ENERGY SECURITY IN AFRICA

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Energetická bezpečnosť v Afrike

Abstract: *The paper focuses on energy security and energy security evaluation in the economies on the African continent. The first part of the paper compares several definitions of energy security and describes the most important methods for the evaluation of energy security of the state. The second part of the paper focuses on the Energy Architecture Performance Index, which is one of the few to evaluate energy security also in developing states, including twenty African states. Based on our results, the energy security in Africa is lower than the world average, but African countries perform well in some categories, namely Environmental Security. The best performing country is Morocco; the worst performer is Benin.*

Keywords: *energy security, Africa, Energy Architecture Performance Index*

JEL Classification: Q 40, N 17

1 Introduction

To evaluate energy security of the system (e. g. country, region, regional organization) we must first define energy security and then proceed to describe various methodologies for energy security evaluation. However, to define energy security is difficult task. For example, The Routledge Handbook of Energy Security (Sovacool, [14]) lists forty-five different definitions of energy security from various scholars and international organizations.

Energy security became an issue in the 1970s because of oil price shocks, that were a consequence of supply disruptions and price volatility from OPEC oil embargos. Since then the definition of energy security has shifted from oil supply security towards broader definition including other energy resources and all parts of energy supply chain. (Erahman, Purwanto, Sudibandriyo and Hidayatno, [3])

The first definition we will introduce is from international organization that focuses on energy security, economic development, environmental awareness

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and engagement worldwide, International Energy Agency. As the IEA was established in 1974, it had, and still has, two main objectives: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on the ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. (IEA, [6]) The IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. (IEA, [7]) This simple definition is only focused on the supply side of energy security; however, it includes both physical dimension (available, reliable and/or accessible energy supply) and economic dimension (which includes price volatility and affordability) of energy security.

Very simply energy security can be defined as "how to equitably provide available, affordable, reliable, efficient, environmentally friendly, and socially acceptable energy services to end-users." (Phdungsilp, [13])

The Asia Pacific Energy Research Centre (World Economic Forum [15]) defined energy security with four As: Availability (geographical and physical elements), Accessibility (geopolitical elements), Affordability (economic elements) and Acceptability (social and environmental elements).

According to some authors (Kleber, [10]) energy security is a situation where fuel, power production/distribution systems, and end user devices possess five characteristics, also known as 5 Ss. These are Surety (access to energy and fuel sources), Survivability (durable and resilient sources), Supply (identified and available source of energy), Sufficiency (adequate quantity) and Sustainability (operating practices can be perpetuated by limiting demand, reducing waste and effectively utilizing alternative energy and renewable resources).

Another definition also known as "four Rs" (Hughes, [5]) balances between definition of energy security and its evaluation. The four Rs describe the process of evaluation of energy security in specific country. First, the components of energy security must be reviewed. This includes existing sources, suppliers, supplies of energy, infrastructure, energy services, energy intensities and potential secure energy supplies. The second step is the reduction of energy demand, which can attribute to higher energy security, but the improvement is not automatic. If the energy remains to be supplied from unreliable sources, even with lower demands, the energy security will not improve. This problem should be solved by replacing unreliable sources of energy. To complete the quest towards higher energy security, the policy makers have to restrict new demands for energy by legislation. This process can therefore be described as "four Rs": Review, Reduce, Replace and Restrict.

Energy security concept is especially important for policy makers, as their decisions should lead to its achievement. However, energy security policies have to take into consideration also related policy areas. This is described by the concept of energy trilemma. (Ang, Choong and Ng, [1]) Energy security, defined by physical availability of energy sources and diversification, is closely interconnected with economic competitiveness (cost of delivered energy) and environmental sustainability (environmental impact of energy system). The intersection of energy security with economic competitiveness is in energy prices and infrastructure cost, while the intersection with environmental sustainability is the environmental impact of energy system.

2 Energy security evaluation

In the previous chapter, we outlined the difficulties in defining energy security, as different authors chose to include or exclude some dimensions of this complex issue. The same incoherence can be seen in evaluation of energy security of specific subjects, usually countries.

