Renewable and Sustainable Energy Reviews xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria

Abubakar Kabir Aliyu, Babangida Modu, Chee Wei Tan*

Department of Electrical Power Engineering, Faculty of Electrical Engineering, Universiti Teknologi, Malaysia

ARTICLE INFO

Keywords:
Renewable energy
Energy efficiency
Energy
Africa

ABSTRACT

Despite its vast natural resources, African is facing serious challenges in sustainable development in an energy sector, if addressed with dispatch could not only check its indispensable needs, but also mitigate some global phenomenon at stake, such as desertification, environmental degradation and green house emission. This paper reviews the prospects of four major renewable energy sources-hydro, solar, wind and biomass- for each of the three leading countries in Africa namely South Africa, Egypt and Nigeria. Based on literature survey of energy efficiency, all the three countries encourage energy efficiency in varying degrees. In the course of this review, several national energy policy frameworks of these countries were looked into, especially on how African countries could overcome the persistent energy crisis in the continent by utilizing the naturally gifted renewable energy sources. This could only be achievable if proper technology, awareness and skills for harnessing the resources are provided. Also lingering energy challenges such as energy efficiency measures, needs for grid extension, energy storage technology and seasonal variation were carefully highlighted.

1. Introduction

Investigation has shown that renewable energy sources such as power from sun (photovoltaic and solar thermal), hydro, wind and biomass-derived fuel have contributed greatly to the sustainability of certain nations with several environmental and socioeconomic benefits to the nations that tap them. A far bigger and wider benefit according to research, is the contribution of renewable energy in the reduction of pollution at both local and global levels, thus helping in the mitigation of climatic change which both industrialized and developing nations committed themselves to in the Kyoto protocol. It has been tested and proven that reliable and affordable power supply is an essential prerequisite for technological and economic growth. Generation of electricity from renewable energy resources can play a major role in electricity generation in African countries.

This paper presents a review of renewable energy technological development in South Africa, Egypt and Nigeria which varies due to factors that included topography, characteristics of the resource, cost of labor and policy regulation. The three countries have about half of the total of Africa's primary energy use as shown in Fig. 1 [1], - a status that can translate into huge economic growth if power supply is reliable and affordable.

In his review of renewable energy for sustainable development in Africa, I.M. Bugaje considered the extent to which policies on solar, wind, biomass and biogas are meeting up top challenges of sustainable development in four countries namely South Africa, Nigeria, Mali and Egypt [2]. In a paper titled “the economics of renewable energy expansion in rural sub-Saharan Africa”, Uwe Deichman chose Ethiopia, Ghana and Kenya [3]. In his short review that focused on poverty and energy in Africa, Stephen Karekezi talked about population, energy consumption, renewable energy, fossil fuel and access to electricity [4]. In his another paper titled “renewable in Africa- meeting the energy needs of the poor”, Karekezi examined the large and small-scale biomass energy, solar PV, solar thermal, evaluates how each of the renewable energy technologies can meet the need of rural and urban poor [5].

In view of the absence of a paper that focuses on the three leading nations namely South Africa, Egypt and Nigeria, this paper has made an extensive review of the four major renewable energy sources (hydro, solar, wind and biomass), energy efficiency of each of the three countries, energy policy, overview of conventional energy, why renewable energy?, strategies towards utilization of energy efficiency in Africa, renewable energy road map in Africa, needs for grid extension, energy storage system and seasonal variations in Africa.

This review paper starts with an introduction, followed by the overview of conventional energy in Africa, why renewable energy?, strategies towards utilization of efficient energy in Africa, an extensive review of the four major renewable energy sources, energy efficiency of

* Corresponding author.
E-mail address: cheewei@fke.utm.my (C.W. Tan).

http://dx.doi.org/10.1016/j.rser.2017.06.055
Received 24 February 2016; Received in revised form 11 June 2017; Accepted 18 June 2017

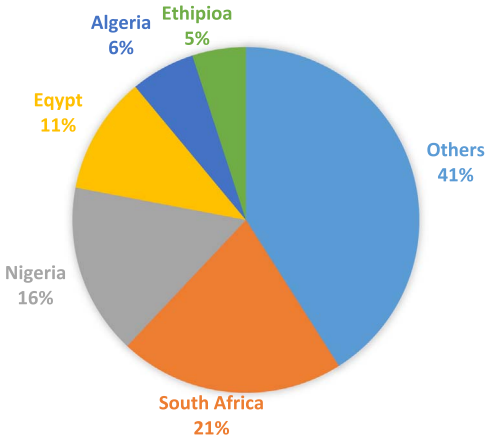

Fig. 1. primary energy use in Africa by country, 2009 [1].

each of the case studies starting with South Africa, Egypt and Nigeria, renewable energy road map for Africa, energy policy in Africa, energy storage systems, general discussion and finally ends with the conclusion.

