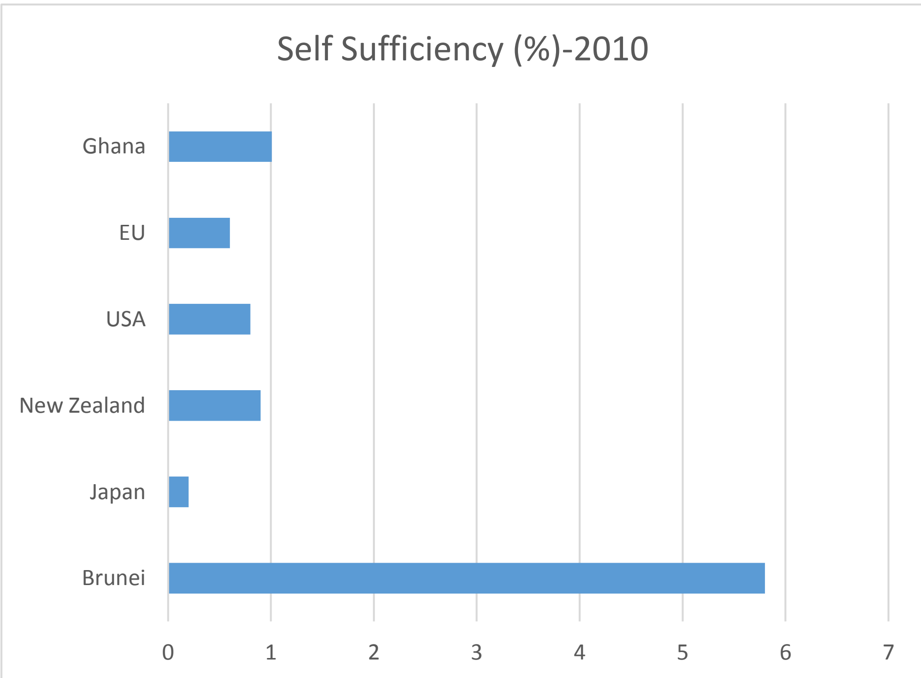

Figure 10. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

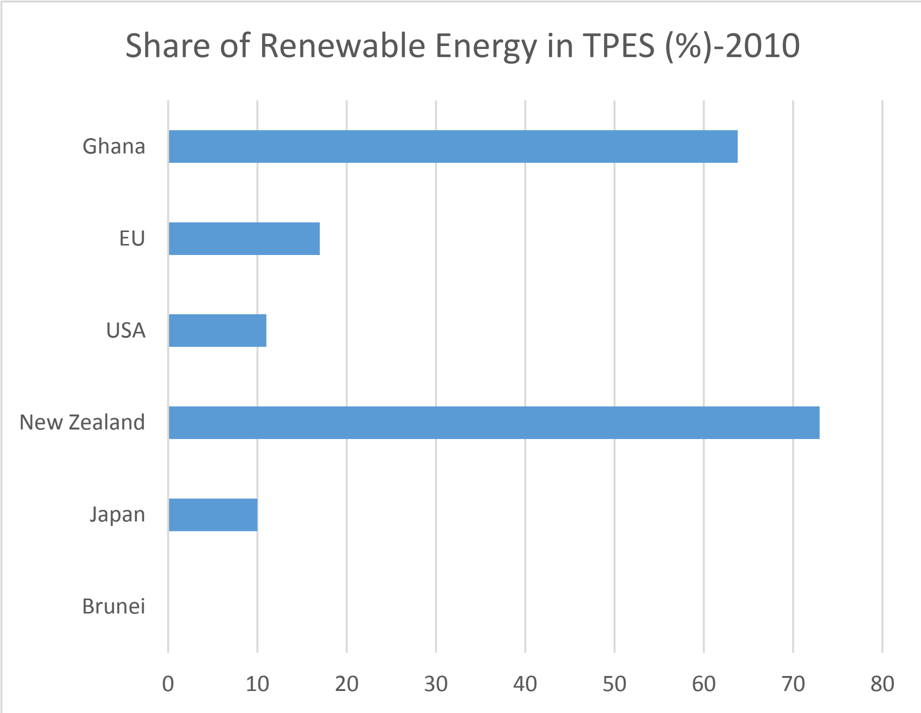

Figure 11. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

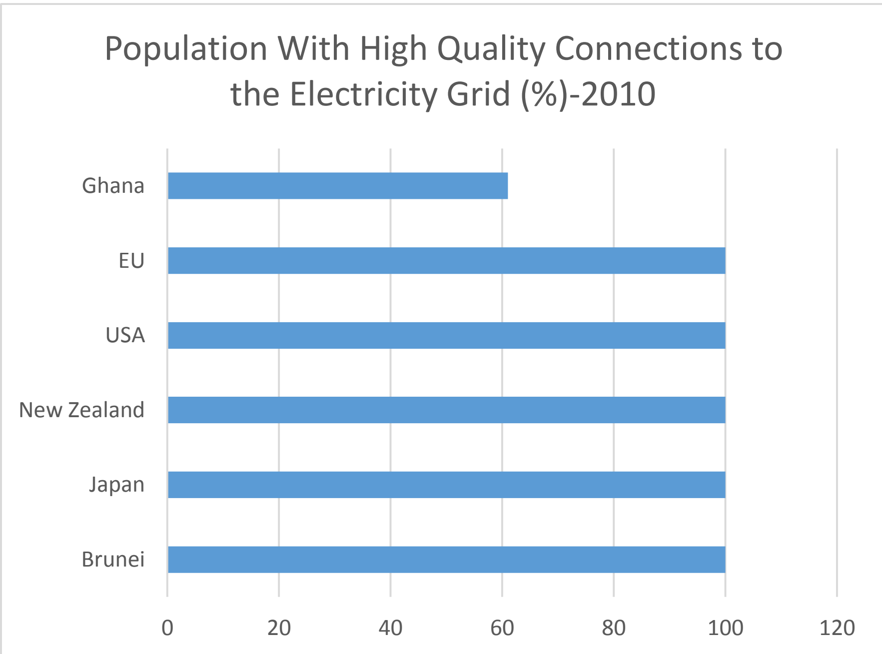

Figure 12. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

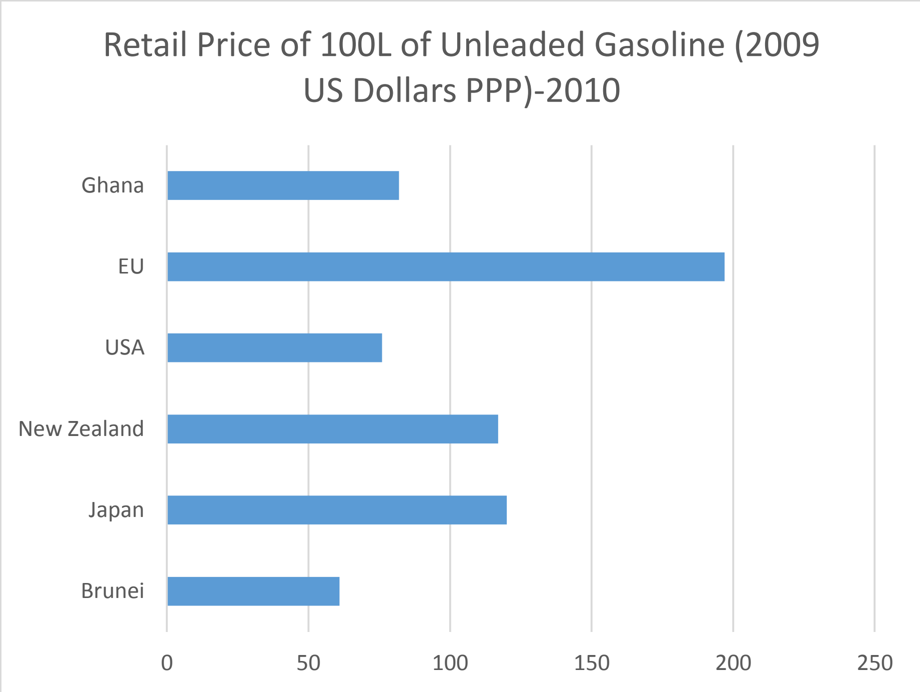

Figure 13. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

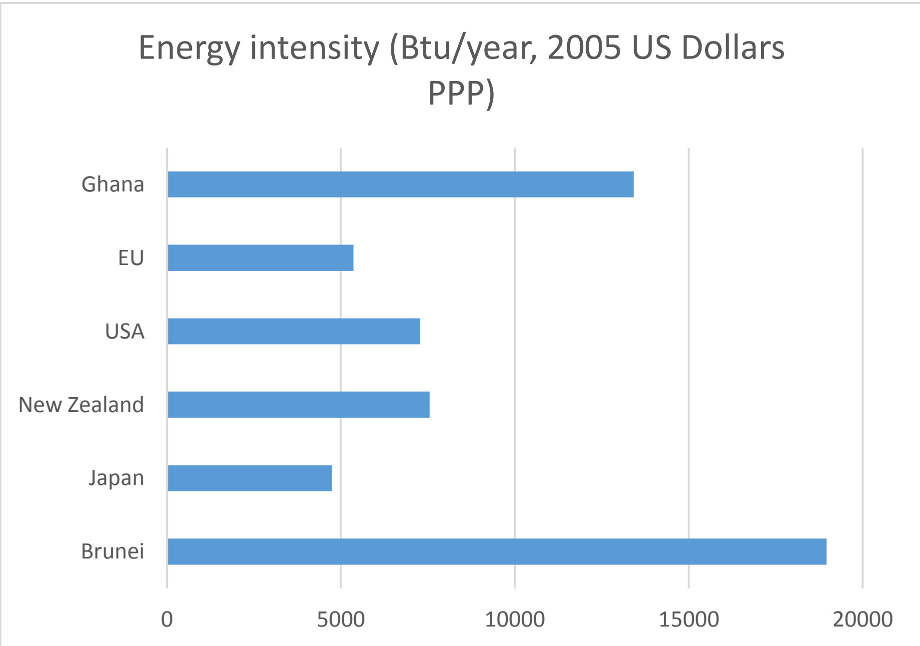

Figure 14. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

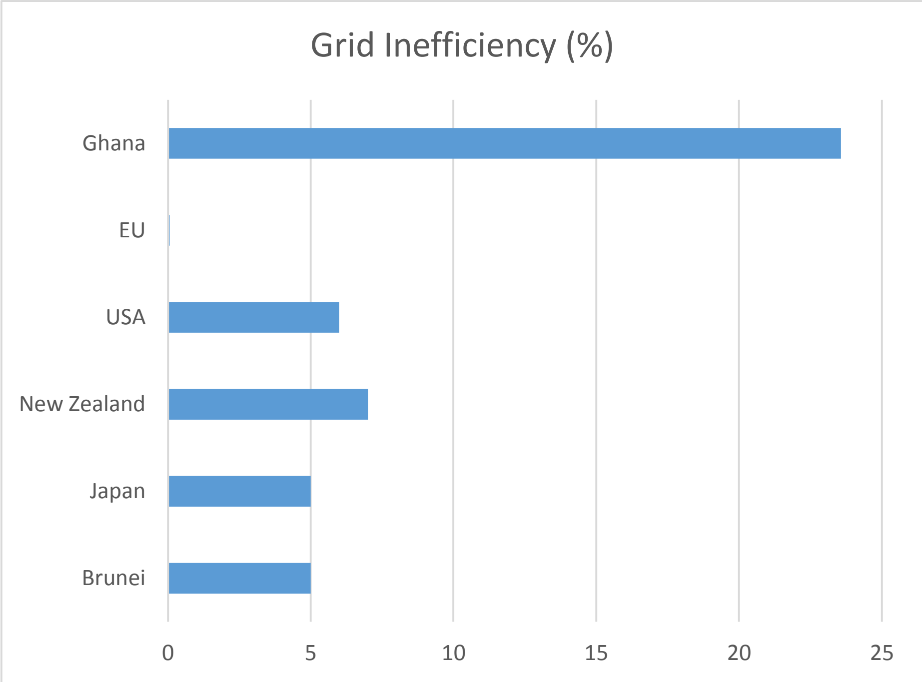

Figure 15. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

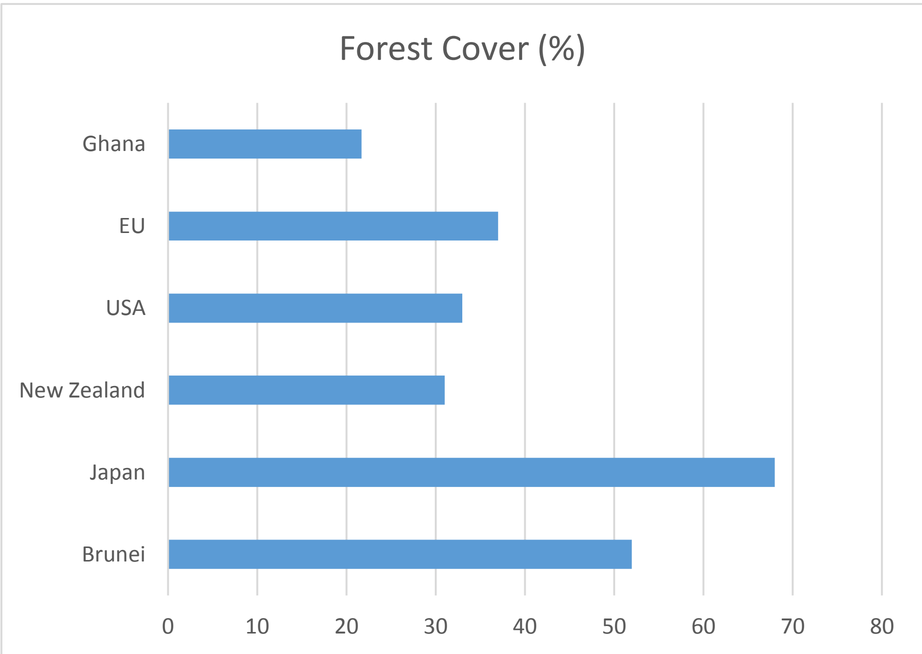

Figure 16. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

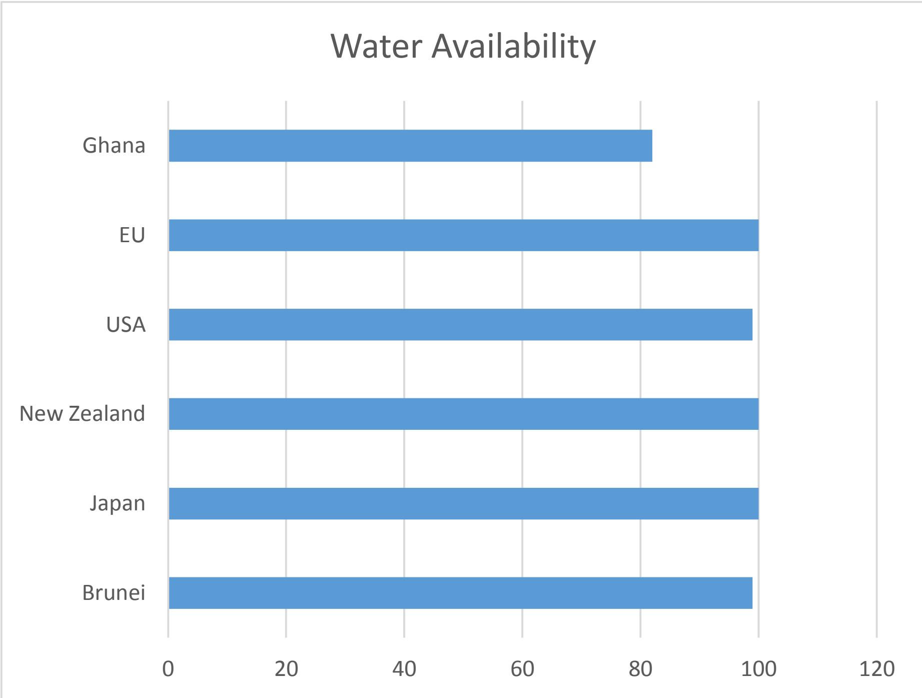

Figure 17. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

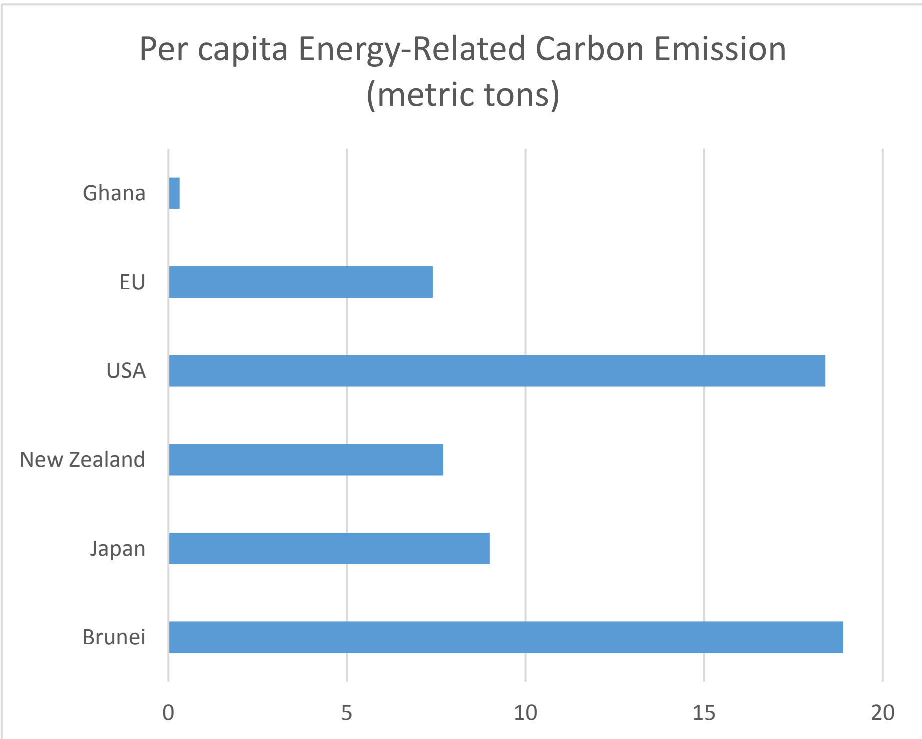

Figure 18. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

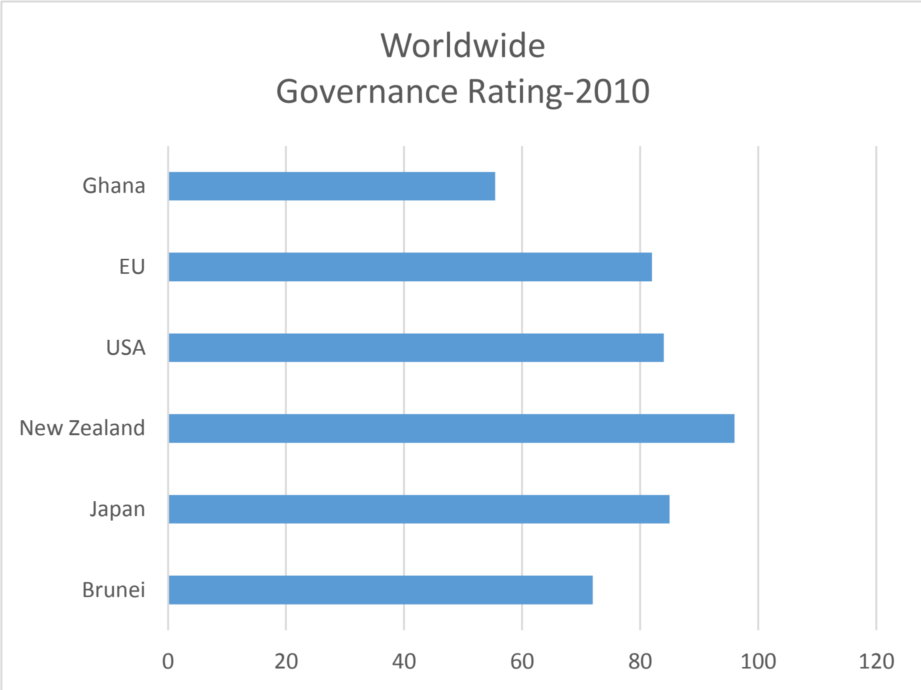

Figure 19. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

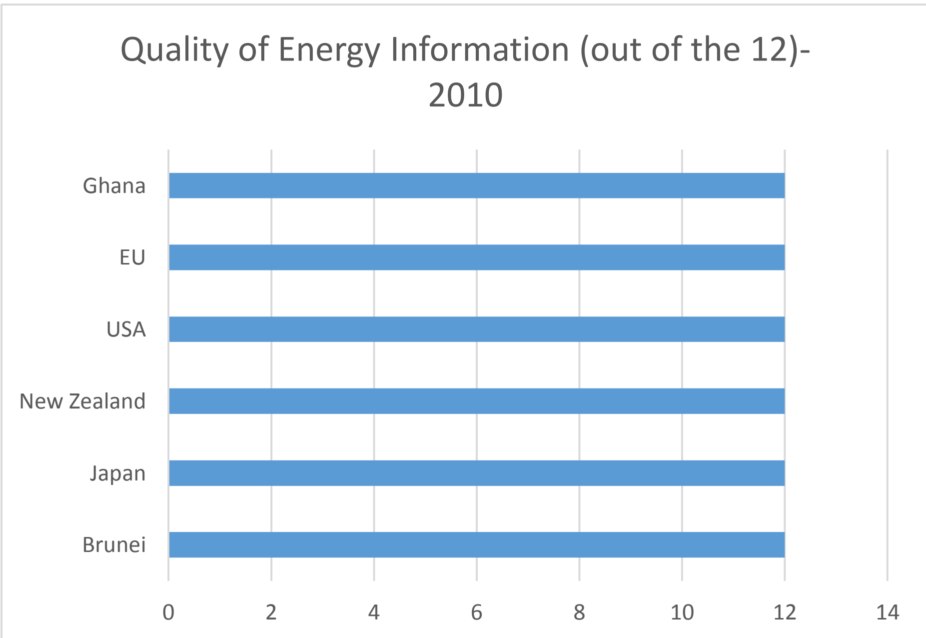

Figure 20. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

5.1.2 Best African Absolute Performers

This analysis could be considered a more realistic comparison due to the relative comparable features of the African countries in terms of political stability and governance, economic structure, energy policy and security priorities, and resource endowment. The top five African performers were Congo DR (201), Cameroun (201), Angola (200), Tanzania (199), and Zambia (187). Ghana was the sixth best performer amongst the African countries, with a score of 185.

