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DRIVERS, BARRIERS AND STRATEGIES FOR IMPLEMENTING SOLAR-POWERED AIRCONDITIONING TECHNOLOGIES IN SOUTH AFRICA

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ABSTRACT

The work described in this journal paper addresses the current literature on the utilization of solar energy as a renewable energy alternative in South Africa from the perspective of environmental conservation. South Africa is a country with no crude oil reserves of its own, all its crude oil must be imported from foreign countries namely Saudi Arabia, Nigeria, and Angola. In 2018, these countries supplied a total of 89 % of crude oil imports. The South African Energy Crisis (SAEC) is a never-ending issue where the country faces widespread rolling blackouts due to electricity supply falling behind demand, which essentially threatens to destabilize the national grid network. This method of inhibiting transmission and distribution lines from becoming overloaded is referred to as load shedding, which was first initiated in 2007 and continues up to this day in South Africa.

The country's future energy supply is in danger due to the fast-declining fossil fuel oil reserves, insufficient refinement capacity to match the country's demands, and severe cases of energy instability in uneasy parts of the country where shortages occur.

South Africa is blessed with a rich supply of renewable energy resources. Solar energy is plentiful and an everlasting energy source that has been used by rural dwellers for various processes e.g., agriculture. In this article, the widespread usage, as well as the different applications of solar resources, are examined and reviewed. The potential motivators for the advancement of solar energy transformation systems are presented together with the drivers and barriers to solar energy advancement.

The various actions and policy measures recommended for controlling the barriers and improving the use of solar energy resources are also discussed.

***Keywords*:** renewable energy, energy crisis, load shedding, motivators, drivers, challenges, barriers, policy measures, actions, solar energy resources.

1.0 INTRODUCTION

'Space cooling' has been, and remains, one of the most challenging topics to be dealt with when considering energy systems. Internationally, an upsurge in refrigeration and air conditioning demands has increased electrical energy demands. Moreover, blackouts in the months of summer have been mainly attributed to a high number of conventional-type air conditioning systems operated by electrical power. The widespread use of cooling systems operating on vapor compression cycles has led to a substantial increase in greenhouse gas emissions which originates from fossil fuel-derived electricity consumption.

Solar energy can provide the necessary cooling demands in building spaces. Solar cooling encompasses photovoltaic and solar thermal systems, both are marketable technologies. The photovoltaic systems operate with vapor compression cooling machines, while the solar thermal system is driven by sorption chiller units. The International Energy Agency Solar Heating and Cooling Program (IEA SHC) provides a review of the latest groundbreaking technologies and markets. Market barriers and innovative challenges are recognized, and suggestions are made to overcome them [1,2].

The most inexhaustible form of energy on the planet's surface is energy from the sun. The prime objective of making use of the sun's energy is to decrease the carbon dioxide (CO_2) and methane (CH_4) gas emissions that add to global warming and ozone layer depletion. The solar industry is novel in South Africa; the quantity of sunshine South Africa obtains is remarkable in comparison to other countries in the world (Figure 1). Therefore, there is great potential for solar photovoltaic (PV) applications in the country. Figure 2 shows the various energy sources for electricity production in South Africa in 2018, with coal being the highest at 89 % and solar being one of the lowest at 1.7 % [6].

"Most parts of South Africa average higher than 2 500 hours of sun hours per annum, with a mean solar-radiation level varying from 4.5 kWh/m^2 to 6.5 kWh/m^2 per day" [3]. This, together with the rise of solar energy in world markets, provides an opportunity for the South African market to flourish.

South Africa also has a moderately dry climate with a mean annual rainfall of 465 mm compared to 805 mm for the world. Solar PV cells can operate without water (H_2O), so when there is less rainfall, there is a greater chance of energy being generated from the panels. This represents yet another huge benefit of South Africa's natural solar resources. All the above points contribute significantly to the development of the solar market industry.

Since solar radiation is at its highest point over the summer periods when cooling is in great demand, this makes air conditioning an appealing field of interest for applications of solar energy. This study gives an account of the need for the development of novel and innovative air conditioning technologies which have minimal operational costs and environmental impacts.

Solar PV is a renewable energy system that makes use of panels to change the sun's power into electric power, which is either stored by deep cycle batteries, directly used, or fed back into the grid. Since solar systems represent energy sources that are pure and dependable, they can fulfill a host of applications e.g., houses, buildings, farming, livestock, etc. [4].