In Global Energy Architecture Performance Index Report 2016 (World Economic Forum [15]), the authors developed the framework for the evaluation of energy security of a country. The framework includes six components, each with defined metrics evaluated by qualitative analysis. The components and their metrics (in parenthesis) are Self-sufficiency and diversity of supply (Diversity of total primary energy supply – HHI (Herfindahl - Hirschman Index), Diversification of import counterparts – HHI, Net energy imports/energy use), International security and geopolitical risks (qualitative analysis), Infrastructure resilience and flexibility (Quality of electricity supply, Alternative and nuclear energy/total energy use including biomass), Economic risks and increases in demand (Fuel price distortion, GDP produced per unit of energy use, Net energy imports/energy use, Net energy exports/energy use), Level and quality of access (Electrification rate, Quality of electricity supply, Percentage of population using solid fuels), and Governance and emergency response mechanism (qualitative analysis).

Anwar [2] offers a list of energy security indicators in two main categories, simple and aggregated indicators. Simple indicators are Resource Estimates, Reserve to Production Ratio, Diversity Indices, Market Concentration, Net Energy Import Dependency, Energy or Oil Intensity, Oil/Energy Expenditures, Energy/Oil Use per Capita, Share of Oil in Transport Sector and Share of Transport Sector in Total Oil Use. The indicators in this paper include physical and economic availability, as well as dependency, so they include wide definition of energy security. There are three aggregated indicators which are described later: Shannon Index based, The IEA's Energy Security Index and Oil Vulnerability Index.

The Shannon index was also applied for energy security. (Kruyt et al., [11]) It combines four energy system risk factors: energy sources diversification, energy suppliers' diversification, political stability and energy resources. It captures the diversity of fuel and the suppliers for each fuel. The importers are weighted by their political stability and the depletion index is also considered. The higher Shannon index means higher energy security.

For energy security evaluation of its member states, IEA uses the Model of Short-Term Energy Security (MOSES). (Jewel, [8]) Based on the set of indicators, MOSES evaluates two aspects of energy security: risk of energy supply disruptions and resilience, or the ability of a national energy system to cope with such disruptions. The indicators are sorted into categories by the resources (crude oil, oil products, natural gas, coal, hydropower, nuclear power) and evaluate both domestic and external risk and resilience. The result of the evaluation is not the exact value of complex index, but the inclusion of each country into one of five groups (A to E).

The methodology of Oil Vulnerability Index (OVI) using principal component analysis is best described by Gupta [4]. It consists of four market risk indicators (the ratio of value of oil imports to GDP, oil consumption per unit of GDP, GDP per capita and oil share in total energy supply) and three supply risk indicators (ratio of domestic reserves to oil consumption, exposure to geopolitical oil market concentration risks and market liquidity). For the OVI the higher value means higher oil vulnerability and lower energy security.

Principal component analysis method applied in different time periods (Li, Shi and Yao, [10]) was used to describe the development of energy security of specific group of countries, resource-poor developed economies (Japan, Korea, Singapore and Taiwan). The indicators used were divided into three categories, each including three indicators, which is the minimum for PCA. The categories are Vulnerability, Efficiency and Sustainability. The indicators are Total energy self-sufficiency, TPES (Total Primary Energy Supply) diversity and Availability factor for electricity (Vulnerability category), Energy intensity, Total thermal efficiency of electricity and heat plants (%) and Electricity distribution efficiency (Efficiency category) and Carbon intensity, TPES per capita and Share of fossil in TPES (Sustainability category).

Energy Security Matrix (Kisel et al., [9]) is the collection of indicators that should cover both long-term and short-term influencing factors of energy security. The indicators are classified by sector (electricity, heat and transport) and by domain, resulting in matrix of 27 indicators. The domains are Operational resilience to internal disturbances (flexibility), Operational resilience to external disturbances (flexibility), Technical resilience (capacity), Technical vulnerability (energy), Economic dependence and

Political affectability. The aim of the authors was to include all aspects of energy security so they assembled exhaustive list of indicators. Hence, they highlight the need for individual approach, as some aspects of energy security may be more important in some countries than in others.