For 1990, the TPES per-capita values were Congo DR 0.32, Cameroun 0.41, Angola 0.55, Tanzania 0.38, Zambia 0.68, and Ghana 0.35, showing that all these countries performed better than Ghana in TPES per capita, apart from Congo DR. Only Angola had a better average reserve-to-production ratio, although the difference was very wide: 61 to 4.54. Cameroun had 3.40 while the other three had 0. The self-sufficiency values were Congo DR 1.02, Cameroun 2.20, Angola 4.87, Tanzania 0.93, Zambia 0.91, and Ghana 1.0, indicating that Ghana did better than only Tanzania and Zambia. The shares of renewable energy figures were Congo DR 84.74, Cameroun 76.70, Angola 73.46, Tanzania 91.73, Zambia 74.29, and Ghana 73.70, showing that all but Angola did better. Only Cameroun (29) had a better grid connection than Ghana (25). The retail prices of unleaded gasoline in Tanzania (42) and Zambia (40) were better than that in Ghana (53). Congo DR had 81 while Cameroun had 68. Ghana’s energy intensity (18,247.58) was better than only Zambia’s (20708.50). Ghana’s grid inefficiency (3.15) was better than those of all the others. Ghana's forest cover and water availability were the least amongst all the countries. Lastly, Ghana performed better than only Angola and Zambia in terms of CO_2 emission per capita.

Figure 21-23 depict the situation as of 2010. Angola (0.64), Tanzania (0.45), and Zambia (0.61) had better TPES per-capita values than Ghana (0.39). Only Cameroun (325.8) had a better average reserve-to-production ratio than Ghana (229.4). Cameroun (1.28) and Angola (8.49) had better self-sufficiency than Ghana (1.01). The share of renewable energy for Congo DR (93.4), Cameroun (63.79), Tanzania (88.59), and Zambia (80.86) were all better than that for Ghana (63.81). Cameroun (12) and Angola (65) had lower prices for unleaded gasoline compared to Ghana (82). Apart from Zambia (14,235.02), all the others had lower energy intensity than Ghana (13,418.05). All the countries also had lower grid inefficiency compared to Ghana (23.57). Ghana again had the smallest forest cover (21.71) but better water availability than all the others. Congo DR (0.05), Tanzania (0.15), and Zambia (0.18) had lower per-capita CO_2 emission than Ghana (0.31). The governance rating in Ghana (55.43), however, was better than those of all the other countries. There was parity in the quality of energy information, apart from Zambia (11).