2. Conventional energy in Africa

With proven oil reserve which increased by 150% from 53.4 billion barrels in 1980 to 13.3 billion barrels as of 2013 (according to BP Statistical Review of Energy), Africa is second only to the Middle East in terms of oil export and it accounts for over 11% of world oil production. However, the bulk of the oil is exported as the continent accounts for only 4% of global oil consumption. Since 2013 Africa's oil export has declined from an average of 6.3million bpd to 5.2 million bpd as a result of sharp drop in Libya's output and low production from Nigeria, Algeria and Sudan. The four countries account for 84% of Africa's oil production (Libya 48.5 billion barrels reserve, Nigeria- 37.1 billion barrels reserve, Angola- 12.7 billion barrels reserve and Algeria- 12.2 billion barrel) and are all members of the Organization of Petroleum Exporting Countries (OPEC), Figs. 2 and 3 show chart representing Africa's oil and gas reserve as well as the production (in million bpd).

Africa's natural gas proven reserve significantly increased between mid-1980 to early 2000s, due to mainly a strong increase in Nigerian reserves. West African contributed almost half of the total natural gas proven reserve increment over a period of mid-1980 to early 2000s, while the North Africa which consists of Libya, Algeria and Egypt accounted for the remaining. As at the beginning of 2014, five countries accounted for 94.4% of the total of Africa's natural gas reserves. The countries are Nigeria (5.1 trillion m^3), Libya, Algeria and Egypt combined (8.1 trillion m^3) while Mozambique whose proven gas rose from 126 billion m^3 to 2.8 trillion m^3 from 2013 to 2014 [6–9]. Table 1 represent the non-renewable energy potential of Africa.

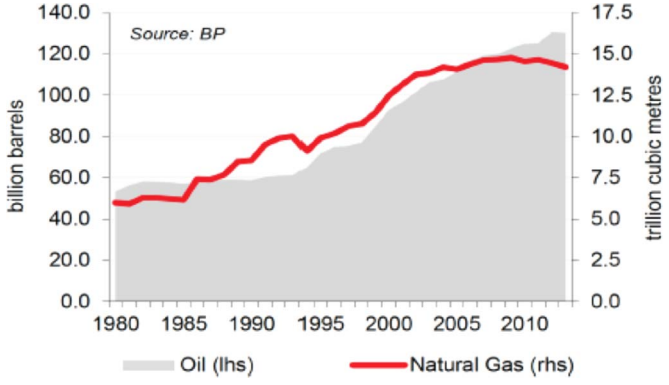

Fig. 2. Africa's proven oil and gas reserve [6].

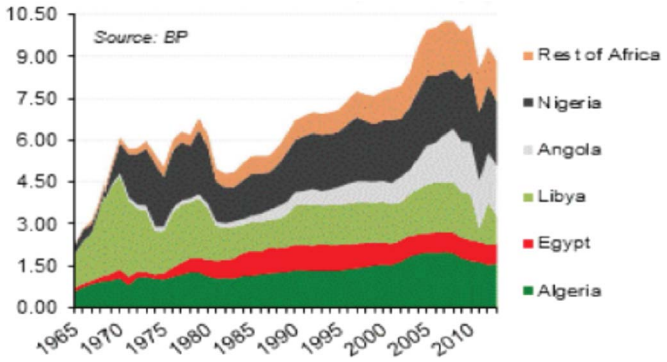

Fig. 3. Africa oil production (million bpd) [6].

Table 1
Non-renewable energy resources potential of Africa [7].

Types energy	Proven reserves	Regional distribution
Non-renewable		
Crude oil	132.1 billion barrels	53.2% Northern Africa 28.2% Western Africa 16.9% Central Africa 1.7% Other Africa
Natural gas	14.7 trillion m^3	55.8% Northern Africa 36.1% Western Africa 8.2% Other Africa
Coal	31.696 billion tones	95.2% Southern Africa 4.8% Other Africa
Nuclear	Reasonably assured resources: 663,400 tones Inferred resources: 286,300 tones	2.9% Northern Africa 36.7% Western Africa 2.7% Central Africa 4.2% Eastern Africa 53.5% Southern Africa

3. Why renewable energy

The united nations has regarded Africa as one of the continents with maximum vulnerability to the effects of climatic change due to population growth and its attendant human activities, overreliance on subsistence agric, low capacity to adapt to change and impending water crises. Whereas the quest for renewable energy in developed countries driven more by insecurity in energy supply, air pollution caused by burning fossil fuel, the need for resource diversification and prospect of resource depletion, Africa remains vulnerable to vagaries of fossil fuel set to developed countries to which they export crude oil [10–12].

Renewable energy as an alternative is a sustainable option that can significantly overdependence on fossil fuel. Furthermore it has the advantage of creating employment, proximity to load and in many cases, led dependence on concentrated energy source. The use of more renewable energy would similarly reduce Africa's economic vulnerability to the adjustable and rising prices of imported fuels. Global and local communities are gradually trying to follow the renewable energy trend by shifting the economy towards greater dependence on renewable source. It is expected that rules and regulations, as well as voluntary structures such as the “Clean Development Mechanism” and Renewable Energy Certificates will offer better sustenance for a prolonged role of renewable energy in the economy [13].

Table 2 shows the renewable energy target of Egypt, Nigeria and South Africa, and Table 3 shows electricity access, population without access and targets access of Egypt, Nigeria and South Africa.

4. Strategies toward utilization of efficient energy in Africa

For an energy need to be attained by all and sundry, proper