3 Energy Architecture Performance Index

The second part of the paper focuses on the evaluation of energy security in African countries. We based our work on the Energy Architecture Performance Index (World Economic Forum 2016) because it offers the data about energy security from many countries in the world, including big group of developing economies. Most databases and indices only cover the member states of the International Energy Agency and do not include data on many other countries of the world.

Energy Architecture Performance Index includes three categories of indices and every category is evaluated with the score on the scale from 0 to 1, where 1 is the best score. The three categories for evaluation are further divided based on the indices used for each category. The three categories are: Economic Growth and Development, Environmental Sustainability and Energy Access and Security. The indices used for the evaluation of each category are listed in Table 1.

Table 1

Energy Architecture Performance Index

Economic Growth and Development
GDP per unit of energy use
Fuel imports
Super Gasoline – Level of price distortion through subsidy or tax
Diesel – Level of price distortion through subsidy or tax
Electricity prices for industry
Fuel exports

Environmental Sustainability
Alternative and nuclear energy
Nitrous oxide emissions in energy sector
CO2 emissions from electricity production
Methane emissions from energy sector
Particulate matter (2.5) concentration
Average fuel economy for passenger cars

Energy Access and Security
Electrification rate
Quality of electricity supply
Percentage of population using solid fuels for cooking
Energy imports, net
Diversity of TPES
Diversification of import counterparts

Source: [15].

The Energy Architecture Performance Index for the year 2016 evaluates energy security of 126 countries. Average value of the index is 0.6. The highest score of the index in 2016 is 0.8, the best performing country is Switzerland. On the other end of the list we can find Bahrain with the value 0.4.

The interesting feature of the results based on this index is the dispersion of good performers across the world regions, as they are not exclusively within the developed regions of Western Europe or North America. The results of the Energy Architecture Performance Index are influenced by the changes in global economics towards more sustainable resource management and higher share of renewables in energy mix.

4 Energy security in Africa

Out of 53 African states, only 20 are included in the database of the Energy Architecture Performance Index in the year 2016. These countries are Algeria, Benin, Botswana, Cameroon, Egypt, Ethiopia, Ghana, Ivory Coast, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, Tanzania, Zambia, and Zimbabwe.

Average value of the Energy Architecture Performance Index for African countries included in the database is 0.545, what is worse than world average of 0.6. Out of the three categories of the Energy Architecture Performance Index, the best average results for Africa are in the second category, Environmental Sustainability. The average value of Energy Sustainability in Africa is 0.7. The average value of Economic Growth and Development category in Africa is 0.455, the average value of Energy Access and Security is 0.45, which puts it in the last place from these three categories. Average values of the indices are in Table 2.

Table 2

Energy Architecture Performance Index – average values in Africa

Economic Growth and Development	**0.455**
GDP per unit of energy use	7.395
Fuel imports	0.06
Super Gasoline – Level of price distortion through subsidy or tax	0.695
Diesel – Level of price distortion through subsidy or tax	0.635
Electricity prices for industry	..
Fuel exports	0.065
Environmental Sustainability	**0.7**
Alternative and nuclear energy	0.51
Nitrous oxide emissions in energy sector	0
CO2 emissions from electricity production	435.565
Methane emissions from energy sector	0
Particulate matter (2.5) concentration	19.585
Average fuel economy for passenger cars	0.705
Energy Access and Security	**0.45**
Electrification rate	0.55
Quality of electricity supply	3.1
Percentage of population using solid fuels for cooking	0.585
Energy imports, net	-0.225
Diversity of TPES	0.48
Diversification of import counterparts	0.34

Source: author's calculations.

On average, economies of Africa produce 7.395 $ per kilogram of oil equivalent. These economies import 0.06 % of energy. The distortion of price of gasoline and diesel is 0.695 and 0.635 respectively, on the scale from 0 to 1, same as for the main index. The data on electricity prices for industry are not available for the countries in our sample. The share of fuel exports on GDP in Africa is 0.065 % on average.