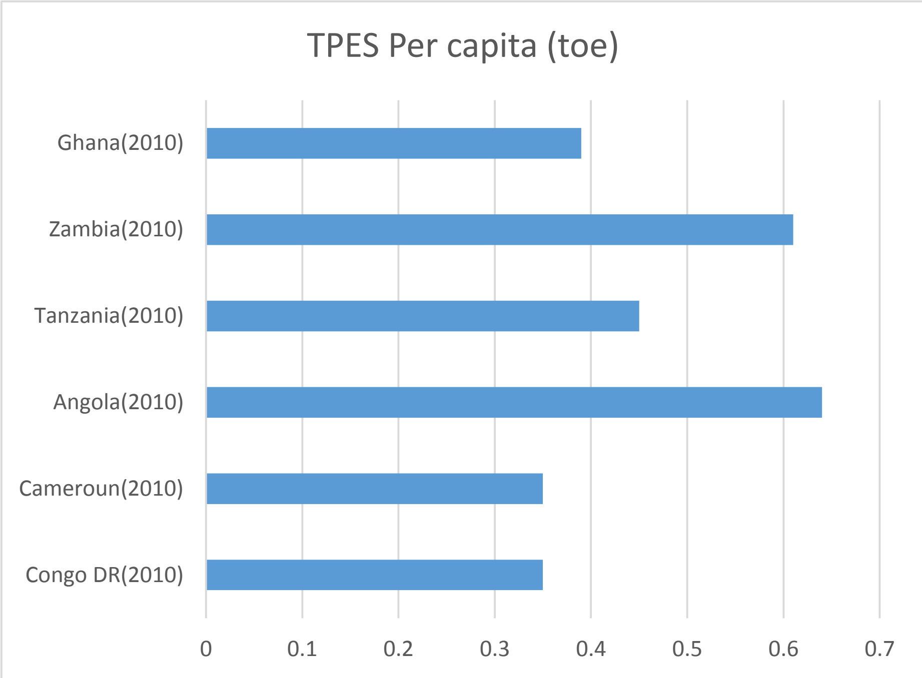

Figure 21. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

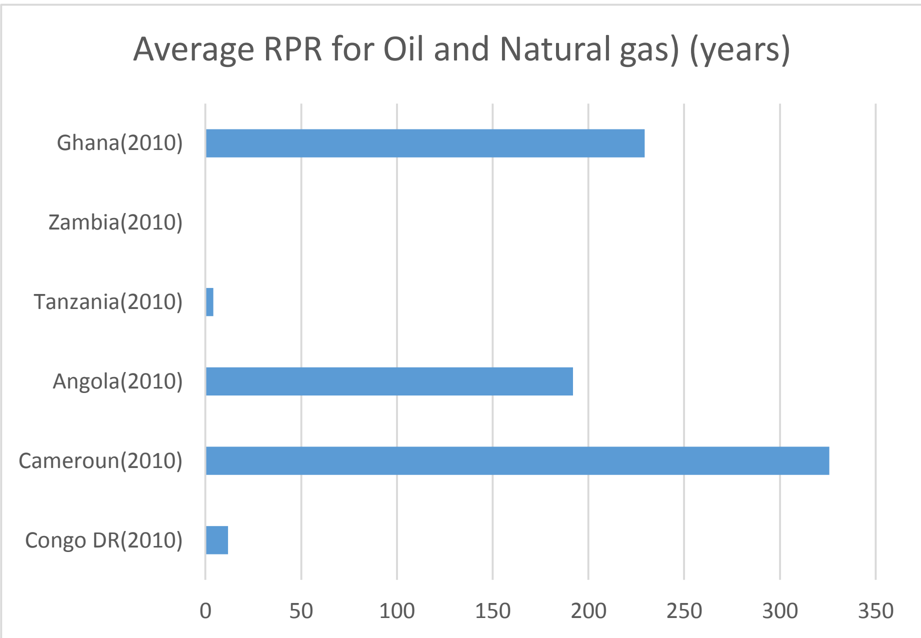

Figure 22. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

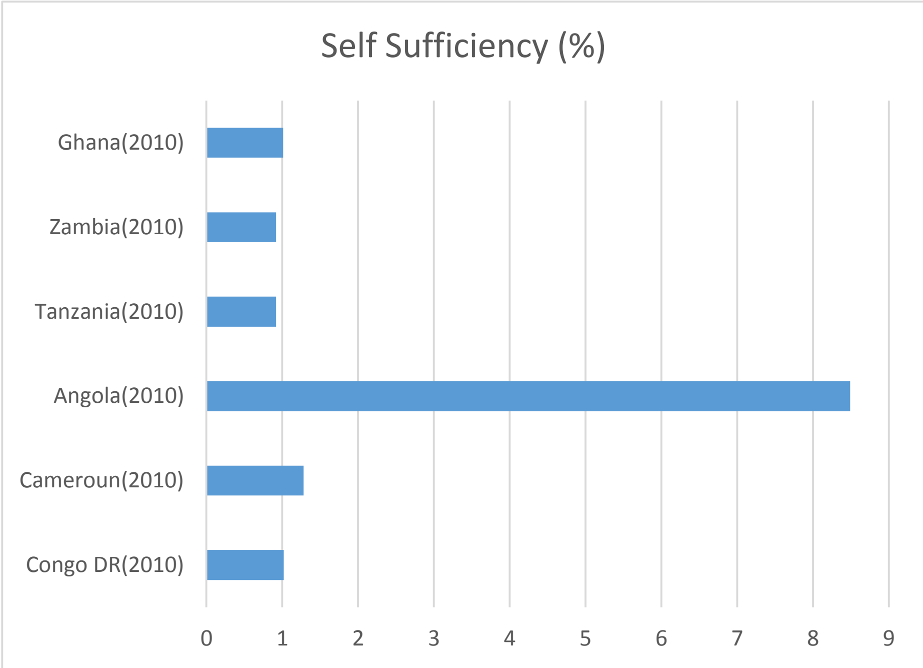

Figure 23. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

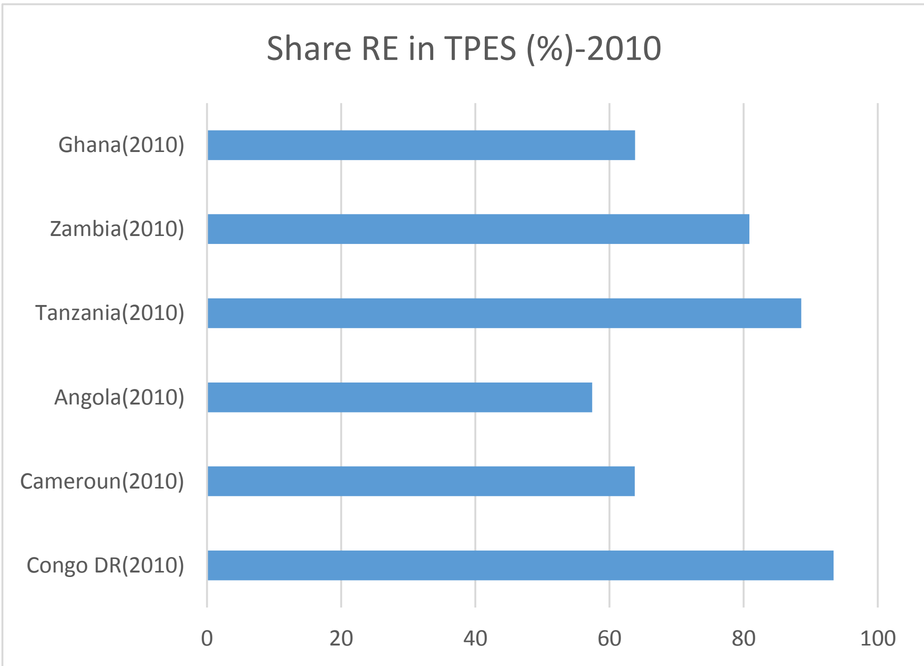

Figure 24. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

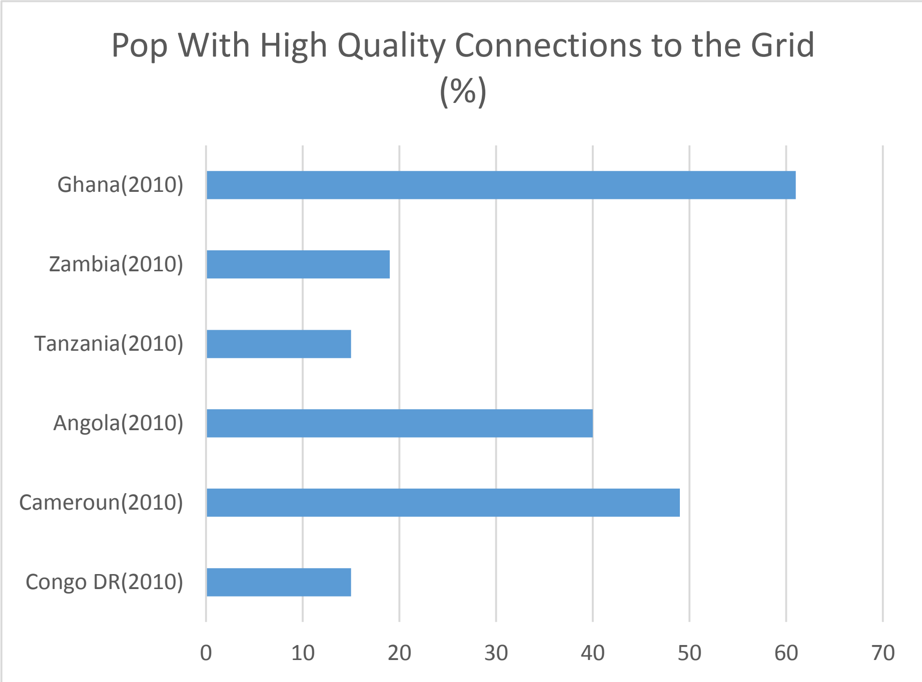

Figure 25. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

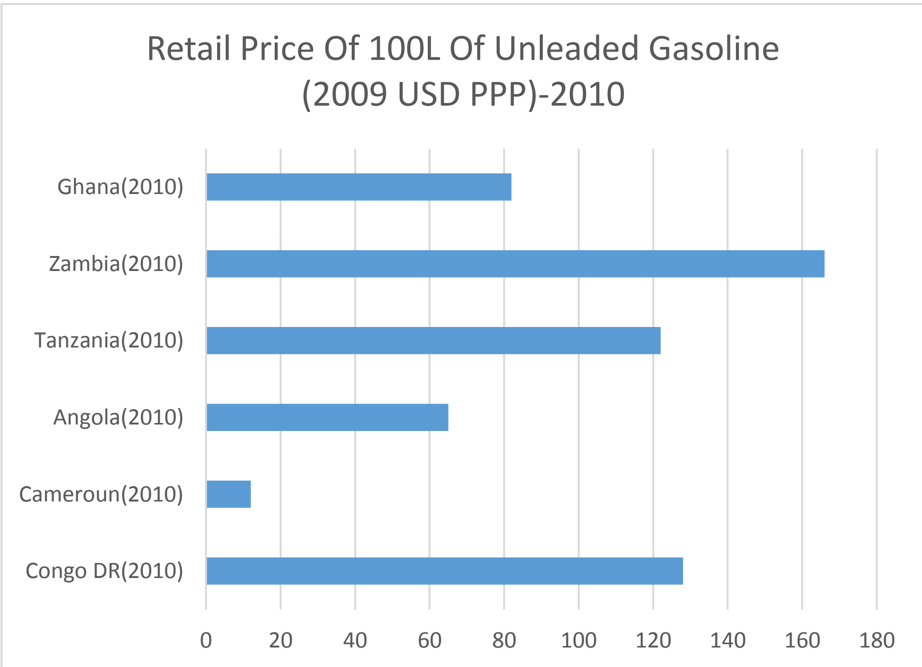

Figure 26. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

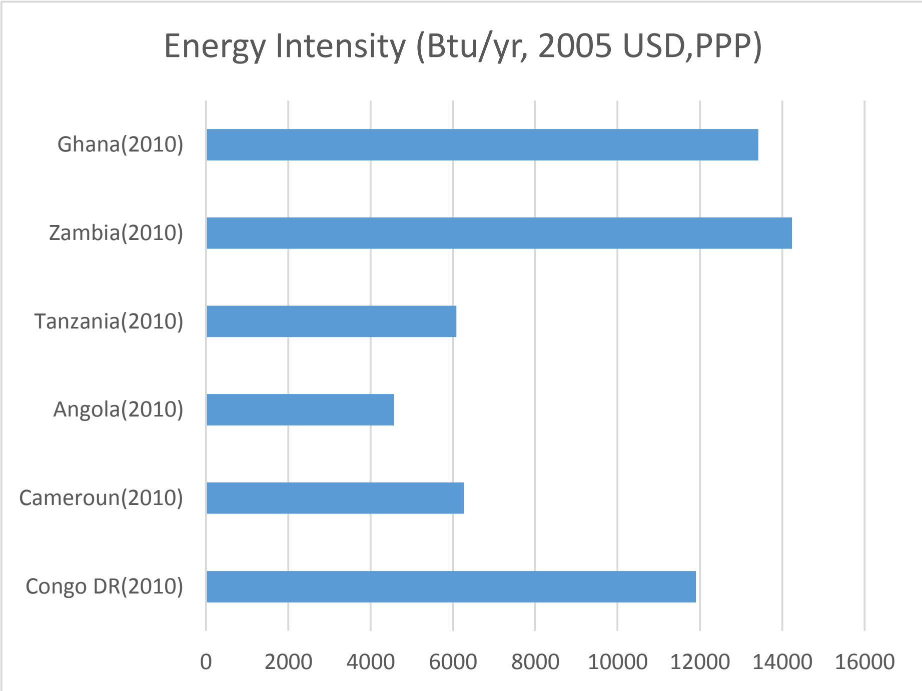

Figure 27. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

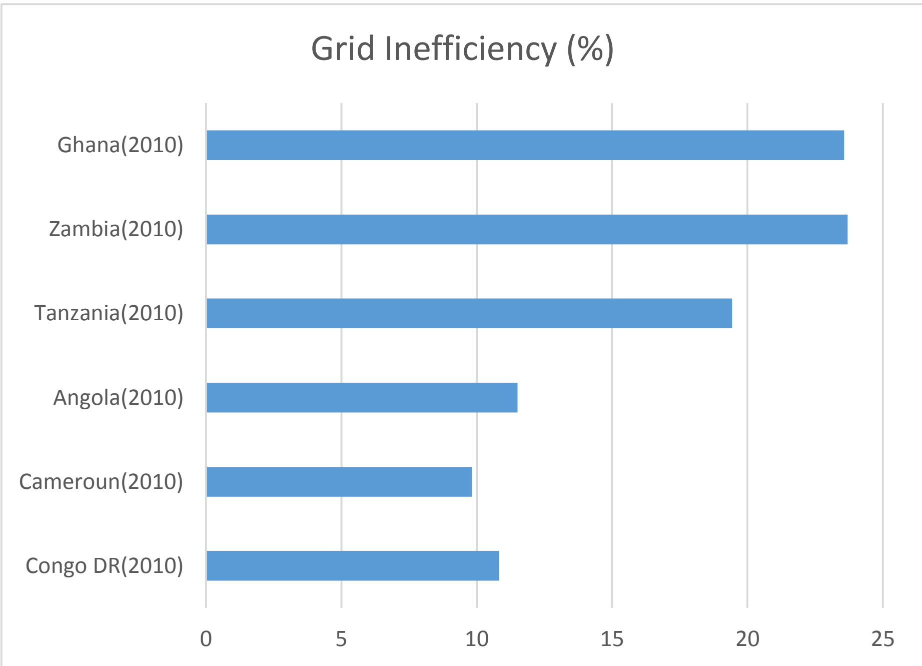

Figure 28. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

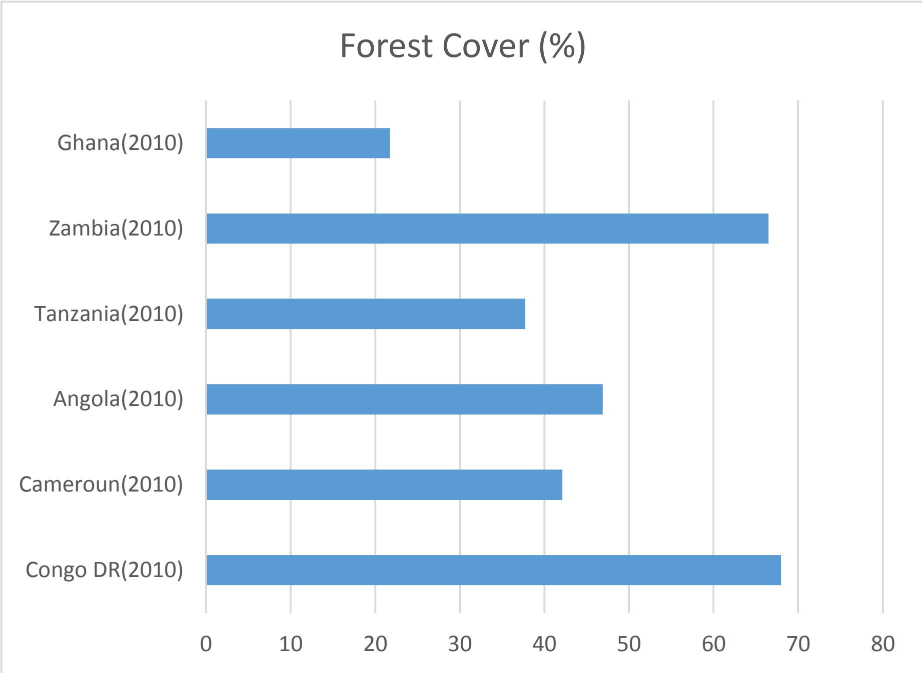

Figure 29. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

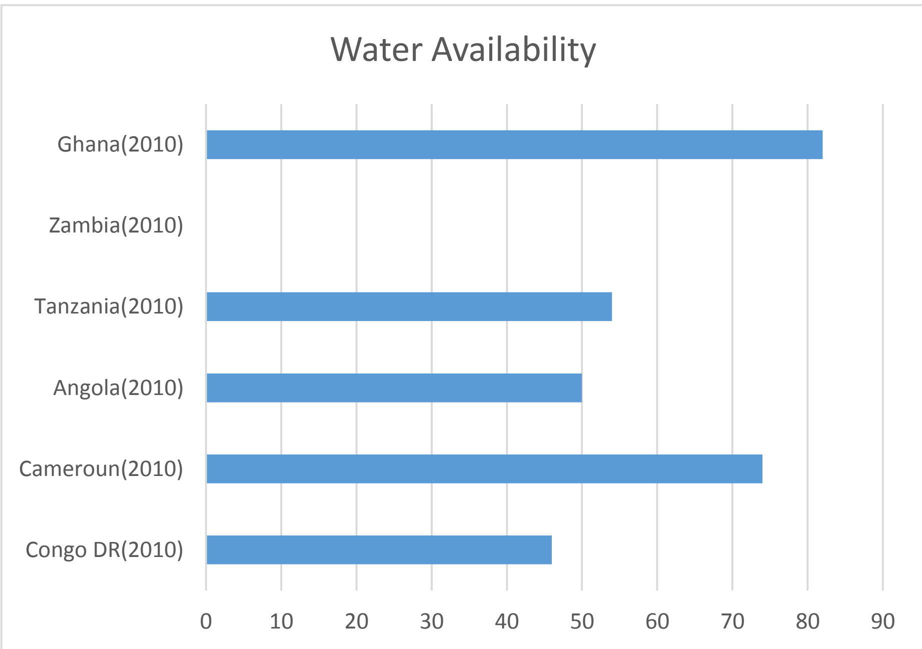

Figure 30. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

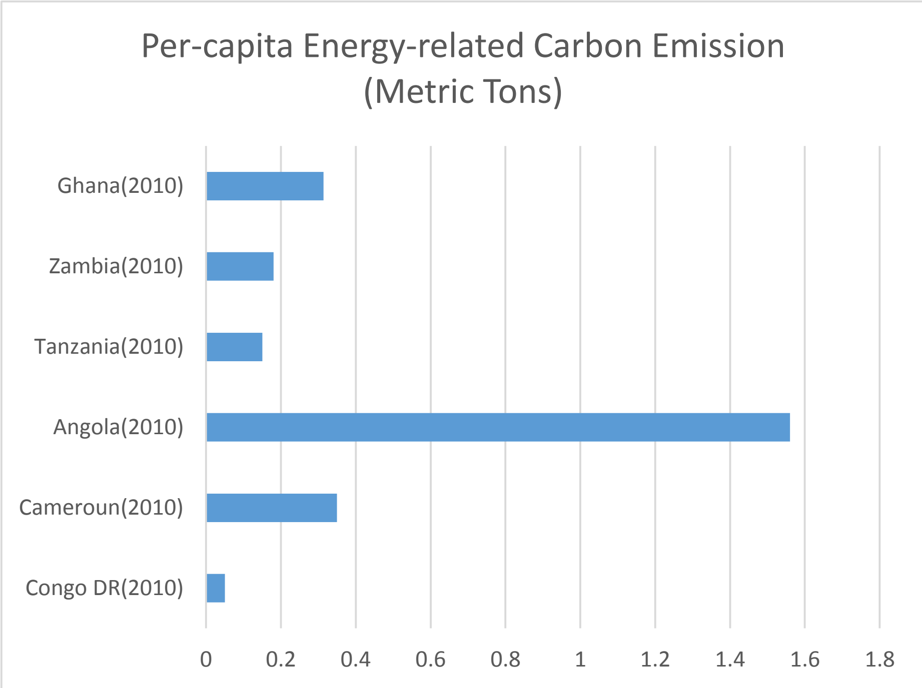

Figure 31. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

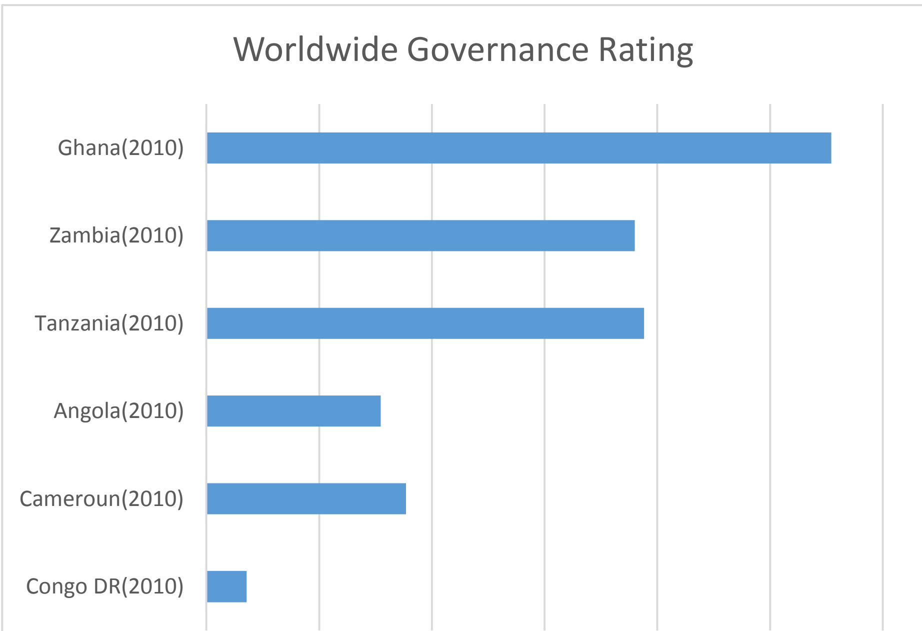

Figure 32. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

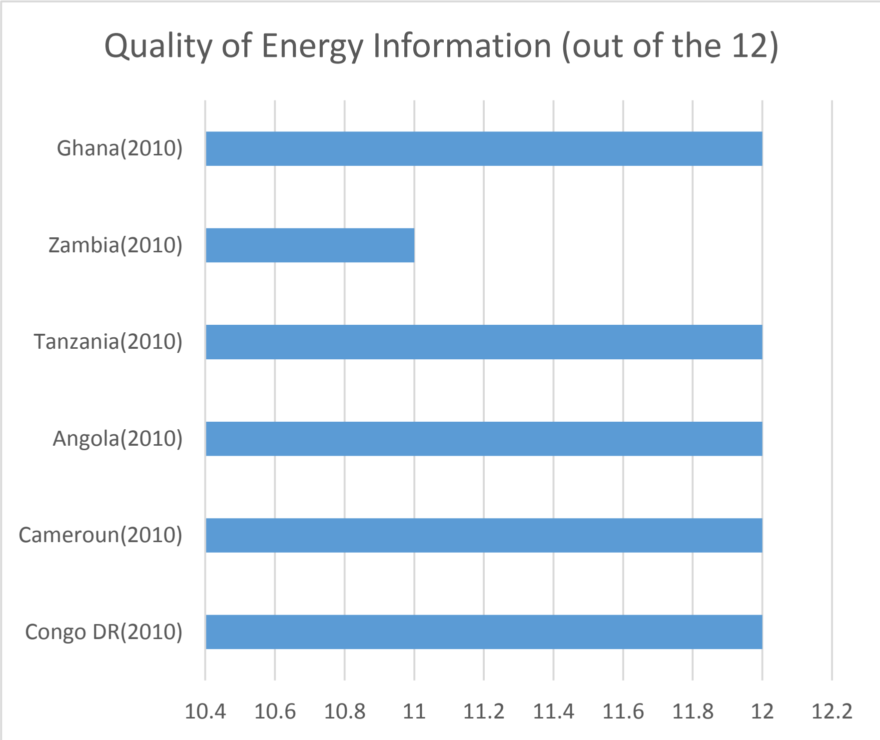

Figure 33. Source: Author's own elaboration using data from EIA, WB, IEA, etc.

Table 3: Summary of Ghana's Performance against the Best Performers (2010)

Metric	Overall Best Performers	Best African Performers
TPES per capita (toe)	Brunei, Japan, New Zealand, USA, EU	Angola, Tanzania, Zambia
Average RPR for oil and natural gas) (years)		Cameroun
Self-sufficiency (%)	New Zealand	Cameroun, Angola
Share RE TPES (%)		Tanzania, Zambia, Cameroun, DR Congo
Pop with high-quality connections to the grid (%)	Brunei, Japan, New Zealand, USA, EU	
Retail price of 100 L unleaded gasoline (2009, USD, PPP)		Cameroun, Angola
Energy intensity (Btu/yr, 2005, USD, PPP)	Japan, New Zealand, USA, EU	Tanzania, Angola, Cameroun, DR Congo
Grid inefficiency (%)	Brunei, Japan, New Zealand, USA, EU	Tanzania, Angola, Cameroun, DR Congo, Zambia
Forest cover (%)	Brunei, Japan, New Zealand, USA, EU	Tanzania, Angola, Cameroun, DR Congo, Zambia
Water availability	Brunei, Japan, New Zealand, USA, EU	
Per-capita energy-related CO_2 emission (metric tons)		Congo, Tanzania, Zambia
Worldwide governance rating	NA	
Quality of energy information (out of the 12)	Parity	Parity

The performance of Ghana in the various metrics vis-à-vis the Absolute Best Performers and Best African Absolute Performers are summarized in Table 3 above. The blue boxes indicate the metrics in which Ghana performed better than the other countries.

5.1.3 Analysis of the effect of sustainable energy policies on the energy security index

Table 4: Comparing Estimators for Panel Data Models

Energy Security Index	**Pooled OLS Regression**	**Fixed Effects or Within**	**Random Effects**
Tax relief	2.24453* (1.39)	0.3057336* (0.24)	1.607541* (1.36)
Time-bound strategic plan	2.898341* (2.28)	2.232819* (2.26)	2.268097* (2.11)
Regulatory instrument	1.598056* (1.36)	0.6097957* 0.48	1.405285* (1.78)
Constant	26.97273* (3.30)	29.02058* (3.38)	28.35605* (3.23)
Adjusted R2	0.8029		
R2-within		0.5605	0.5246
R2-between		0.7339	0.8373
R2-overall		0.7015	0.8062
Rho			0.77186568
Theta (λ)			0.7005

* represent coefficients; ( ) represent t-values

Confidence interval = 80%

<u>Hausman test for the fixed vs. random effects models</u>

- Prob>chi2 = 0.8511 (if less than 0.05, use the fixed effects model)
- Hence, the random effects model was adopted.

<u>Testing for random effects: Breusch-Pagan Lagrange multiplier (LM)</u>

chibar2 (01) = 22.66

Prob>chibar2 = 0.0000

Here, the null hypothesis is rejected, and it was concluded that the random effects model is appropriate. This is so because there is evidence of a significant difference across countries; therefore, the panel effect is present.

The results show that the higher values of the time-bound strategic plan, tax relief, and regulatory instruments are associated with the higher values of the energy security index. The Hausman test showed no significant differences between the coefficients for the fixed and random effects models; as such, the random effects model was adopted. Rho is the proportion of the variation due to the individual specific term. A 0.77 value means that 77% of the variation is explained by the individual specific term, and the rest is due to the idiosyncratic error. Lambda is 70%, which means that the RE estimates are much closer to the within estimates than to the OLS estimates. The 0.8062 R2 value shows that the random effects model can explain 81% of the variation.

5.2 Economy-wide Energy Security Performance

Table 5: Results of Economy-wide Energy Security Assessment

Energy Security Indicator	**2001**	**2012**	**% Change**
Energy intensity (toe per GH₵1000	0.94	0.61	-35.41
Oil intensity (toe per GH₵1000	0.20225661	0.212700066	5.16
Energy use per capita (toe per capita)	0.421649485	0.429686161	1.91
Oil use per capita (toe/capita)	0.090969072	0.118213439	29.95
Share of energy in the transport sector	0.23	0.33	46.70
Share of oil in the transport sector	0.819582956	0.751304615	-8.33
RPR of oil (2002-2012)	6.46183953	23.07721005	257.13
SWI	0.80	0.96	20.20
NCFP	0.069470868	0.062358622	-10.24
CO_2 emission ($MtCO_2$)	5.1761	9.51816092	83.89
CO_2 per capita (tCO_2 per capita)	0.27	0.37	37.74
CO_2 per GDP (tCO_2 per GH₵1000)	0.59	0.52	-12.70
Net energy import dependency (NEID) - %	59.31	25.15	-57.59
Energy import (ktoe)	26.71149144	39.72280546	48.71
SWI (power gen)	0.44	0.83	89.68

Table 5 above shows the results of the economy-wide energy security assessment, highlighting the priority areas of Ghana as stipulated in the National Energy Policy. In summary, the performances in oil intensity, non-carbon fuel portfolio (NCFP), CO_2 emission ($MtCO_2$), CO_2 emission per capita (tCO_2 per capita), and energy import declined between 2001 and 2012.

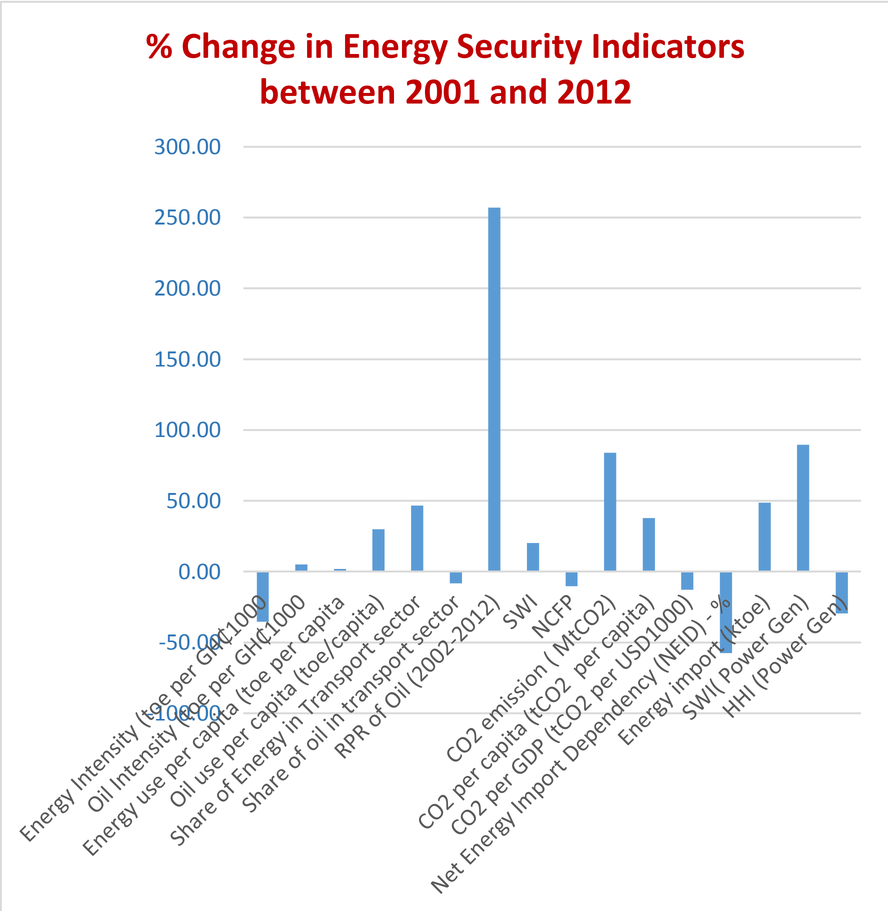

Figure 34. Source: Author's own elaboration using data from EC of Ghana and IEA.

Figure 34 elaborates the percentage changes in the performances of the indicators between 2001 and 2012. These results are shown in detail in Figure 35 to 44. The figures show the trends of these key indicators, emphasizing the salient events in the energy security situation in Ghana over the study period.

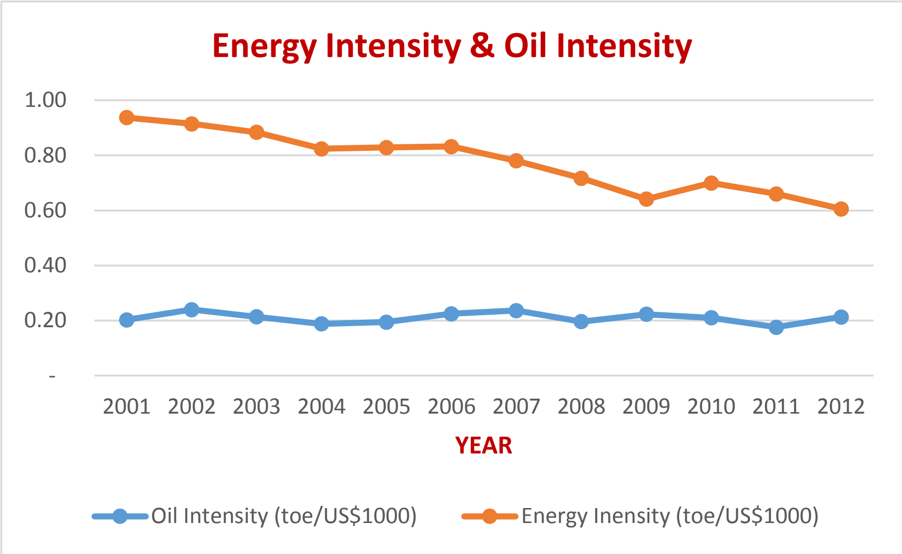

Figure 35. Source: Author's own elaboration using data from EC of Ghana and IEA.

Energy is essential for social and economic development, but its use affects resource availability and the environment. Especially, fossil use is a main source of air pollution and climate change. In this light, policymakers have been encouraged to improve efficiency and also to decouple economic development from energy use. A decreasing trend of energy use to GDP is therefore recommended (IAEA, 2005).