The main objective of this study is to identify and discuss the drivers (motivators) and barriers (obstacles) to the application of solar-powered air conditioning systems for building infrastructure in South Africa.

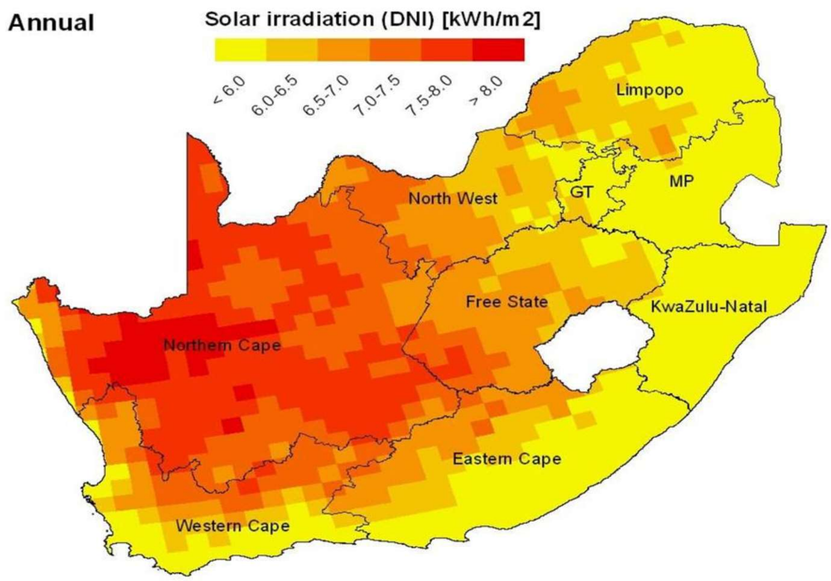

Figure 1. Solar radiation map showing concentrated solar power in South Africa [5]

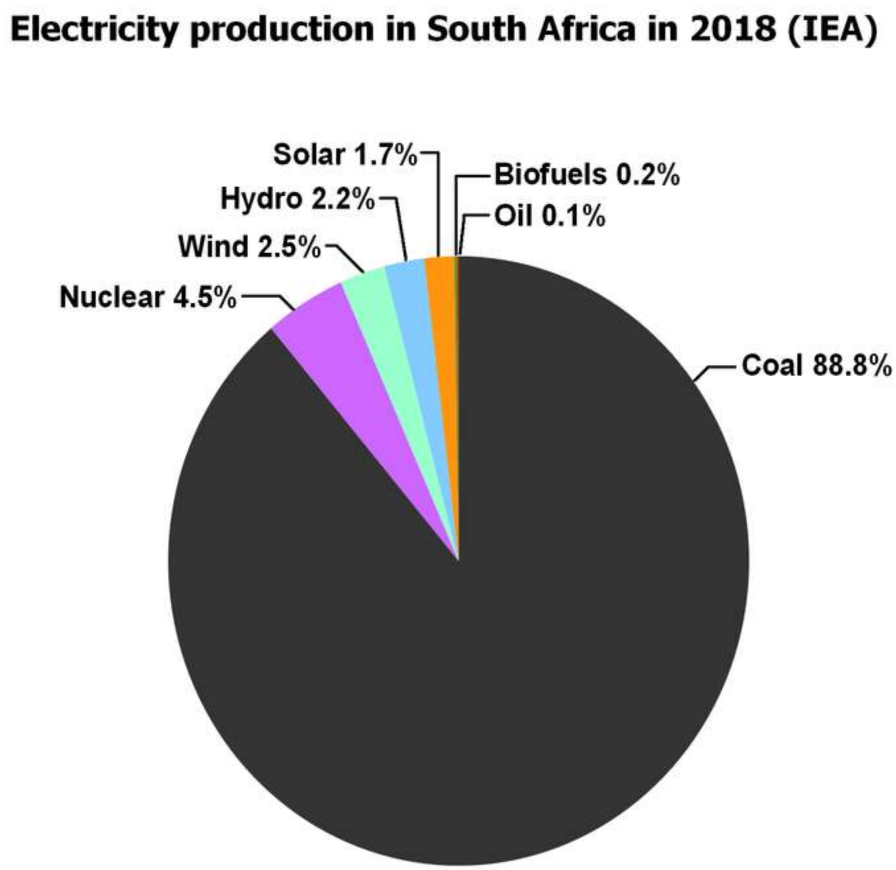

Figure 2. Electricity production in South Africa, 2018, IEA [6]