The share of alternative and nuclear energy in Africa is very high, namely 0.6, which is mainly because of wide biomass use in households. There are essentially no nitrous oxide emissions or methane emissions in African energy sector. In Africa, 435.565 grams of CO2 are emitted for every kWh of electricity produced. The concentration of particulate matter in Africa is 19.585 μg per cubic meter. The index of average fuel economy for passenger cars is also evaluated on the scale from 0 to 1 and the value in Africa is 0.705 on average.

Electrification rate in Africa is far behind developed world with the average value of 0.55. Quality of electricity supply is another big problem of African economies. In this indicator, the quality of electricity supply is measured on the scale from 1 to 7, where 7 is the best situation. The average value in Africa is 3.1. The percentage of population using solid fuels for cooking is significant, 0.585. African countries included in the sample are net exporters of energy, as the value of net energy imports to energy use is negative, -0.225. Diversity of TPES is measured by Herfindahl index on the scale from 1 to 0, where 0 is the best situation. The value in Africa is 0.48. Same scale is used to measure diversification of import counterparts, the value of which is 0.34 in Africa.

Table 3 concludes the performance of African countries in each of the described indicators. In the columns, we include the best and the worst performing economy for each indicator, although in many cases the values are very similar for some countries. We can identify the difference between resource rich and resource poor countries based on their rankings in this table.

Table 3

Energy Architecture Performance Index – best and worst countries in Africa

Highest rank country		**Lowest rank country**
Ghana	**Economic Growth and Development**	**Ethiopia**
Botswana	GDP per unit of energy use	Mozambique
Ghana	Fuel imports	Senegal
Ivory Coast	Super Gasoline – Level of price distortion through subsidy or tax	Algeria, Libya
Zimbabwe, Senegal	Diesel – Level of price distortion through subsidy or tax	Algeria, Egypt, Libya
..	Electricity prices for industry	..
Libya	Fuel exports	Zimbabwe
Mozambique	**Environmental Sustainability**	**Libya**
Ethiopia	Alternative and nuclear energy	Algeria
Senegal	Nitrous oxide emissions in energy sector	Namibia
Ethiopia	CO2 emissions from electricity production	Botswana
Morocco	Methane emissions from energy sector	Libya
Mozambique	Particulate matter (2.5) concentration	Senegal
South Africa	Average fuel economy for passenger cars	Benin, Botswana, Cameroon, Ethiopia, Ghana, Ivory Coast, Kenya, Mozambique, Namibia, Nigeria, Senegal, Tanzania, Zambia, Zimbabwe

Algeria	**Energy Access and Security**	**Ethiopia**
Algeria, Egypt, Morocco, Libya	Electrification rate	Mozambique
Morocco	Quality of electricity supply	Nigeria
Algeria, Egypt, Libya	Percentage of population using solid fuels for cooking	Ethiopia
Libya	Energy imports, net	Morocco
Botswana	Diversity of TPES	Ethiopia
Morocco	Diversification of import counterparts	Botswana

Source: author's calculations.

The results of our paper show the distinction between richer oil exporting economies in the north of Africa and poorer, less developed economies of sub-Saharan Africa. The first group performs better in infrastructure measures, while the later are better in environmental indicators, which means lower levels of pollution in these countries. The former group can be represented by Algeria, while the latter is best represented by Ethiopia.

5 Conclusions

Energy security is a topic creating lot of debate concerning its definition and measurement. In the first part of the paper we collected and compared the definitions of energy security and described the development and widening of the definition of energy security. Then we collected and compared the approaches to the measuring of energy security throughout the decades since the first oil shock until today.

In the second part of the paper we chose the indicator of energy security called Energy Architecture Performance Index. The choice on this particular indicator was influenced mainly by the availability of data on energy security in African countries, as the majority of energy security indicators only cover developed economies, OECD member states or the member states of IEA.

The last part of the paper analyses the data on energy security in African economies based on the Energy Architecture Performance Index and its components. Energy security in Africa is lower than the world average, the best performer is Morocco, at the other end we can find Benin. In general, richer countries in the north of Africa perform better in infrastructure measures but struggle with environmental sustainability. On the other hand, poor sub-Saharan economies have very low levels of pollution but fall behind in infrastructure measures.

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