Figure 35 shows a steady decline in energy intensity from 0.9 toe/USD1000 in 2001 to 0.61 toe/USD1000 in 2012, which is in agreement with the globally accepted trends. The oil use per unit of GDP, however, was rather undulating, from the value of 0.20 toe/USD1000 in 2001 to a slightly higher value of 0.21 toe/USD1000 in 2012. Although this is not gloomy due to the marginal rise, appropriate measures must be taken to ensure a progressive decline of oil intensity.

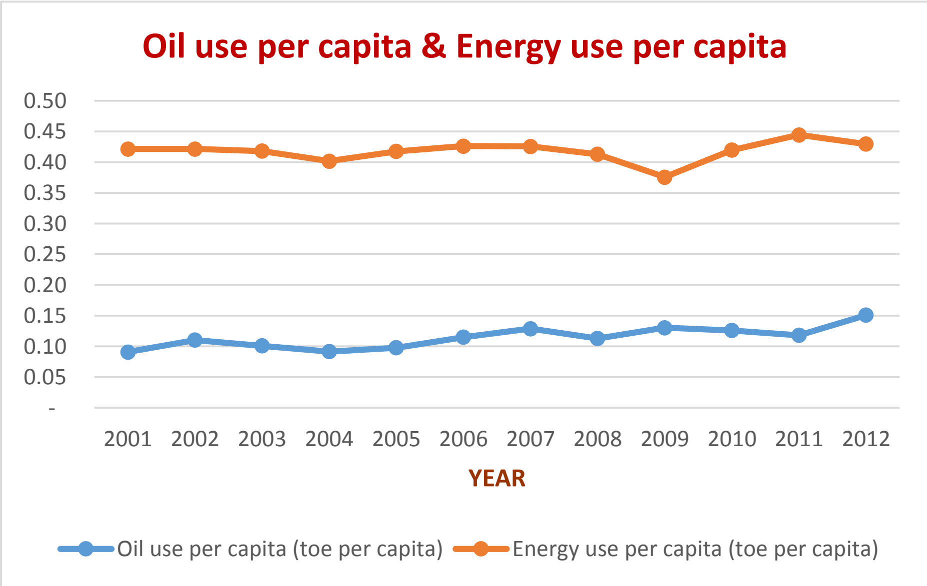

Figure 36. Source: Author's own elaboration using data from EC of Ghana and IEA.

Energy is critical to economic development and to the provision of essential services that improve the quality of life. Having said this, it is worth mentioning that the production, use, and by-products of energy have grossly compromised the integrity of the environment both by depleting the resources and creating pollution. On one hand, the long-term goal is for development and prosperity to continue through gains in energy efficiency rather than increased use, and through a transition towards the use of environmentally benign options. On the other hand, limited access to energy is a serious constraint to economic development, especially in the developing world, where the per-capita energy use is less than one-sixth that of the industrialized world (IAEA, 2005).

As can be seen in Figure 36, the energy use per capita slightly increased from 0.42 toe per capita in 2001 to 0.43 toe per capita in 2012. There was a dip to 0.38 toe per capita in 2009. This is an evidence of the serious power supply shortages in Ghana in 2009 due to the very low import levels of light crude oil, which was the main source of fuel for the Aboadze thermal plant in Takoradi (Energy Commission, Ghana, 2013). Although the country has registered a positive increase in energy use per capita, this is still inadequate to spur the projected economic development. The oil use per capita increased, however, from 0.09 to 0.15 toe per capita, signaling a positive quality of life.

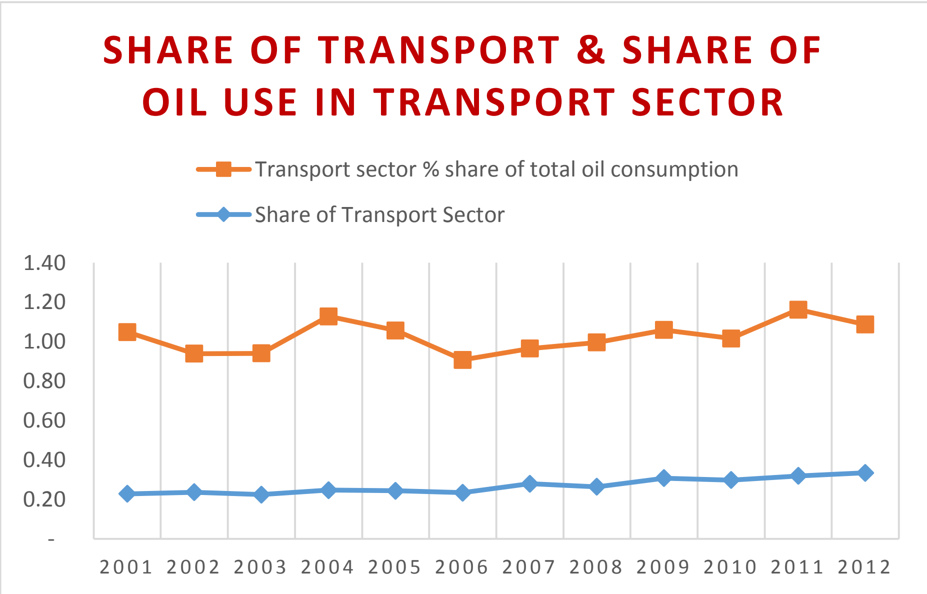

Figure 37. Source: Author's own elaboration using data from EC of Ghana and IEA.

The transport sector is essential for the movement of people, goods, and services, and hence plays a critical role in social and economic development

(IAEA, 2005). Its share in the total energy use is an indication of social and economic progress, but it is also a measure of the dependency on oil.

Figure 37 shows that the share of the transport sector in the total energy consumption increased from 0.23 in 2001 to 0.33 in 2012. The transport sector's share of oil use, however, decreased from 0.81 in 2001 to 0.75 in 2012. It must be stated that this is not an indication of a decreasing rate of oil consumption by the transport sector but rather of the increasing consumption of light crude oil by power plants (Energy Commission, Ghana, 2013). The curve, however, does not depict a steady decrease; hence, there is a need for appropriate policies to ensure consistent policy results. The discrepancies can be attributed to the suppressed demand during the periods of supply shortages.

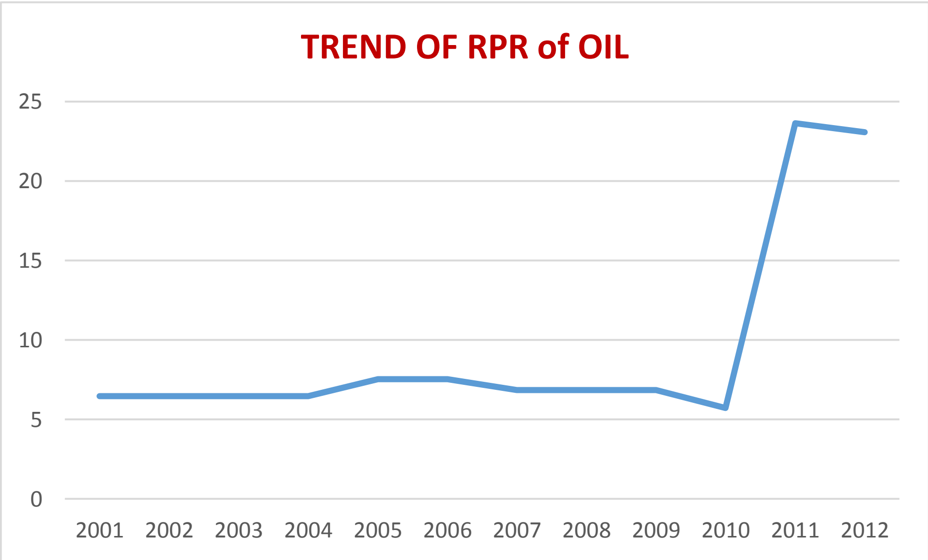

Figure 38. Source: Author's own elaboration using data from EC of Ghana and IEA.

The availability of energy fuel has been identified as a key aspect of sustainability. This parameter provides a basis for estimating the future energy supplies with respect to the current available levels of energy reserves and of the production. The proper management of proven energy reserves is a necessary component of national sustainable energy programs. Increasing levels of reserve-to-production ratio are considered more appropriate. This indicator is linked with the annual production, annual energy use, imports, prices, and resources (IAEA, 2005). Figure 38 shows that the reserve-to-production ratio of oil moved from 6.4 in 2001 to 23 in 2012. Before the major commercial discovery of oil in July 2007, Ghana's oil production was from Saltpond Fields, which currently produces about 500 barrels per day. The discovery of Jubilee Field is the reason for the sharp increase in the RPR of oil (Energy Commission, Ghana, 2013).

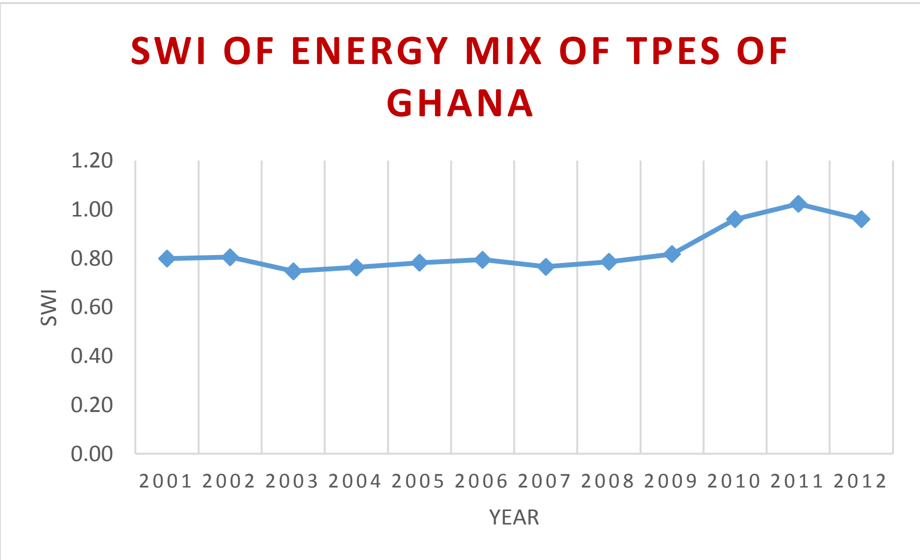

Figure 39. Source: Author's own elaboration using data from EC of Ghana and IEA.

The energy supply mix is a key determinant of energy security. Hence, the appropriate energy mix for a country relies on a well-diversified portfolio of domestic and imported or regionally traded fuels and sources of energy (IAEA, 2005). Also, the particular mix of fuels used in energy affects the energy intensities. Ghana's overall energy supply mix increased from 0.8 in 2001 to 0.96 in 2012, which is a good trend despite the predominant reliance on wood fuel.

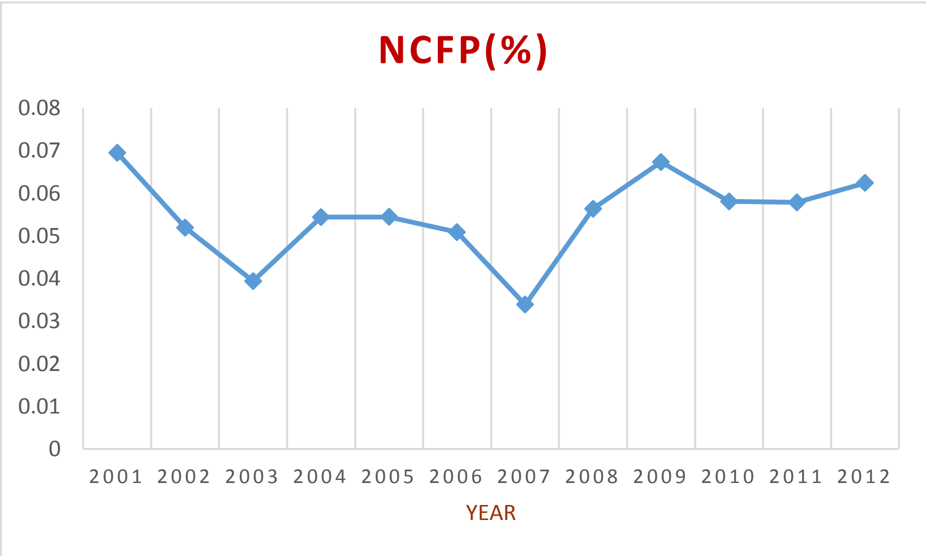

Figure 40. Source: Author's own elaboration using data from EC of Ghana and IEA.

This indicator measures the share of non-carbon energy sources in TPES and electricity generation. The promotion of energy and electricity generation from non-carbon sources has been tagged as critical for sustainable energy development due to a number of reasons, ranging from environmental protection to the security and diversification of energy supply. An increase in the proportion of non-carbon fuels reduces the specific emissions – that is, the emissions per unit of total energy of greenhouse gases (GHGs) as well as other pollutants affecting the local air quality and regional acidification (IAEA, 2005).

As shown in Figure 40, Ghana's NCFP was reduced from 0.069 in 2011 to 0.062 in 2012, demonstrating a negative trend. This means that the country is progressively using less renewable energy in its TPES.

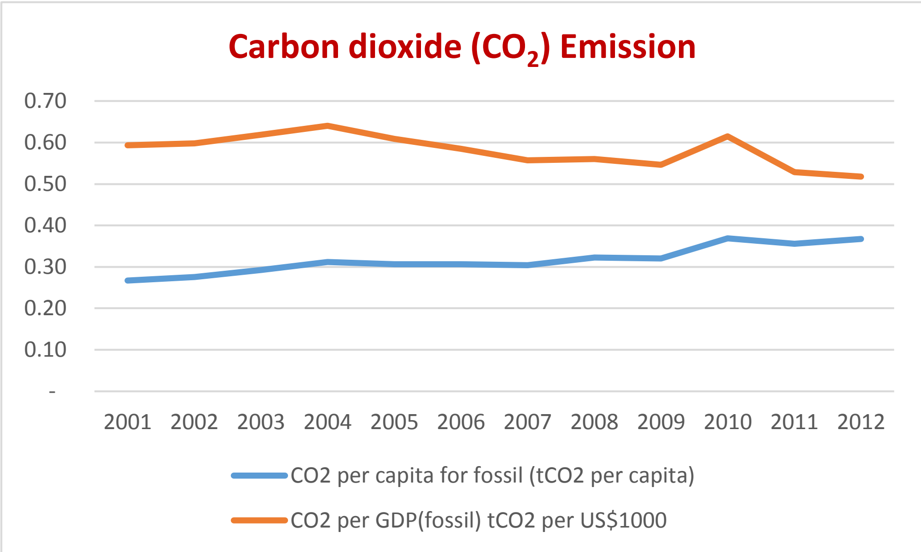

Figure 41. Source: Author's own elaboration using data from EC of Ghana and IEA.

This indicator measures the total per-capita CO_2 emission per unit of GDP from energy production, which have a direct impact on climate change. The 20th century saw an around 0.06˚C increase in average global temperature, with increasing evidence that most of this warming can be attributed to the increasing concentrations of GHGs in the atmosphere. The amount of CO_2 in the atmosphere has increased by more than 30% since the pre-industrial times, and is currently increasing at an unprecedented rate of 0.4% per year mainly due to the combustion of fossil fuels and deforestation. A continuation of this trend will lead to even more extreme weather events than in the past (IAEA, 2005). Generally, a declining trend in the per-capita CO_2 emission per unit of GDP is encouraged. Figure 41 shows that Ghana's per-capita CO_2 emission increased from 0.27 to 0.37. The per-capita CO_2 emission per unit of GDP, however, declined from 0.59 to 0.52, which is encouraging.

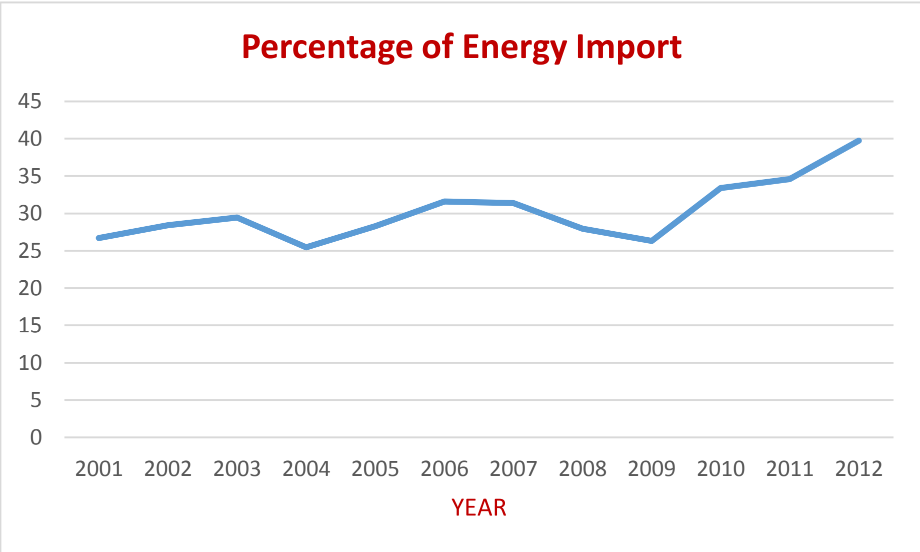

Figure 42. Source: Author's own elaboration using data from EC of Ghana and IEA.

Net energy import dependency (NEID) is used to measure the extent of a country's reliance on imports to meet its energy requirements. The physical availability of supplies to satisfy the demand at a given price for economic and social sustainability is paramount. The level of a country's reliance on imported fuel has a corresponding measure of risk in supply reliability. The general exposure to energy supply disruptions can be limited by decreasing the import dependency. This can be achieved through policies towards enhancing indigenous energy production, energy efficiency, fuel source diversification, and fuel mix optimization (IAEA, 2005).

Figure 42 indicates that Ghana's energy imports increased from 26.7% in 2001 to 39.7% in 2012, a worrying trend. The NEID, however, decreased from 59.3% in 2001 to 25.1% in 2012, as shown in Figure 43. This can be attributed to the major discovery of oil and gas in July 2007. The entire production volume has been exported since the commencement of production in December 2010, resulting in a declining NEID, which is a positive trend. The local consumption of the oil produced, however, will largely reduce the country's import dependency.

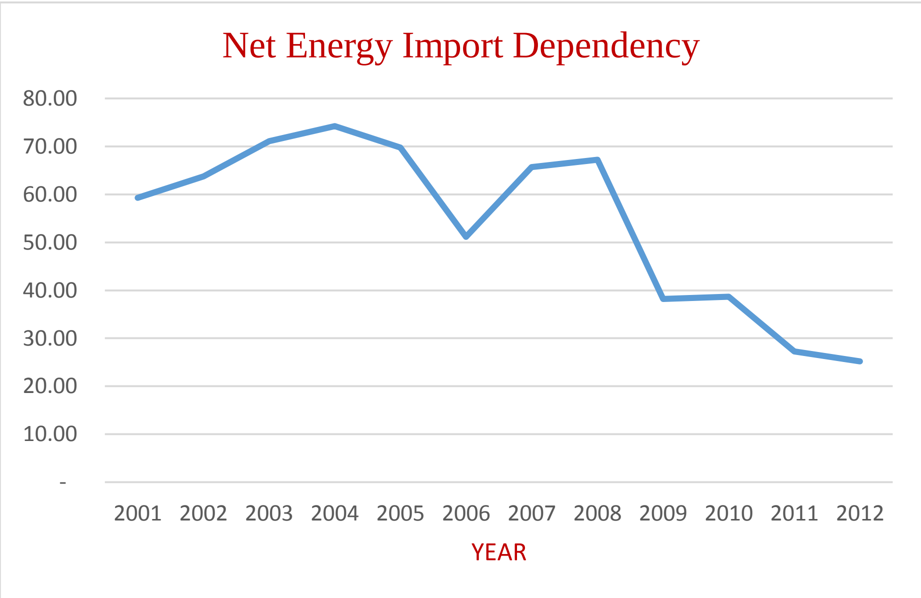

Figure 43. Source: Author's own elaboration using data from EC of Ghana and IEA.