2.0 DRIVERS AND BARRIERS TO SOLAR APPLICATION AND DEVELOPMENT

The evolution of solar energy has huge potential to provide benefits in energy for economic and social advancement in South Africa, particularly in rural areas of the country. The advancement of solar energy transformation systems is set in motion by drivers (motivators), however, solar energy advancement also meets many obstacles (barriers). The drivers and barriers are discussed in sections 2.1 and 2.2.

2.1 Drivers

Apart from South Africa’s superior solar radiation and its plenitude being major beneficial factors, certain other drivers boost solar energy advancement, and these are outlined below.

2.1.1 Power sector amendments law

The National Energy Regulator of South Africa (NERSA) is authorized to regulate electric power, pipeline gases, and petroleum product industries, as well as issue electric generator licenses and registrations for the operations of generator amenities. No operator is permitted to run a generator facility without possession of a valid license and the facility must be deemed safe for use as per Schedule II of the Energy Regulation Act (ERA) set out by the Ministry of Mineral Resources and Energy (MMRE). The exemptions, however, refer to small generator units operating below 1 MW and units that are operated for private use and not connected to the grid network [7]. The Act, therefore, entitles a person or group of persons to start investing in independent off-the-grid energy generation systems. Solar energy will no doubt play a significant role in obtaining the goals in both grid-connection and off-the-grid connection systems due to its rich and abundant supply.

2.1.2 Reduction of gas emissions (CO_2 and CH_4)

The energy derived from planet earth’s natural resources (renewables) will play a vital role in new and upcoming energy systems since there is a huge demand to reduce the carbon dioxide (CO_2) and methane (CH_4) gas emissions that originate from conventional, fossil-fuel energy sources.

2.1.3 Energy demand

The present population of South Africa is an estimated 59 million and this figure is predicted to surge to 78 million in 2040, which is a growth of 19 million at a mean annual rate of 1.3 % [8]. An upsurge in the energy demand will provide greater opportunities for the use of solar energy since the standard energy sources will no longer be viable to meet the needs of the ever-increasing population. Furthermore, an increase in the economic expansion opportunities in rural areas will push the demand for renewable energy options due to the grid's inability to supply generated conventional electricity to such areas [9].

2.1.4 Energy Dependability and Access to rural electricity

Almost one-third (31 %) of the population of South Africa live in rural areas and more than 60 % of rural dwellings do not have access to electric power. This suggests that the percentage of rural dwellers in households not having electricity is higher than 50 %. South Africa’s electricity public utility, ESKOM, is chiefly responsible for power generation, transportation, and electricity distribution in the whole country but only 5 million households are supplied directly, which suggests that a major portion of the communities are dependent on municipalities for their supply. ESKOM must ensure that at all times the supply is adequate to match the demand. However, electricity demand is not always constant due to the following factors:

- a much higher demand during the peak periods; and
- a constant rise in clients needing electrical power supplies

This means that the public utility provider must cautiously manage its supply to match the demand, but as of today, it is still facing the challenges of a constrained power system. This, unfortunately, is going to continue to impact South Africa's power generation until such time a new power utility provider comes to the rescue. In the interim, to match the demand, ESKOM's current 27 power stations (in total) and infrastructure must be utilized to their fullest capacity. Furthermore, routine and compulsory maintenance of the plant/infrastructure needs to be scheduled properly to minimize supply capacity being compromised during peak periods of demand. Local outages must not be misinterpreted as load shedding. If a mechanical/electrical defect is detected in the transmission and distribution (T & D) network, or there is some tampering with electrical equipment (e.g., cable stealing), or overloading of a local system due to irregular high usage (electricity has been stolen or normal faults), this can cause local outages.

Load shedding is applied throughout South Africa as a precautionary measure in response to unexpected eventualities and to prevent the power utility provider from a complete blackout (i.e., the collapse of the system) [10]. The term blackout is used to signify that there are "no lights" in a local area. A country-wide blackout has very serious consequences and can occur when demand far exceeds supply, forcing the power system into a state of imbalance– i.e., the entire power system trips off!