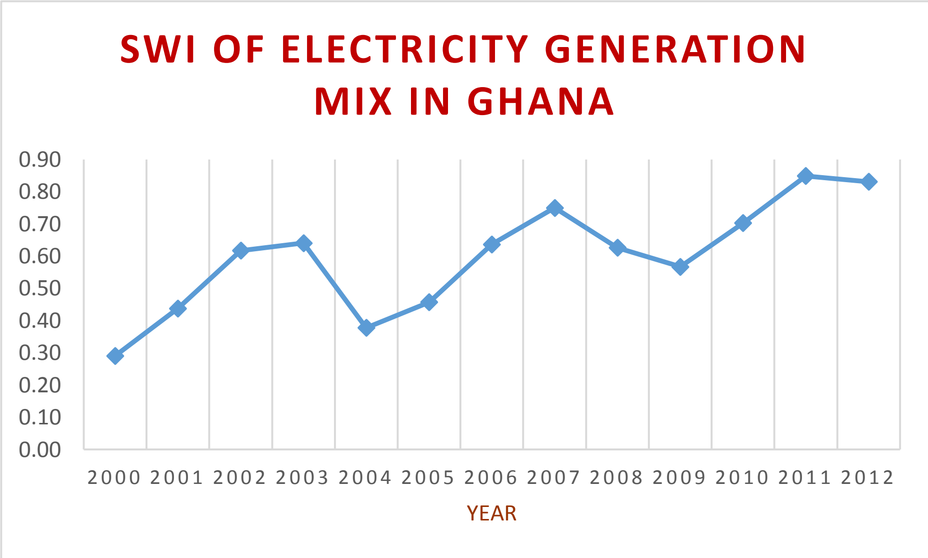

Figure 44. Source: Author's own elaboration using data from EC of Ghana and IEA.

The SWI for electricity generation measures the fuel type diversity for electricity generation. The electricity generation mix is a key determinant of energy security. This relies on a well-diversified portfolio of domestic and imported or regionally traded fuels and sources of energy (IAEA, 2005). Exposure to generation reductions due to a supply disruption in a particular fuel type is a limiting factor for energy security. Also, the particular mix of fuels used in energy affects the energy intensities. If all the fuels are from a single source, the minimum value for SWI (0) is reached. As the number of fuel sources increases, the SW index also increases. Ghana's electricity generation mix increased from 0.29 in 2001 to 0.83 in 2012, which is a very positive sign.

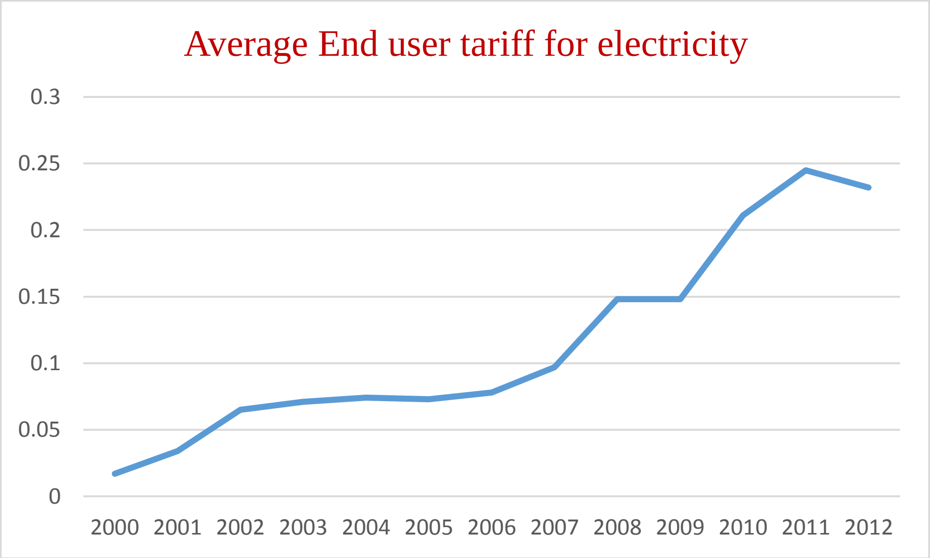

Figure 45. Source: Author's own elaboration using data from EC of Ghana and IEA.

There is an option to regulate energy prices to internalize the environmental and social costs as well as to manage the demand and to encourage the development of alternative and renewable energy sources. Developing countries, on the other hand, have a dire need to increase their energy availability and affordability, particularly for the lower-income groups of the population, to boost social and economic development. Efficient energy use in developing and developed countries is a major priority nonetheless. Consequently, pricing mechanisms can be explored to mitigate the inefficiencies (IAEA, 2005).

In figure 45, the average end user tariff for electricity steadily increased from 2000 to 2012. In 2002, the government of Ghana introduced a 25-cent subsidy per consumer in the lifeline band (50 kWh per month or less), to be paid to the electricity distributors. The lifeline subsidy was raised to 30 cents in October 2003 to keep the lifeline tariff at 32 cents while the tariff for the other customers increased according to the newly implemented automatic formula (Banerjee, 2005).

A research by ESMAP revealed that the lifeline tariff represents an imperfect mechanism of targeting the 5-20% of the consumers who show signs of vulnerability. Indeed, as per the report, it was originally designed not to target the poor but to ease the administrative burden on the utility and to provide a "basic needs" level of service. This notwithstanding, it has the potential to provide vital protection to the minority of electricity consumers who have (a) exhibited indicators of vulnerability, and (b) stated that they have trouble paying their bills. The reality, however, is that most of the target customers are not using the lifeline, which can be attributed to the knowledge gap because the target group predominantly consists of the rural poor, who unfortunately are also largely illiterate (Banerjee, 2005).

Figure 50 in Appendix D shows the price trend of the major petroleum products from 2007 to 2012. The figure shows a steady yet marginal rise in the prices of gasoline and gasoil, reflecting the increasing world prices. The prices of LPG and kerosene were relatively low, however, because of the existing policies. In the bid to address the issue of deforestation, LPG was highly subsidized to encourage its use. This policy has come under serious scrutiny of late, however, due to the abuse of the policy by the commercial drivers. The Kerosene Improvement Program, which essentially aims to make the commodity available at all areas of the country at the same subsidized price, accounted for the steady price of kerosene over the study period (Ministry of Energy, Ghana, 2013).

Chapter 6 - Conclusion and Policy Implications

6.1 Conclusion

According to the panel data analysis, all the variables (energy security index and metrics), apart from the reserve-to-production ratio, had more between variations than within variations. This shows that energy security metrics vary widely from country to country. Metrics like the reserve-to-production ratio, and to some extent forest cover and renewable energies, can be attributed to natural-resource endowment, but the same cannot be said of the others. The panel data variation showed that more has to be done to bridge the energy security gap between countries. The more within variations than between variations for the reserve-to-production ratio indicates increasing volumes of the global reserves of oil and gas.

Natural endowment without appropriate policies to improve the other metrics does not guarantee energy security. This is illustrated by the performances of Brunei, Japan, New Zealand, USA, and EU compared to those of Tunisia, Egypt, Algeria, and Libya.

The objective of the country comparative analysis was to determine which countries performed better than Ghana in terms of absolute performance, and then to identify in which indicators they did so. The essence of this exercise was to identify which countries and policies Ghana can learn from, the reason being that good performance is linked to good policies. It is worth noting, however, that different countries have different conditions, and therefore, it is imperative that their respective situations be juxtaposed on that of Ghana to know which country has a similar situation as Ghana to determine which of the policies are doable in the Ghanaian context. This research, however, ends at identifying the country and metric.

Extensive policy analysis is required to identify the best policy alternatives with respect to the different metrics. One can be tempted to identify all the counties that performed better than Ghana in the individual metrics, but that will defeat the very essence of the composite index, which is to eliminate the limitations of measuring the performances of individual indicators in isolation. The logic here is that a country with a good overall energy security performance must be implementing policies targeting not only individual metrics but also the comprehensive energy security of the country.

Based on the discussion of Table 2, which is a summary of the analysis results, it can be said that Ghana has room for improvement in all the metrics. The better absolute performers in the respective metrics provide the benchmark for policy adoption and adaptation. It will be appropriate to start from the African countries and to progressively consider much higher benchmarks outside Africa.

The sustainable policy analysis revealed that higher values of time-bound strategic plan, tax relief, and regulatory instruments are associated with the higher values of the energy security index.

The economy-wide security analysis revealed that Ghana has negative trends for oil intensity, non-carbon fuel portfolio, CO_2 emission, CO_2 emission per capita, and energy import.

6.2 Policy Implications

The relative natures of the energy security indices imply that the energy security of countries are interrelated and hence require a global concerted effort.

Although natural-resource endowment is a key factor of energy security and is largely responsible for the disparity in the index, it is necessary that other equally important metrics be given due attention through the formulation and implementation of the appropriate policies.

The overall best performers and the best African performers provide a good lead for Ghana in its quest to improve its existing energy security situation. Ghana has to strengthen its policies regarding the formulation of a time-bound strategic plan, tax relief, and regulatory instruments to improve its energy security situation for sustainable development. This can be done through a review of the existing policies as well as the strengthening of the relevant institutions.

Improvement in the portion of modern forms of alternative and renewable energies such as wind and solar energy and biofuel, alongside afforestation programs, can reverse the trend of NCFP and CO_2 emission per capita. Also, the shift from power generation from light crude oil and gas to purely gas, with recourse to the country's gas resources and also from Nigeria via the West African Gas Pipeline, can reverse the oil intensity trend. Also, the development of indigenous oil and gas resources as well as the progressive inclusion of solar and wind energy as well as biogas and biodiesel with recourse to the country's natural-resource endowment can help reduce the dependency on energy import.

In terms of the electricity tariff and the prices of petroleum products, there is a need to explore a mechanism that can progressively encourage economic growth and yet mitigate the inefficiencies. One alternative is to review the existing lifeline tariff policy to make it useful to the target group.

Finally, it is necessary for Ghana to review the respective country-specific energy security policies and strategies to address the performances of the indicators that registered a negative trend. This is needed to address the specific issues related to the country's energy security situation as per the National Energy Policy.

Again, the fact that there were better performers than Ghana in Africa and beyond indicates that there is room for improvement. In this regard, there is a need to review the overall energy security policy of Ghana, and to incorporate the international best practices therein.

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Appendix A

Table 6: Dimensions, components, and metrics compromising an energy security index

Dimension	Component	Metric	Unit	Definition
Availability	Security of Supply	Total primary energy supply per capita	Thousand tons of oil equivalent (ktoe)	Total primary energy supply comprises the production of coal, crude oil, natural gas, nuclear fission, hydroelectric, and other renewable resources plus imports less exports, less international marine bunkers and corrected for net changes in energy stocks.
	Production	Average reserve-to-production ratio for the three primary energy fuels (coal, natural gas, and oil) Self-sufficiency	Remaining years of production	Ratio of proven recoverable reserves at the end of a given year to the production of those reserves in that year
	Dependency Diversification	Share of renewable energy in total primary energy supply	% Energy demand by domestic production % of supply	Percentage of total primary energy supply divided by total primary energy consumption Share of geothermal, solar, wind, hydroelectric, tidal, wave, biomass, municipal waste, and biofuel based energy in total primary energy supply

Source: (Benjamin K. Sovacool*, 2011)

Table 7: Dimensions, components, and metrics compromising an energy security index-cont.

Dimension	Component	Metric	Unit	Definition
Affordability	Access	% of population with high quality access to the electricity grid	% Electrification	Combined percentage of urban and rural electricity customers with reliable grid connections compared to all people in the country
	Affordability	Retail price of gasoline/petrol	Average price in US$ for 100 L of regular gasoline/petrol PPP (adjusted for Purchasing Power Parity)	Actual prices paid by final consumers for ordinary gasoline inclusive of all taxes and subsidies
Technology development and efficiency	Energy Efficiency,	Energy intensity	Energy consumption per dollar of GDP	Total primary energy consumption in British thermal units per dollar of GDP (2005 US$ PPP)
	Safety and Reliability	Grid efficiency	% of Electricity transmission and distribution losses	Electric power transmission and distribution losses include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage.

Table 8: Dimensions, components, and metrics compromising an energy security index-cont.

Dimension	Component	Metric	Unit	Definition
Environmental sustainability	Land use	Forest cover	Forest area as percent of land	Forest area is land under natural or planted stands of trees of at least 5 m in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens
	Water	Water availability	% of population with access to improved water	Improved sources include household connections, public standpipes, boreholes, protected wells, and/or spring and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 L a person a day within 1 km of dwelling.
	Climate change Pollution	Per capita energy-related carbon dioxide emissions	Metric tons of CO_2 per person	Annual tons of carbon dioxide emissions from fuel combustion divided by total national population

(Benjamin K. Sovacool*, 2011)

Table 9: Dimensions, components, and metrics compromising an energy security index-cont.

Dimension	Component	Metric	Unit	Definition
Regulation and Governance	Governance	Worldwide governance rating	Worldwide governance score	Mean score given for the six categories of accountability, political stability, government effectiveness, regulatory quality, rule of law, and corruption.
	Information	Quality of energy information	% Data complete	% of data points complete for this index out of all possible data points

(Benjamin K. Sovacool*, 2011)

Table 10: The criteria that define energy security by various sources

No.	Criterion to define energy security	WEC	APERC	IEA	Brazil	India	Japan	Kenya	Senegal	South Africa	Ghana	USA
1	Availability of energy resources supply, greater self-reliance/ self-sufficiency	√	√	√	√	√	√	√		√	√	
2	Covering energy requirement/demand diversity	√	√	√	√	√	√		√		√	
3	Energy price – affordable price or acceptable price	√	√	√		√	√		√	√	√	
4	Diversification of energy resources, Diversification of import source countries/ suppliers		√				√	√		√	√	√
5	Not adversely affect the economic performance, interactions among economic sectors	√	√				√		√	√		
6	Without harming the environment, Good quality energy supply			√					√	√	√	

(Jutamanee Martchamadol, 2012); (Ministry of Energy, Ghana, 2010)

Table 11: The criteria that define energy security by various sources-cont.

No.	Criterion to define energy security	WEC	APERC	IEA	Brazil	India	Japan	Kenya	Senegal	South Africa	Ghana	USA
7	Geopolitical concerns surrounding resource acquisition risk, risks reduction/risk management (transportation, domestic, supply interruption)		√	√			√					
8	Available in timely manner		√	√		√					√	
9	Fight against poverty								√	√	√	
10	Mixes in a cost effective manner-production cost reduction							√				
11	Prescribed confidence level considering shocks and disruptions			√		√						
12	Resilient energy system supply/withstanding threats/less vulnerable infrastructure			√								
13	Securing energy supply for Social activities. Defense and other purposes						√					√

(Jutamanee Martchamadol, 2012); (Ministry of Energy, Ghana, 2010)

Table 12 Selected Indicators to assess energy security

No.	Indicator	Definition
Energy Demand		
1	Energy and oil intensity	The ratio of energy/oil consumption to GDP
2	Energy and oil use per capita	The ratio of energy/oil consumption to country’s population
3	Share of transport sector	The share of energy consumption in transportation sector per total final energy consumption
4	Share of oil use in transport sector	The share of oil use in transportation sector per total oil consumption in all sector
The availability of energy supply resources		
1	Resource estimate	Quantity and likelihood of occurrence of fossil resource
2	Reserve to production ratio (RPR)	Resource estimate and production ratio (at country or global level)
3	Diversity indices (Shannon Wiener Index SW1)	Shares of fuel in total primary
Environmental concerns		
1	Non-carbon incentive fuel portfolio (NCFP)	The total of non-carbon fuel (hydro, nuclear, new and renewable) consumption for per total primary energy supply
2	CO_2 emission	The estimation of annual CO_2 emission of all fossil fuel (oil, natural gas, and coal) consumption

(Jutamanee Martchamadol, 2012)

Appendix B

Table 13 Energy security indicators based on energy demand

No.	Indicator	Equation	Data requirement and definition
1	Energy and oil intensity	$OI = \frac{\text{Oil consumption}}{\text{GDP}}$, $EI = \frac{\text{TPES}}{\text{GDP}}$	EI Energy intensity (kgoe per GH₵) TPES Total primary energy supply (Mtoe) GDP Gross domestic production (billion GH₵) OI Oil intensity (kgoe per GH₵1000)
2	Energy and oil use per capita	Oil use per capita $\frac{OC}{pop}$, Energy use per capita = $\frac{TPES}{pop}$	TPES Total primary energy supply (Mtoe) OC Oil Consumption (Mtoe) pop Population (Million)
3	Share of transport sector	$Trans\ share = \frac{Energy_{trans}}{TFEC}$	Trans share Share of energy consumption in transportation (%) TFEC Total final energy consumption (Mtoe) $Energy_{trans}$ Energy consumption in transportation sector (Mtoe)
4	Share of oil use in transport sector per total oil use	Historical data of oil consumption, domestic oil production, and import oil $OS = \frac{\text{Oil consumption in Transportation}}{\text{Total oil consumption in all sectors}}$	Total oil consumption in all sectors (Mtoe) Domestic production (Mtoe) Import oil (Mtoe) OS Share of oil in transportation sector (%) Oil consumption in transportation sector (Mtoe) Total oil consumption in all sectors (Mtoe)

Table 14 Energy security indicators based on energy supply

No.	Indicator	Equation	Data requirement and definition
1	Resource		Proven reserve of oil (Mtoe) Proven reserve of natural gas (Mtoe)
2	Reserve to production ratio (RPR)	$\text{PRP}= \frac{\text{Proven reserve of fuel } i}{\text{Domestic production of fuel } i}$	Proven reserve of each type of fuel (Mtoe) Domestic production of each fuel (Mtoe/year)
3	Diversity index	$\text{SWI} = -\sum \text{S}_\text{i} \times \ln(\text{S}_\text{i})$	SWI Shannon-Wiener index S_i Share of fuel *i* in total primary energy supply (TPES) (%)

Table 15 Energy Security Indicators based on energy market and expenditure

No.	Indicator	Equation	Data requirement and definition
1	Energy import	$\sum_{i=1}^{n} IM_i/TPES$	IM_i Import of energy carrier i (Mtoe) TPES Total primary energy supply (Mtoe)
2	Net energy import dependency (NEID)	$NEID=\frac{\sum_i m_i p_{i \ln p_i}}{\sum_i p_i \ln p_i}$	NEID Net energy import dependency (%) *mi* Share in net imports of energy carrier (%) *pi* Share in total primary energy supply (TPES) of energy carrier I (%)

Appendix C

Table 16 Energy Security data 35 countries for 1990

No	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid con (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Quality of energy Information (out of 11)
1	Ghana	0.35	0	1.0	74	25	53	18248	3.15	32.7	21	0.27	11
2	Nigeria	0.73	345.6970726	2.1	80		50	12387	38.42	18.9	49	0.47	10
3	Cote d' Ivoire	0.34	68.49315068	0.8	73		124	6168	18.36	32.1	71	0.48	10
4	Togo	0.32	0	0.8	83		81	5916	20.88	12.6	-	0.20	9
5	Cameroun	0.41	3.403386369	2.2	77	29	68	6228	13.05	51.4	44	0.14	11
6	South Africa	2.67	0	1.2	11			20623	6.03	7.6	-	9.47	8
7	Congo DR	0.32	4.540387341	1.0	85		81	10181	19.75	70.7	36	0.11	10
8	Zambia	0.68	0	0.9	74	19	40	20709	3.22	71.0	-	0.31	10
9	Angola	0.55	61.10021629	4.9	73			4598	25.10	48.9	35	0.43	9
10	Egypt	0.55	27.55066004	1.7	3		29	27942	10.96	0.0	90	1.35	10
11	Algeria	0.88	42.5767066	4.5	0		15	17840	14.36	0.7	-	3.00	9
12	Tunisia	0.61	154.9436589	1.2	13		58	12327	10.34	4.1	-	1.63	9
13	Morocco	0.28	35.97646646	0.1	5		82	8359	8.53	11.3	56	0.95	10
14	Libya	2.60	80.93399751	6.5	1			12830	31.20	0.1	-	8.63	8
15	Kenya	0.47	0	0.8	77		53	9566	15.00	6.5	-	0.25	9
16	Ethiopia	0.29	0	1.0	95		27	7377	9.98	15.2	-	0.06	9

Table 17 Energy Security data 35 countries for 1990-cont.

No.	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Quality of energy Information (out of 11)
17	Tanzania	0.38	0	0.9	92	7	42	8138	19.96	46.8		0.09	10
18	Brunei	6.90	30.43443612	8.9	0		0	12976	5.00	59.0		13.10	9
19	Cambodia		0		41		0	623		73.0	35	0.10	7
20	Indonesia	1.70	34.84146591		18	37	0	6280	14.00	64.0	71	0.80	10
21	Laos		0		95		0	1911		75.0	29	0.10	7
22	Malaysia	1.20	46.2073254	2.2	16		151	7920	7.00	68.0	88	2.70	10
23	Myanmar	0.30	129.4846376	1.0	49		0	1791	26.00	60.0	57	0.10	10
24	Philippines	0.40	4.371903235	0.6	46	55	0	4919	15.00	35.0	84	0.60	11
25	Singapore	3.80	0	0.0	0		93	11262	3.00	3.0	100	9.50	10
26	Thailand	0.70	23.83890362	0.6	11	93	120	5577	11.00	31.0	91	1.40	11
27	Vietnam	0.40	38.20071894	1.0	63		0	4430	25.00	29.0	58	0.30	10
28	China	0.80	46.59582929	1.0	21		0	21261	7.00	17.0	67	2.00	10
29	India	0.40	44.38888473	0.9	26		518	7696	20.00	22.0	72	0.70	10
30	Japan	3.60	10.21590493	0.2	12	100	0	5794	5.00	68.0	100	8.60	11
31	Korea	1.60	0	0.2	5	100	136	8564	9.00	65.0	93	5.40	11
32	USA	7.70	9.627223179	0.9	12	100	0	10540	9.00	33.0	99	19.50	11
33	EU	3.20	11.97432069	0.6	12	100	0	7268	0.00	34.0	100	7.90	11
34	Australia	5.00	15.38201088	1.8	10	100	0	8861	7.00	22.0	100	15.20	11
35	New Zealand	3.60	20.14792899	0.9	80	100	0	11090	11.00	29.0	100	6.30	11

Table 18 Energy Security data 35 countries for 1995

No	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance. rating	Quality of energy Info (out of 12)
1	Ghana	0.38	0.171232877	1	73.0649	31	38	17,272	3.33		56	0.323	42	11
2	Nigeria	0.72	339.6726985	2.11	83.46		13	14,397	37.718	16.67	39	0.32	13	11
3	Cote d' Ivoire	0.34	185.8666084	0.84	72.79	37	83	5,914	16.19	32.31	72	0.5	42	12
4	Togo	0.35	0	0.87	85.24		47	7,305	10.36	10.76	63	0.22	26	11
5	Cameroun	0.39	4.936443293	1.78	79.49		68	6,734	21.83	49.11		0.31	14	10
6	South Africa	2.78	6.927188674	1.24	11.04		51	23,045	6.22	7.62	70	9.03	61	11
7	Congo DR	0.29	8.538812785	1.05	89.64		73	15,107	3.35	70	27	0.07	2	11
8	Zambia	0.64	0	0.92	78.67	19	60	20,139	2.83	69.9	43	0.25	28	12
9	Angola	0.51	57.00027947	5.69	76.17		29	6,375	28.44	48.4	32	0.91	8	11
10	Egypt	0.55	26.82646909	1.69	3.38			26,107	10.65	0.05	64	1.56	44	10
11	Algeria	0.85	42.03976899	4.43	0.16		40	18,864	16.94	0.68		3.23	17	10
12	Tunisia	0.65	52.27196144	0.92	12.92		64	10,710	9.89	4.76	99	1.76	50	11
13	Morocco	0.32	45.26914914	0.1	4.64		94	9,661	5.73	11.28	52	1.13	50	11
14	Libya	3.27	124.7474981	4.82	0.89			14,451	23.24	0.12		9.69	15	9
15	Kenya	0.45	0	0.84	79.18	11	56	9,800	18.33	6.4	53	0.28	27	12
16	Ethiopia	0.29	0	0.95	95.32		32	6,771	10.01	14.41		0.04	13	10

Table 19 Energy Security data 35 countries for 1995-cont.

No	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid connection (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance. rating	Quality of energy Information
17	Tanzania	0.37	0	0.91	89.84	-	56	5,988	12.99	44.57	-	0.12	27	10
18	Brunei	7.8	32.54475743	7.9	0	-	0	9,791	4	57	-	15.9	71	10
19	Cambodia	0.3	0	0.9	26	-	0	1,348	40	69	37	0.1	19	11
20	Indonesia	0.7	19.65618957	1.6	18	63	675	6,061	12	59	74	1	38	12
21	Laos		0		97	15	0	1,801	-	73	44	0.1	28	9
22	Malaysia	1.8	41.96732639	1.7	14	-	121	7,617	9	67	92	3.8	66	11
23	Myanmar	0.3	91.69718334	0.9	41	-	0	1,851	38	56	60	0.2	9	11
24	Philippines	0.5	5027.721883	0.5	38	-	143	5,825	17	31	87	0.8	52	11
25	Singapore	5.3	0	0	0	-	95	10,886	4	3	100	10.8	84	11
26	Thailand	1	14.19356532	0.5	9	-	85	6,222	8	30	94	2.4	58	11
27	Vietnam	0.4	77.74563459	1.2	73	-	326	5,385	22	32	68	0.4	37	11
28	China	0.9	60.04695185	1	20	-	102	15,349	7	18	74	2.5	42	11
29	India	0.4	31.14029605	0.9	18	-	312	8,723	19	22	76	0.8	44	11
30	Japan	4	8.310870601	0.2	10	100	63	6,077	5	68	100	9.1	78	12
31	Korea	1	0	0.1	2	100	125	9,735	14	64	90	8	65	12
32	USA	7.8	9.094226986	0.8	12	100	46	10,030	7	33	99	19.3	91	12
33	EU	3.2	11.88416878	0.7	13	100	0	6,506	0	35	100	7.6	79	12
34	Australia	5.1	13.42420941	2	10	100	0	8,447	7	22	100	15.7	90	12
35	New Zealand	4	14.9238811	0.8	84	100	75	10,658	11	30	100	6.7	98	12

Table 20 Energy Security data 35 countries for 2000

No	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid con (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance rating	Quality of energy Information
1	Ghana	0.4	3.230919765	1	68.7058	-	20	17,057	18.87	26.78	64	0.334	50.01166667	11
2	Nigeria	0.72	155.1375688	2.25	81.76	45	27	11,929	38.147	14.42	57	0.64	16.02	12
3	Cote d' Ivoire	0.39	22.92668382	0.89	62.73	-	76	8,158	14.56	32.47	77	0.42	18.95833333	11
4	Togo	0.4	0	0.84	83.19	15	48	11,615	47.42	8.93	54	0.29	22.44833333	12
5	Cameroun	0.4	6.459911597	1.77	79	-	56	5,664	21.87	46.79	62	0.22	19.39666667	11
6	South Africa	2.6	8.239901131	1.27	11.56	63	50	22,401	8.2	7.62	86	8.38	62.535	12
7	Congo DR	0.33	9.852476291	1.05	94.48	-	1	15,620	2.95	69.36	45	0.04	1.226666667	11
8	Zambia	0.6	0	0.95	82.31	19		17,235	3.18	68.8	64	0.18	31	11
9	Angola	0.52	50.17189909	5.88	74.77	12	30	4,856	14.6	47.91	38	0.69	3.593333333	12
10	Egypt	0.64	32.4731913	1.25	3.21	-	26	25,594	13.76	0.059	95	2.14	41.78666667	11
11	Algeria	0.89	37.5453304	5.26	0.19	-	27	15,366	16.15	0.66	94	2.77	14.23666667	11
12	Tunisia	0.76	26.06559226	0.91	12.78	-	49	11,559	10.54	5.39		2.1	52.33333333	10
13	Morocco	0.36	22.55092297	0.06	4.26	-	82	9,575	8.4	11.24	82	1.18	48.93833333	11
14	Libya	0.31	138.1504793	4.39	0.88	-	25	15,583	23.18	0.12	72	9.1	17.435	11
15	Kenya	0.44	0	0.84	78.27	-	71	9,135	20.67	6.29	49	0.33	24.345	11
16	Ethiopia	0.28	0	0.94	95.17	13	46	7,173	9.98	13.71	24	0.09	20.345	12

Table 21 Energy Security data 35 countries for 2000-cont.

No.	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance rating	Quality of energy Information
17	Tanzania	0.39	0	0.95	93.04	-	0.75	5,785	22.38	42.29	54	0.08	31.48666667	11
18	Brunei	7.4	29.33769357	8	0	99	87	9,607	1	55	99	14	68	12
19	Cambodia	0.3	0	0.8	10	16	293	1,526	19	65	46	0.2	26	12
20	Indonesia	0.8	20.9296564	1.6	17	53	148	6,997	11	54	77	1.3	26	12
21	Laos	-	0		90	-	315	3,756	-	72	48	0.2	19	8
22	Malaysia	2	33.27731831	1.6	19	97	83	8,108	8	66	97	4.8	61	12
23	Myanmar	0.3	47.2276564	1.2	38	5	12	1,751	31	53	66	0.2	6	12
24	Philippines	0.5	4310.379162	0.5	44	87	152	6,248	14	27	88	0.9	42	12
25	Singapore	4.5	0	0	0	100	130	10,285	4	3	100	10.6	87	12
26	Thailand	1.2	13.51893211	0.6	8	82	141	7,421	8	29	96	2.6	61	12
27	Vietnam	0.5	86.31958817	1.3	56	76	273	5,936	14	38	79	0.6	33	12
28	China	0.9	35.21500876	1	17	99	141	10,619	7	19	80	2.4	38	12
29	India	0.5	24.64939406	0.8	14	43	299	7,729	28	23	81	1	47	12
30	Japan	4.1	14.90895535	0.2	11	100	67	6,180	4	68	100	9.3	83	12
31	Korea	0.9	0	0.2	2	100	168	9,684	16	64	93	9	67	12
32	USA	8	9.485078188	0.7	10	100	58	8,820	6	33	99	20.2	92	12
33	EU	3.3	11.74144524	0.7	14	100	248	5,958	0	36	100	7.6	82	12
34	Australia	5.6	24.75310839	2.2	9	100	121	8,246	7	21	100	17.6	94	12
35	New Zealand	4.3	10.54720189	0.9	73	100	89	9,663	11	31	100	7.7	95	12

Table 22 Energy Security data 35 countries for 2005

No	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid con (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance rating	Quality of energy Information
1	Ghana	0.39	3.769406393	1.01	68.6968	48	49	13,918	23.968	24.246	78	0.325	51.335	12
2	Nigeria	0.74	129.6245458	2.24	78.58	52	39	9,634	23.705	12.175	57	0.75	15.775	12
3	Cote d' Ivoire	0.5	14.40346133	1.1	74.45	59	114	6,969	19.92	32.72	79	0.44	8.488333333	12
4	Togo	0.4	0	0.84	84.08	-	85	16,114	45.5	7.09	58	0.25	13.40166667	11
5	Cameroun	0.39	6.656681522	1.5	79.86	47	95	4,965	17.43	44.46	71	0.2	20.45166667	12
6	South Africa	2.76	0.630788532	1.21	10.57	10	81	20,734	8.49	7.62	89	8.39	62.87666667	12
7	Congo DR	0.34	12.97169496	1.04	94	-	92	13,652	11.27	68.68	45	0.04	3.513333333	11
8	Zambia	0.61	0	0.92	80.05	19	11	16,700	5.36	67.7	58	0.19	30.66666667	12
9	Angola	0.55	41.21586166	7.79	70.96	15	39	4,820	23.76	47.4	47	1.16	11.04	12
10	Egypt	0.79	27.61990137	1.26	2.28	-	28	28,860	11.59	0.067	98	2.33	36.865	11
11	Algeria	0.91	35.01704603	5.17	0.22	-	32	14,475	13.19	0.64	85	3.15	32.71666667	11
12	Tunisia	0.82	21.19165289	0.81	13.48	-	68	11,101	13.48	5.95	94	2.27	49.66666667	11
13	Morocco	0.43	16.55969077	0.05	3.46	-	11	8,362	6.3	11.38	80	1.52	38.27333333	11
14	Libya	2.96	97.86663851	5.38	0.87	-	0.9	15,162	12.54	0.12	-	9.31	20.56833333	10
15	Kenya	0.46	0	0.29	77.54	16	-	9,765	18.39	6.19	56	0.24	28.31333333	11
16	Ethiopia	0.28	0	0.94	94.02	14	6	7,405	10.02	13	35	0.06	15.745	12

Table 23 Energy Security data 35 countries for 2005-cont.

No.	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance rating	Quality of energy Information
17	Tanzania	0.44	27.77777778	0.92	89.02	11	-	6,392	27.62	40.01	54	0.14	36.89833333	12
18	Brunei	6.8	26.6789215	8.3	0	99	68	12,121	4	53		13.6	64	11
19	Cambodia	0.3	0	0.7	5	20	328	8,790	23	59	56	0.3	21	12
20	Indonesia	0.8	28.60379029	1.6	14	54	128	16,480	12	49	80	1.5	30	12
21	Laos	0	0	0.3	91	44	171	12,730	21	70	54	0.2	15	12
22	Malaysia	2.4	25.57622267	1.5	12	98	97	16,596	1	64	100	6	64	12
23	Myanmar	0.3	14.31564959	1.5	5	11	1	23,208	35	49	71	0.3	4	12
24	Philippines	0.5	26.73454371	0.6	33	81	176	13,292	12	24	90	0.8	42	12
25	Singapore	5.6	0	0	0	100	142	16,216	5	3	100	10.5	88	12
26	Thailand	1.5	12.32700443	0.6	7	99	167	20,794	8	28	98	3.3	54	12
27	Vietnam	0.6	26.26477632	1.4	41	84	275	22,651	11	42	88	1	36	12
28	China	1.3	22.05186489	1	17	99	145	30,236	7	21	86	3.9	35	12
29	India	0.5	26.56546183	0.8	16	56	350	19,468	26	23	85	1.1	48	12
30	Japan	4.1	16.22505851	0.2	10	100	92	5,032	5	68	100	9.6	85	12
31	Korea	0.9	3.050379024	0.2	1	100	193	10,924	16	65	96	9.7	74	12
32	USA	7.8	10.98266717	0.7	9	100	61	7,960	6	33	99	19.5	85	12
33	EU	3.4	11.89659737	0.6	14	100	294	5,726	0	37	100	7.6	82	12
34	Australia	5.8	14.65631537	2.3	8	100	100	7,360	6	21	100	19	92	12
35	New Zealand	3.9	7.888639295	0.8	65	100	72	7,862	7	31	100	8	96	12

Table 24 Energy Security data 35 countries for 2010

No	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid con (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance rating	Quality of energy Information
1	Ghana	0.39	229.390867	1.01	63.8051	61	82	13,418	23.574	21.71	82	0.314	55	12
2	Nigeria	0.7	111.243007	2.11	82.36	50	44	4,572	17.216	9.926	58	0.49	16	12
3	Cote d' Ivoire	0.49	12.56405488	1.15	75.27	59	168	6,863	20.2	32.71	80	0.31	12	12
4	Togo	0.4	0	0.83	82.59	28	118	9,549		5.27		0.24	22	11
5	Cameroun	0.35	325.8104001	1.28	63.79	49	12	6,270	9.83	42.13	74	0.35	18	12
6	South Africa	2.92	13.09286451	1.12	10.01	76	119	19,397	9.53	7.62	91	9.2	61	12
7	Congo DR	0.35	11.74168297	1.02	93.41	15	128	11,899	10.83	67.98	46	0.05	4	12
8	Zambia	0.61	0	0.92	80.86	19	166	14,235	23.7	66.5		0.18	38	11
9	Angola	0.64	191.8897508	8.49	57.43	40	65	4,569	11.51	46.9	50	1.56	15	12
10	Egypt	0.87	22.31743297	1.22	2.13	99.6	48	26,311	10.16	0.07	99	2.62	33	12
11	Algeria	1.14	37.45856943	3.83	0.13	99.3	32	15,300	19.89	0.63	83	3.33	24	12
12	Tunisia	0.88	23.81115138	0.85	14.39	99.5	94	7,692	11.64	6.48		2.45	46	11
13	Morocco	0.47	14.56128374	0.05	2.99	98.9	123	8,908	12.01	11.49	81	1.59	45	12
14	Libya	3.18	82.52955979	4.27	0.78	99.8	17	14,040	13.06	0.12		9.77	16	11
15	Kenya	0.47	0	0.83	72.18	18	133	9,370	15.73	6.09	59	0.3	29	12
16	Ethiopia	0.39	0	0.93	93.2	23	91	6,815	10	12.29	38	0.07	23	12

Table 25 Energy Security data 35 countries for 2010-cont.

No.	Country	TPES per capita (toe)	ARPR (natural gas and oil)	SS (%)	Share of RE in TPES (%)	Grid (%)	Retail price of 100L of gasoline (2009 USD PPP)	Energy Intensity (Btu/year, 2005 USD PPP)	Grid inefficiency (%)	Forest Cover (%)	Water availability (%)	Per capita energy related carbon emission (metric tons)	Worldwide governance rating	Quality of energy Information
17	Tanzania	0.45	4.17488029	0.92	88.59	15	122	6,085	19.43	37.74	54	0.15	39	12
18	Brunei	9.1	27.62462442	5.8	0	100	61	18,968	5	52	99	18.9	72	12
19	Cambodia	0.4	0	0.7	4	24	290	8,055	12	57	61	0.3	23	12
20	Indonesia	0.9	24.38690399	1.8	14	65	114	17,125	11	47	80	1.7	37	12
21	Laos	0	0	0.3	92	55	292	11,815	13	69	57	0.2	18	12
22	Malaysia	2.7	28.84303491	1.3	9	99	102	15,064	2	63	100	6.7	57	12
23	Myanmar	0.3	15.11888837	1.5	62	13	1	16,844	29	48	71	0.2	2	12
24	Philippines	0.5	22.69038965	0.6	34	90	188	11,185	13	23	91	0.8	37	12
25	Singapore	3.8	0	0	0	100	180	15,784	5	3	100	9.2	86	12
26	Thailand	1.6	7.151190434	0.6	8	99	246	19,855	6	28	98	3.4	46	12
27	Vietnam	0.7	14.30991825	1.2	37	98	242	24,332	11	43	94	1.2	36	12
28	China	1.6	22.88163733	0.9	17	99	190	26,718	6	22	89	4.9	37	12
29	India	0.5	20.52395121	0.8	15	66	296	18,825	25	23	88	1.3	46	12
30	Japan	3.7	14.26111889	0.2	10	100	120	4,741	5	68	100	9	85	12
31	Korea	4.7	1.05814586	0.2	1	100	217	10,349	16	64	98	10.3	72	12
32	USA	7.1	11.57080042	0.8	11	100	76	7,280	6	33	99	18.4	84	12
33	EU	3.2	10.42279641	0.6	17	100	197	5,360	0.06	37	100	7.4	82	12
34	Australia	6.1	41.12944287	2.4	8	100	83	7,106	7	21	100	18.5	93	12
35	New Zealand	4.2	5.06579784	0.9	73	100	117	7,549	7	31	100	7.7	96	12

Table 26 Socioeconomic Energy Parameters

Socio-economic energy parameters	Unit	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Population	Million	19.40	19.80	20.30	20.80	21.30	21.80	22.30	22.90	23.40	24.70	25.30	25.90
GDP at 2005 constant prices	Billion USD	8.73	9.12	9.60	10.14	10.73	11.42	12.16	13.18	13.71	14.81	17.03	18.38
GDP growth rate	%	4.18	4.55	5.25	5.58	5.87	6.43	6.46	8.43	3.99	8.01	15.01	7.91
TPES	ktoe	8,180.00	8,344.00	8,489.00	8,354.00	8,895.00	9,503.00	9,494.00	9,459.00	8,790.00	10,365.00	11,242.00	11,128.87
TFC	ktoe	6,337.00	6,470.00	6,539.00	6,781.00	6,926.00	7,388.00	7,051.00	7,146.00	7,441.00	7,478.00	7,892.00	8,771.33
Domestic Oil Production	ktoe	-	0.89	1.03	2.29	1.18	2.29	2.71	3.05	2.48	19.50	340.48	413.38
Domestic hydro production	ktoe	ktoe	568.27	433.02	334.14	454.08	484.01	483.15	321.00	532.67	591.32	601.55	650.13
Domestic biofuels and waste (wood fuel)	ktoe	ktoe	5,427.00	5,541.00	5,657.00	5,776.00	5,897.00	6,021.00	6,197.00	6,326.00	5,888.00	5,948.00	6,009.00
Imported Oil	ktoe	1,764.80	2,183.60	2,052.60	1,906.90	2,083.50	2,566.20	2,874.10	2,586.20	3,052.80	3,109.60	2,990.80	3,909.20
Imported gas	ktoe	-	-	-	-	-	-	-	-	-	354.00	692.00	307.00
Imported hydropower	ktoe	39.72	98.54	80.83	75.49	70.08	54.08	37.40	23.65	17.02	9.11	6.96	11.01

Appendix D

Table 27 Panel data summary of energy security indicators: Within-variation and between-variation

Variable		**Mean**	**Std. Dev.**	**Min**	**Max**
Country	overall	18	10.12848	1	35
	between		10.24695	1	35
	within		0	18	18
Year	overall	3	1.418272	1	5
	between		0	3	3
	within		1.418272	1	5
Energy Security Index	overall	37.252	9.669533	14.7	60.1
	between		8.428893	24.62	54.64
	within		4.907838	25.132	50.832
TPES per capita	overall	1.71462	2.066474	0	9.1
	between		2.040958	0	7.68
	within		0.4081774	-0.4653801	4.59462
Average Reserve to production ratio	overall	85.08057	498.8976	0	5027.7
	between		314.7565	0	1878.38
	within		390.0059	-1788.899	3234.401

Table 28 Panel data summary table: Within-variation and between-variation -cont.

Variable		Mean	Std. Dev.	Min	Max
Self Sufficiency	overall	1.554706	1.796646	0	8.9
	between		1.763637	0	7.78
	within		0.3606167	-0.4252939	3.494706
Share of Renewable Energy	overall	38.81657	35.16062	0	97
	between		35.14685	0	94.62
	within		5.419026	4.816571	62.61657
Grid connection (%)	overall	65.11416	36.28175	0	100
	between		36.05775	9.666667	100
	within		9.71234	25.44749	93.11416
Gasoline (unleaded) Price	overall	97.75808	100.7952	0	675
	between		72.84818	2.8	354.94
	within		70.12945	-125.4419	559.7581
Energy Intensity	overall	11050.75	6123.751	623	30236
	between		5022.455	4068.4	26963
	within		3585.409	833.152	25169.75
Grid inefficiency	overall	13.50234	9.313222	0	47.4
	between		7.997061	0.02	31.8
	within		5.021915	-7.147661	30.00234

Table 29 Panel data summary table: Within-variation and between-variation -cont.

Variable		Mean	Std. Dev.	Min	Max
Forest cover	overall	33.17356	23.44369	0	75
	between		23.51596	0.08	71.8
	within		2.542369	25.37356	42.57356
Water availability	overall	75.15686	22.69423	0	100
	between		21.3245	32.33333	100
	within		8.654662	31.40686	96.95686
CO2 emission per capita	overall	3.969714	5.250391	0	20.2
	between		5.268018	0.04	19.38
	within		0.6727367	0.8897144	7.769714
Governance rating	overall	42.99143	26.83749	1.2	98
	between		26.81434	2.375	96.25
	within		4.093902	31.26643	64.26643
Quality of Energy Information	overall	11.18286	1.072511	7	12
	between		0.525517	9.6	11.8
	within		0.9383282	7.382857	13.58286

Table 30 Scores for 1990

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability (%)	Per capita energy-related carbon emission (metric tons)	Quality of Energy Information (out of the 19)	Mean Score
1	Ghana	1	0	11	78	19	0	15	68	44	0	27	100	30
2	Nigeria	6	100	24	84		3	19	0	25	35	8	75	35
3	Cote d' Ivoire	1	20	9	77		0	43	18	43	63	7	75	32
4	Togo	1	0	9	87		0	45	13	17		40	50	26
5	Cameroun	2	1	25	81	24	0	39	27	69	29	44	100	37
6	South Africa	32	0	14	12			14	52	10		0	25	18
7	Congo DR	1	1	11	89		0	25	18	94	19	44	75	34
8	Zambia	5	0	10	78	13	6	5	65	95		14	75	33
9	Angola	4	18	55	77			65	8	65	18	10	50	37
10	Egypt	4	8	19	3		8	0	29	0	87	3	75	21
11	Algeria	8	12	51	0		10	16	23	1		1	50	17
12	Tunisia	4	45	13	14		0	20	34	6		2	50	19
13	Morocco	0	10	1	5		0	28	39	15	44	3	75	20
14	Libya	31	23	73	1			19	8	0		0	25	20
15	Kenya	3	0	9	81		0	26	23	9		32	50	23
16	Ethiopia	0	0	11	100		8	35	36	20		100	50	36
17	Tanzania	1	0	10	97	0	5	29	18	62		78	75	34
18	Brunei	89	9	100	0		100	18	65	79		0	50	51
19	Cambodia		0		43		29	100		97	18	68	0	44
20	Indonesia	19	10		19	32	26	38	26	85	63	4	75	36

Table 31 Scores for 1990-cont.

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability (%)	Per capita energy-related carbon emission (metric tons)	Quality of Energy Information (out of the 19)	Mean Score
21	Laos		0		100		24	74		100	10	49	0	45
22	Malaysia	12	13	25	17		0	30	52	91	85	1	75	36
23	Myanmar	0	37	11	52		23	76	8	80	46	48	75	41
24	Philippines	2	1	7	48	52	18	63	22	47	80	7	100	37
25	Singapore	47	0	0	0		0	21	81	4	100	0	75	30
26	Thailand	6	7	7	12	92	0	45	29	41	89	2	100	36
27	Vietnam	2	11	11	66		16	73	13	39	47	15	75	33
28	China	7	13	11	22		16	4	51	23	58	2	75	26
29	India	2	13	10	27		0	33	16	29	65	5	75	25
30	Japan	45	3	2	13	100	16	45	54	91	100	0	100	47
31	Korea	18	0	2	5	100	0	28	39	87	91	1	100	39
32	USA	100	3	10	13	100	13	24	37	44	99	0	100	45
33	EU	39	3	7	13	100	11	36	100	45	100	1	100	46
34	Australia	64	4	20	11	100	10	27	48	29	100	0	100	43
35	New Zealand	45	6	10	84	100	10	21	29	39	100	1	100	45

Table 32 Scores for 1995

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
1	Ghana	1	0	13	75	22	13	18	94		40	17	42	67	33
2	Nigeria	6	7	27	86		16	19	8	23	16	20	11	67	25
3	Cote d' Ivoire	1	4	11	75		6	56	18	44	62	12	41	100	36
4	Togo	1	0	11	88		11	34	27	15	49	47	25	67	31
5	Cameroun	1	0	23	82		8	35	13	67		35	12	33	28
6	South Africa	33	0	16	11		10	2	46	10	59	1	62	67	26
7	Congo DR	0	0	13	92		7	19	71	96	0	82	0	67	37
8	Zambia	5	0	12	81	9	9	2	95	96	22	41	27	100	38
9	Angola	3	1	72	79		14	38	8	66	7	6	6	67	31
10	Egypt	3	1	21	3			0	26	0	51	4	43	33	17
11	Algeria	7	1	56	0		13	16	18	1		1	15	33	15
12	Tunisia	5	1	12	13		9	20	30	6	99	4	50	67	26
13	Morocco	0	1	1	5		5	29	48	15	34	5	50	67	22
14	Libya	40	2	61	1			19	10	0		0	13	0	15
15	Kenya	2	0	11	82	0	10	22	16	9	36	39	26	100	27
16	Ethiopia	0	0	12	98		14	34	28	20		100	11	33	32
17	Tanzania	1	0	12	93		10	55	23	61		50	26	33	33
18	Brunei	100	1	100	0		103	24	58	78		0	72	33	52

Table 33 Scores for 1995-cont.

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
19	Cambodia	0	0	11	27		50	100	0	95	14	81	18	67	38
20	Indonesia	5	0	20	19	58	0	53	25	81	64	5	38	100	36
21	Laos		0		100	4	47	87		100	23	56	27	0	45
22	Malaysia	20	1	22	14		0	34	32	92	89	1	67	67	37
23	Myanmar	0	2	11	42		22	76	7	77	45	47	7	67	34
24	Philippines	3	100	6	39		0	64	18	42	82	9	52	67	40
25	Singapore	67	0	0	0		4	20	55	4	100	0	85	67	34
26	Thailand	9	0	6	9		6	38	35	41	92	2	58	67	30
27	Vietnam	1	2	15	75		0	71	10	44	56	13	36	67	32
28	China	8	1	13	21		2	18	43	25	64	2	42	67	25
29	India	1	1	11	19		0	30	14	30	67	8	44	67	24
30	Japan	49	0	3	10	100	9	53	55	93	100	1	79	100	50
31	Korea	9	0	1	2	100	0	25	20	88	86	1	66	100	38
32	USA	100	0	10	12	100	11	22	42	45	99	0	93	100	49
33	EU	39	0	9	13	100	19	37	100	48	100	1	80	100	50
34	Australia	64	0	25	10	100	18	33	40	30	100	0	92	100	47
35	New Zealand	49	0	10	87	100	7	21	25	41	100	1	100	100	49

Table 34 Scores for 2000

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
1	Ghana	1	0	13	72		87	14	17	37	53	24	52	75	37
2	Nigeria	5	4	28	86	42	48	18	2	20	43	12	16	100	33
3	Cote d' Ivoire	1	1	11	66		22	33	21	45	70	14	19	75	31
4	Togo	1	0	11	87	11	41	19	0	12	39	38	23	100	29
5	Cameroun	1	0	22	83		27	59	13	65	50	41	19	75	38
6	South Africa	30	0	16	12	61	28	1	34	11	82	1	65	100	34
7	Congo DR	0	0	13	99		95	17	65	96	28	100	0	75	49
8	Zambia	4	0	12	86	15		9	59	96	53	52	32	75	41
9	Angola	3	1	74	79	7	45	65	18	67	18	10	3	100	38
10	Egypt	4	1	16	3		53	0	23	0	93	3	43	75	26
11	Algeria	8	1	66	0		47	18	17	1	92	2	14	75	28
12	Tunisia	6	1	11	13		38	20	30	7		4	55	50	21
13	Morocco	1	1	1	4		21	28	31	16	76	6	51	75	26
14	Libya	0	3	55	1		79	18	8	0	63	1	17	75	27
15	Kenya	2	0	11	82		24	28	15	9	33	38	25	75	28
16	Ethiopia	0	0	12	100	8	45	36	31	19	0	69	20	100	34
17	Tanzania	1	0	12	98		100	58	8	59	39	87	32	75	48
18	Brunei	92	1	100	0	99	18	27	80	76	99	0	71	100	59

Table 35 Scores for 2000-cont.

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
19	Cambodia	0	0	10	11	12	4	100	15	90	29	46	26	100	34
20	Indonesia	6	0	20	18	51	8	38	30	75	70	5	26	100	34
21	Laos		0		95		0	65		100	32	45	19	0	39
22	Malaysia	22	1	20	20	97	18	34	40	92	96	1	64	100	46
23	Myanmar	0	1	15	40	0	93	87	6	74	55	44	5	100	40
24	Philippines	3	100	6	46	86	8	42	23	37	84	10	43	100	45
25	Singapore	55	0	0	0	100	15	23	49	4	100	1	91	100	41
26	Thailand	12	0	8	8	81	14	34	34	40	95	3	64	100	38
27	Vietnam	3	2	16	59	75	6	58	22	53	72	13	34	100	39
28	China	8	1	13	18	99	9	23	44	26	74	3	39	100	35
29	India	3	1	10	15	40	0	34	7	32	75	6	49	100	28
30	Japan	49	0	3	12	100	26	42	47	94	100	1	87	100	51
31	Korea	8	0	3	2	100	8	24	17	89	91	1	70	100	39
32	USA	100	0	9	11	100	26	30	46	46	99	0	97	100	51
33	EU	39	0	9	15	100	8	43	100	50	100	1	86	100	50
34	Australia	69	1	28	9	100	15	32	40	29	100	0	99	100	48
35	New Zealand	52	0	11	77	100	16	26	29	43	100	1	100	100	50

Table 36 Scores for 2005

No.	Country	Total primary Energy Supply per capita (ktoe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
1	Ghana	5	3	12	73	42	40	24	11	35	66	31	51	100	38
2	Nigeria	9	100	27	84	47	48	41	13	17	34	17	13	100	42
3	Cote d' Ivoire	6	11	13	79	54	19	63	15	47	68	20	5	100	39
4	Togo	5	0	10	89		26	16	0	10	35	43	10	50	25
5	Cameroun	5	5	18	85	41	23	95	18	63	55	50	18	100	44
6	South Africa	35	0	15	11	0	27	8	35	11	83	1	64	100	30
7	Congo DR	4	10	13	100		26	25	28	98	15	100	-1	50	39
8	Zambia	8	0	11	85	10	79	10	52	97	35	54	29	100	44
9	Angola	7	32	94	75	6	41	100	12	68	18	8	8	100	44
10	Egypt	10	21	15	2		50	1	26	0	97	5	36	50	26
11	Algeria	12	27	62	0		49	19	24	1	77	4	31	50	30
12	Tunisia	11	16	10	14		32	35	22	8	91	5	50	50	29
13	Morocco	6	13	1	4		55	45	46	16	69	6	37	50	29
14	Libya	38	76	65	1		100	19	25	0		1	18	0	31
15	Kenya	6	0	3	82	7		38	15	9	32	48	26	50	26
16	Ethiopia	4	0	11	100	4	84	47	30	18	0	97	13	100	39
17	Tanzania	6	21	11	95	1		63	9	57	29	67	36	100	41
18	Brunei	87	21	100	0	99	28	33	61	76		1	65	50	52

Table 37 Scores for 2005-cont.

No.	Country	Total primary Energy Supply per capita (ktoe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
19	Cambodia	4	0	8	5	11	0	44	13	84	32	41	18	100	28
20	Indonesia	10	22	19	15	49	17	12	26	70	69	8	28	100	34
21	Laos	0	0	4	97	38	9	31	14	100	29	49	12	100	37
22	Malaysia	31	20	18	13	98	20	12	77	91	100	1	65	100	50
23	Myanmar	4	11	18	5	1	94	1	2	70	55	39	0	100	31
24	Philippines	6	21	7	35	79	8	29	25	34	85	16	41	100	37
25	Singapore	72	0	0	0	100	14	14	57	4	100	1	91	100	43
26	Thailand	19	10	7	7	99	11	6	38	40	97	4	54	100	38
27	Vietnam	8	20	17	44	82	3	4	29	60	82	12	35	100	38
28	China	17	17	12	18	99	11	0	44	30	78	2	34	100	36
29	India	6	20	10	17	51	0	10	11	33	77	11	48	100	30
30	Japan	53	13	2	11	100	24	72	53	97	100	1	88	100	55
31	Korea	12	2	2	1	100	3	36	19	93	94	1	76	100	41
32	USA	100	8	8	10	100	36	46	52	47	98	0	88	100	53
33	EU	44	9	7	15	100	1	70	100	53	100	1	85	100	53
34	Australia	74	11	28	9	100	19	58	51	30	100	0	96	100	52
35	New Zealand	50	6	10	69	100	28	46	40	44	100	1	100	100	53

Table 38 Scores for 2010

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
1	Ghana	4	70	12	68	55	61	22	17	31	71	35	57	100	46
2	Nigeria	8	34	25	88	43	82	98	21	14	32	18	15	100	44
3	Cote d' Ivoire	5	4	14	81	53	28	57	17	47	68	39	10	100	40
4	Togo	4	0	10	88	17	40	33		8		49	21	0	25
5	Cameroun	4	100	15	68	41	99	65	45	61	58	26	17	100	54
6	South Africa	32	4	13	11	72	40	7	45	11	85	1	62	100	37
7	Congo DR	4	4	12	100	2	34	22	41	99	13	100	2	100	41
8	Zambia	7	0	11	87	7	31	16	17	96		54	38	0	30
9	Angola	7	59	100	61	31	64	100	38	68	19	9	14	100	52
10	Egypt	10	7	14	2	100	73	0	41	0	98	6	33	100	37
11	Algeria	13	11	45	0	99	83	13	21	1	73	4	23	100	37
12	Tunisia	10	7	10	15	99	45	47	38	9		7	47	0	28
13	Morocco	5	4	1	3	99	38	43	35	17	69	8	45	100	36
14	Libya	35	25	50	1	100	98	20	33	0		1	15	0	31
15	Kenya	5	0	10	77	6	32	40	24	9	34	47	29	100	32
16	Ethiopia	4	0	11	100	11	56	64	45	18	0	98	22	100	41
17	Tanzania	5	1	11	95	2	39	67	21	55	26	97	39	100	43
18	Brunei	100	8	68	0	100	66	8	82	75	98	0	74	100	60

Table 39 Scores for 2010-cont.

No.	Country	Total primary Energy Supply per capita (toe)	Average reserve to production ratio for oil and natural gas) (years)	Self Sufficiency (%)	Share of renewable energy in TPES (%)	Population with high quality connections to the electricity grid (%)	Retail price of 100L of unleaded gasoline (2009 US Dollars PPP)	Energy intensity (Btu/year, 2005 US Dollars PPP)	Grid inefficiency (%)	Forest cover (%)	Water availability	Per capita energy-related carbon emission (metric tons)	Worldwide governance rating	Quality of Energy Information (out of the 19)	Mean Score
19	Cambodia	4	0	8	4	13	5	44	37	83	37	41	22	100	31
20	Indonesia	10	7	21	15	60	41	10	40	68	68	8	37	100	37
21	Laos	0	0	4	98	48	4	26	34	100	31	52	17	100	40
22	Malaysia	30	9	15	10	99	43	14	86	91	100	1	59	100	51
23	Myanmar	3	5	18	66	0	100	11	0	70	53	49	0	100	37
24	Philippines	5	7	7	36	89	25	30	34	33	85	17	37	100	39
25	Singapore	42	0	0	0	100	27	12	81	4	100	1	89	100	43
26	Thailand	18	2	7	9	99	11	4	69	41	97	2	47	100	39
27	Vietnam	8	4	14	40	98	15	1	40	62	90	14	36	100	40
28	China	18	7	11	18	99	22	0	67	32	82	2	37	100	38
29	India	5	6	9	16	61	0	10	7	33	81	13	47	100	30
30	Japan	41	4	2	11	100	40	89	70	99	100	1	88	100	57
31	Korea	52	0	2	1	100	16	33	24	93	97	1	74	100	46
32	USA	78	4	9	12	100	63	51	59	48	98	1	87	100	55
33	EU	35	3	7	18	100	20	69	100	54	100	1	85	100	53
34	Australia	67	13	28	9	100	57	55	55	30	100	0	97	100	55
35	New Zealand	46	2	11	78	100	41	48	54	45	100	1	100	100	56

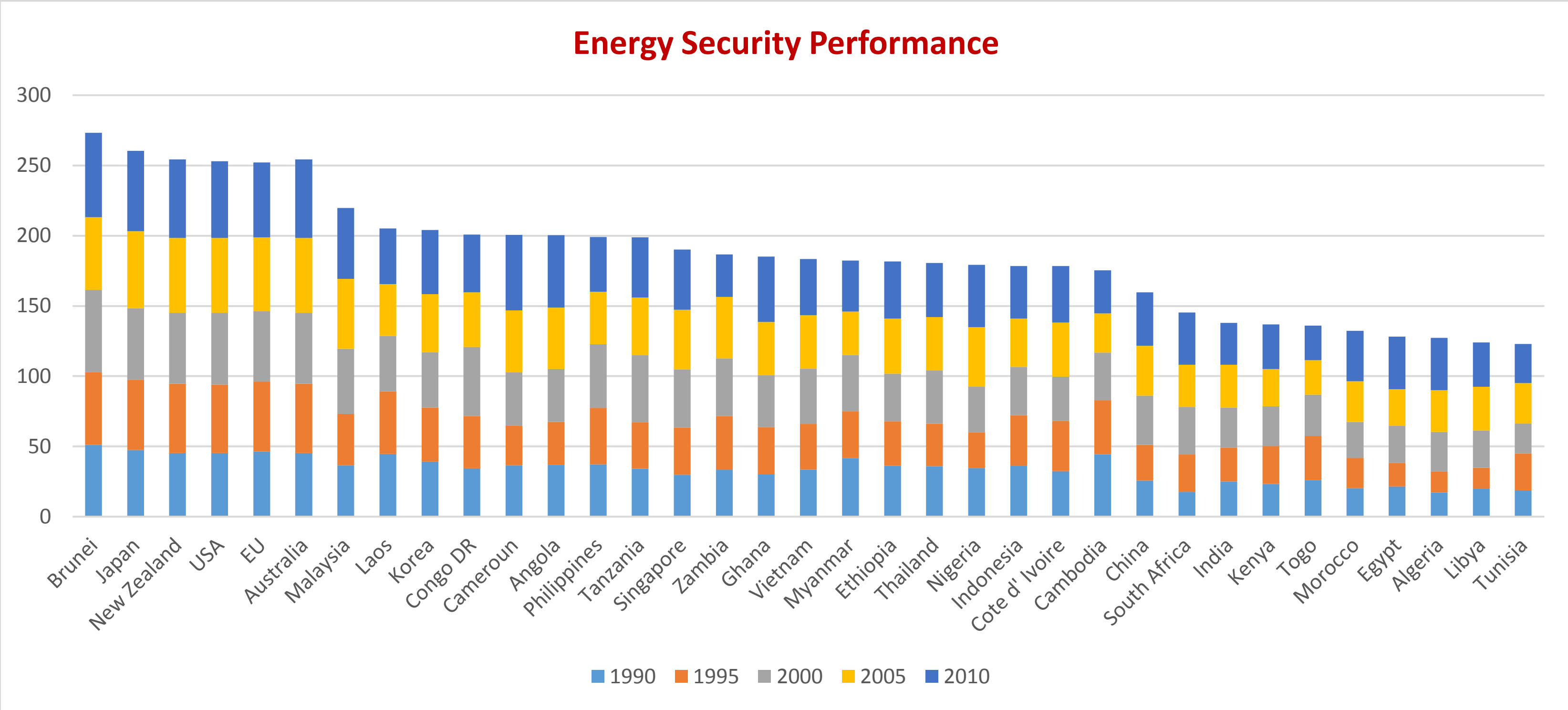

Figure 46 Source Author's own elaboration using data EIA, WB, IEA etc.

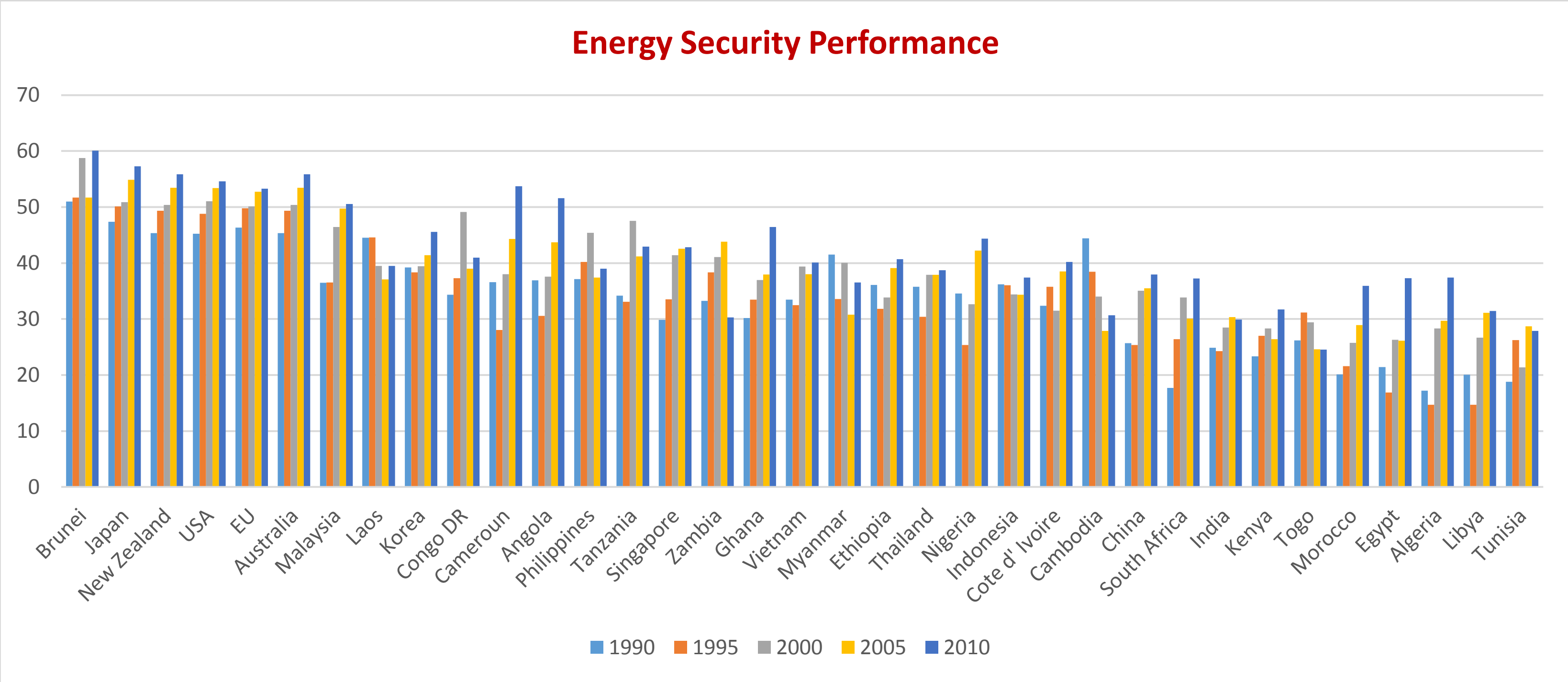

Figure 47 Source Author's own elaboration using data EIA, WB, IEA etc.

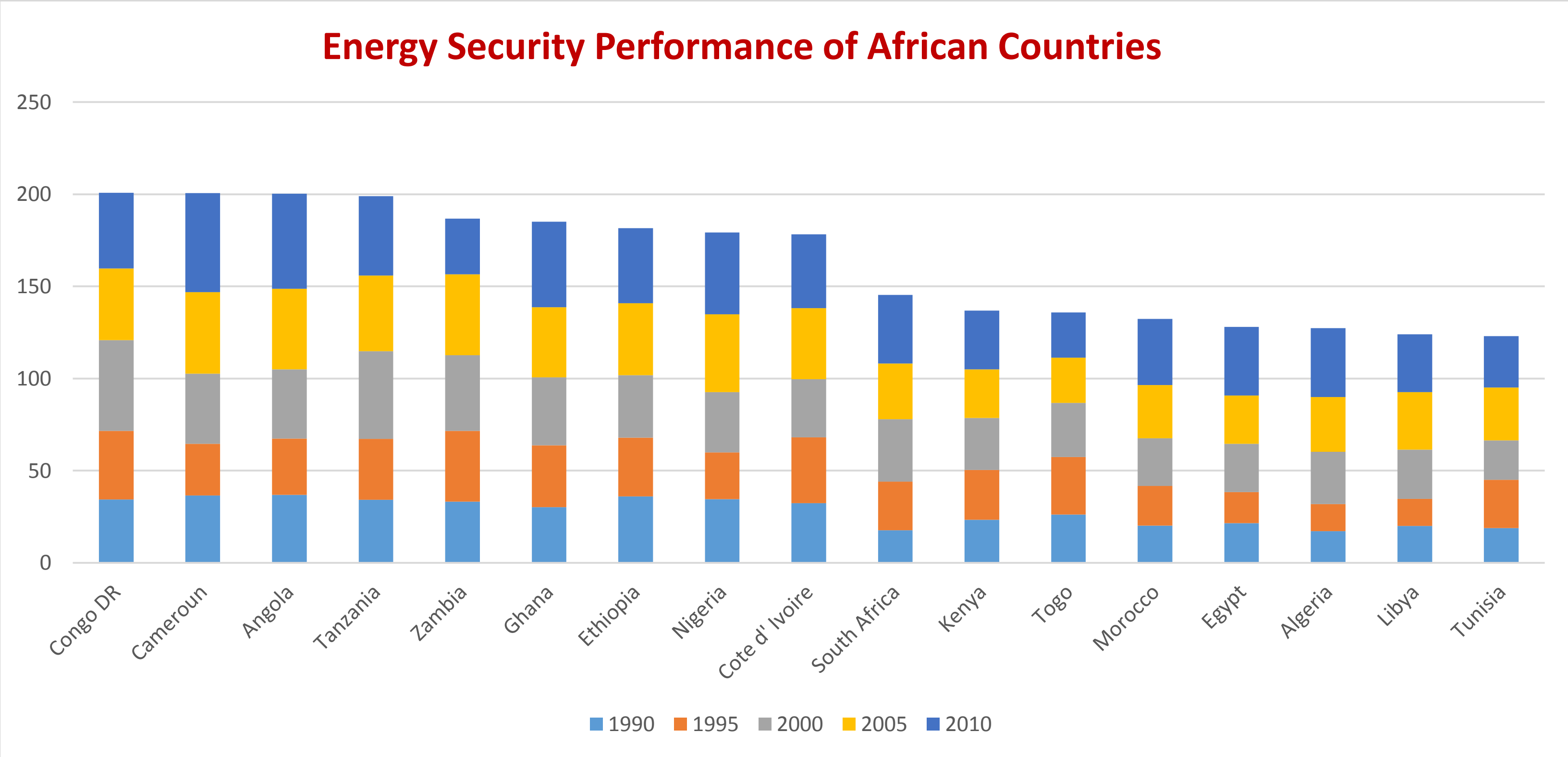

Figure 48 Source Author's own elaboration using data EIA, WB, IEA etc.

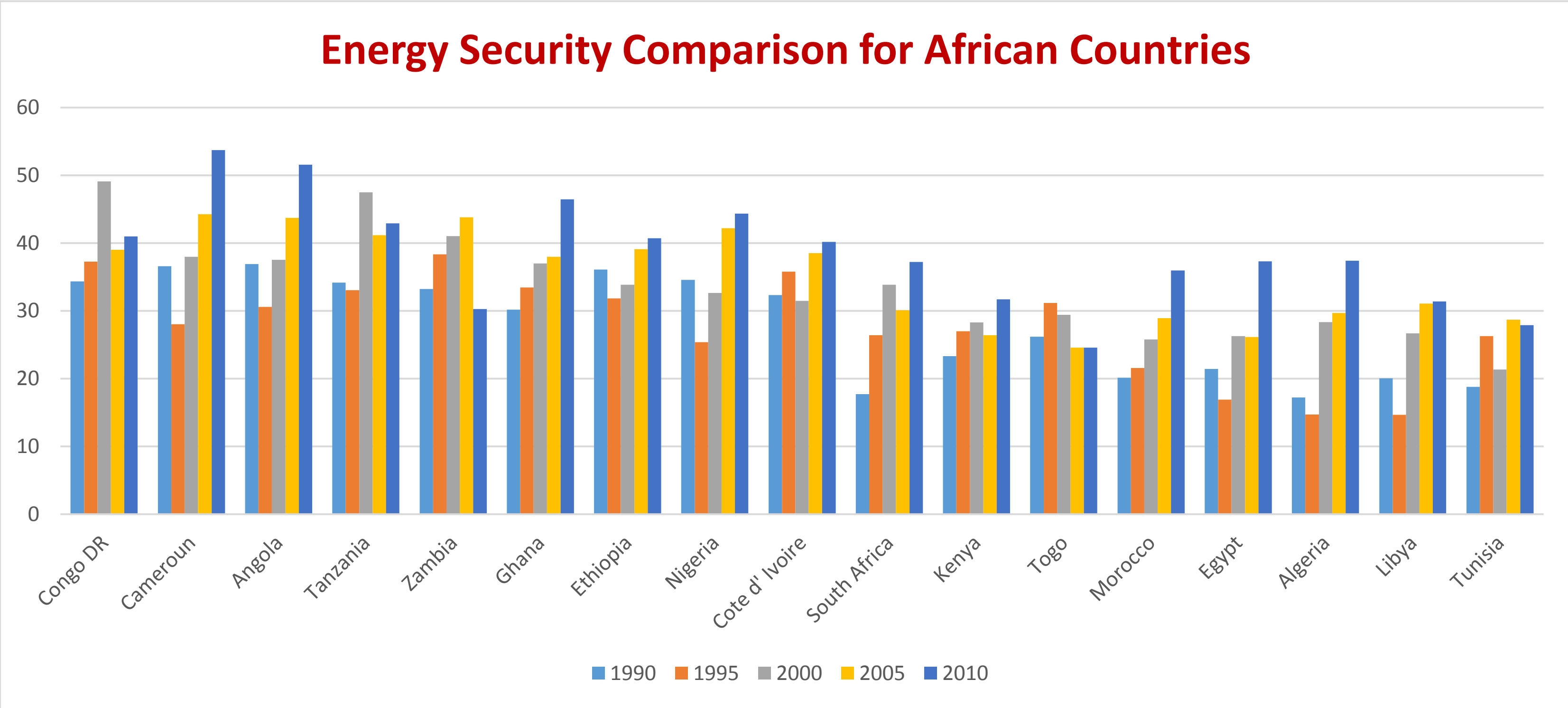

Figure 49 Source Author's own elaboration using data EIA, WB, IEA etc.

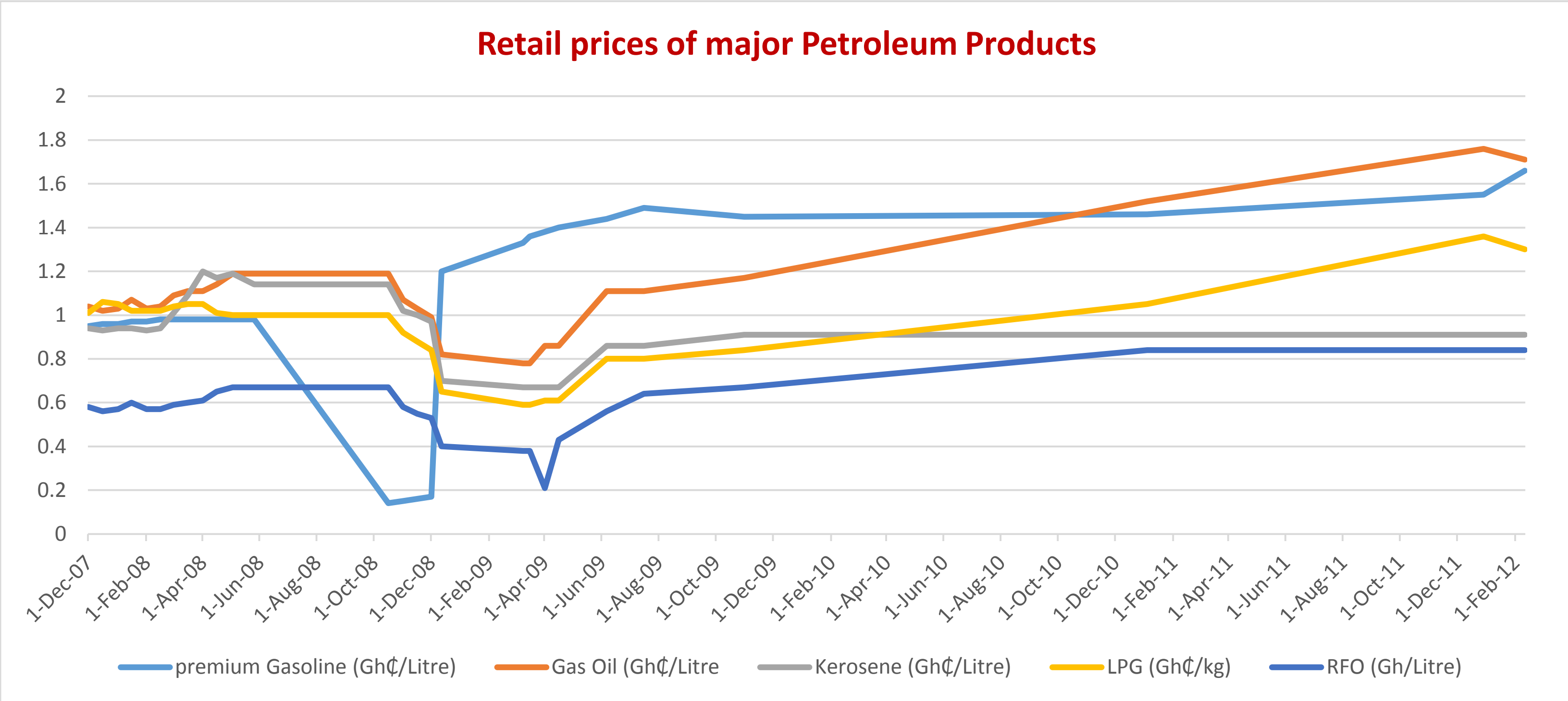

Figure 50 Source (Energy Commission of Ghana, 2013)

초록

에너지 안보와 국가별 비교분석을 통한 에너지 안보 정책에 대한 평가

: 가나 사례를 중심으로

찰스 아쿠아

협동과정 기술경영경제정책전공

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에너지 수급을 안정화하고 사회경제적인 발전을 위해 에너지 공급을 적절히 하기 위한 연속적인 가나 정부의 분주한 노력은 아직까지 기대했던 결과를 얻지 못하였다. 가나는 여전히 전기 공급과 석유제품이 부족할 뿐만 아니라 원유와 가스도 부족한 실정이다. 부주의한 산림 벌채는 남아 있는 산림 자원을 경고 수준까지 감소시켰다. 결과적으로 이 연구는 가나의 에너지 안보에 대한 현실에 접근해보자하는 것을 그 목표로 하고 있으며 이를 위해 에너지 정책의 효과성을 분석하고 대안이 되는 정책을 개발하고자 한다.

이 연구는 B.K. Sovacool (2011)에 의해 개발된 복합적인 에너지 안보 인덱스를 사용하여 가나의 에너지 안보 상황을 다른 국가들과

비교하고자 하며 주로 아세안 국가, 미국, 유럽연합, 일본, 대한민국, 인도, 오세아니아 국가, 17 개의 아프리카 국가 들의 20 년간의 데이터를 이용해 그것을 수행하고자 한다. 비교할 항목은 다음과 같이 분류할 수 있는데 유효성(availability), 가격 정당성 (affordability), 기술발전과 효율 (technology development and efficiency), 지속가능성(environmental sustainability), 규제와 통치 (regulation and governance)가 그것이다. 가장 좋은 성과를 낸 상위 5 개 국은 부루나이 (273), 일본 (260), 뉴질랜드(254), 미국 (253), 유럽연합(252)이고 하위 5 개국은 튀니지(123), 리비아 (124), 알제리 (127), 이집트(128), 모로코(132) 이다. 가나는 185 점으로 17 위를 기록하였다. 가장 성과가 좋은 아프리카 국가들은 콩고 공화국 (201), 카메룬 (201), 앙골라 (200), 탄자니아 (199), 잠비아(187)이었다. 가나는 아프리카 국가 중에서 여섯 번째로 좋은 점수를 받았다. 또한, 시간제약하에서의 전략적 계획인 세금 구제와 규제 도구은 에너지 안보에 긍정적인 영향을 주는 것으로 드러났다.

이 연구의 두번째 부분에서는 가나의 에너지 안보 지수 성과를 2001 년과 2012 년에 사이 기간에 초점을 맞추어 다룰 것인데 이 기간은 가나의 에너지 부분에 있어 가장 변화가 많았던 시기였기 때문이다. 지표들은 가나 국가 에너지 정책 the National Energy

Policy of Ghana 에 의해 선택되었다. 가나는 석유 비중, 비탄소 연료 포트폴리오, 이산화탄소 배출, 인당 이산화탄소 배출, 에너지 수입에 있어서 음의 트렌드를 보였다. 결과적으로, 이 흐름을 반전시키기 위하여 기존의 에너지 정책들을 국제적인 우수 사례들로써 재평가하는 것이 필요할 것이다.

주요어: 에너지 안보, 평가, 지속 가능한 에너지 정책, 가나

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