The above factors motivate or drive the requirement for solar-powered systems.

2.1.5 Escalating demand for local added value

For evolving countries like South Africa, solar energy technologies can contribute significantly in supporting the country's energy demands through locally added value. Although 85 % of the population is grid-connected on a national level, but the remaining 15 % (mostly rural dwellers) are stranded and have no alternative but to resort to biomass and fuelwood as their energy sources for basic day-to-day needs.

Rural dwellers are very skilled people so they can develop their solar energy applications in many ways (sun stoves, chicken brooders, solar water geysers, etc.). Most of the applications based on solar power fit in with current technologies and thus have a huge potential for local added value; some have only a few high-tech components that can be exchanged with other components and can easily be manufactured locally. This will promote socio-economic stableness, acquiring of skills, and employment creation.

2.1.6 Employment creation

The progression of solar technologies can make a significant impact in reducing poverty in local communities that can profit from business prospects, skills acquisitions, investment prospects, and technological changes. Many renewable energy trial projects in emerging countries have demonstrated the role that renewable sources can play in energy-poor neighborhoods [11,12,13].

Thus, if the investment in solar application is improved, then this leads to the development of home-grown expertise in repair-type work, installing, and producing various types of solar devices across the country, thereby leading to job creation. This refers more explicitly to the rural communities not connected to the grid network. To alleviate the instability in international markets, it becomes necessary to safeguard the local energy supply. Solar air conditioning technology is thus important as it provides an opportune market for stakeholders which include building owners, planners, manufacturing, and installation companies, hence the huge demand for it.

2.2 Barriers

At the current moment, the application of solar energy in South Africa is undergoing a host of challenges even though there are:

- Reasonably good levels of solar radiation available
- Essential benefits and motivators; and
- Prospective markets by dwellers who have/do not have constrained electricity supply

The various obstacles to the advancement of solar energy in South Africa are discussed below.

2.2.1 Changeability and irregularity of radiation

The energy from the sun is a source of energy that varies according to the sun's strength and its availability throughout the country. South Africa's sunshine hours range from 10 hours to 14 hours per day [14]. As a result, the electrical power generated from solar power plants will also vary accordingly, since demand doesn't necessarily follow the same trend. The grid-connected and hybrid solar electricity (electricity from one or more sources) can only be practicable in the Northern Cape province (see 'red' section in Figure 1) where the solar irradiation is at its peak and ranges from 8 kWh/m^2 to 9 kWh/m^2. Stand-alone and off-the-grid solar implementations, for example, lanterns, battery chargers, etc. might be a practicable alternative in parts of the country where solar irradiation is lower than 6 kWh/m^2. These inadequacies can be overcome by designing new and innovative solar technologies for storing the energy when the sun is readily accessible and then re-using these stored energies when the sun is not so readily accessible.

2.2.2 Network grid irregularity

Even though the supply of electricity in developed countries may well be on an upsurge, households, and industries that are linked to the grid often receive a low-quality, untrustworthy, and unpredictable service. A survey in 2019 suggested that more than 200 million households across the world use an undependable grid connection, and less than 50 % of Africa's population has a dependable electricity supply. Industries and households are disturbed by unscheduled, unstable power outages that can at times last for hours or days, and they must also bear with planned and regulated electricity shutdowns i.e., load shedding – where electricity is cautiously rationed to relieve stress and prevent a total grid collapse. The capacity and quality of electrical systems are typically related to reliability issues. This can be attributed to inadequate generating capacity or a generating mix that is unable to upscale/downscale to match fluctuations in demand; maintenance needs; the collapse of T & D lines, transformers, and machinery [15]. At present, the country's national power grid is under-designed and cannot deal with irregular electricity generating systems; therefore, grid-connected solar installations will involve building new and high-calibre transmission lines which have been demonstrated to be very challenging in the past due to exorbitant costs.

2.2.3 Absence of knowledge and awareness

The general population and policymakers seated at various political and organizational levels seem to have a lack of knowledge and awareness when it pertains to the vast socio-economic and environmental gains arising from solar energy. The level of education of the consumer has also proven to be inadequate. In some cases, solar projects (solar streetlights, traffic lights, information boards, etc.) in the various regions of the country have been installed by untrained persons or contractors using inferior quality products, which is why these amenities break down so often. So, when it comes to the operation of specialty equipment companies (SECs), a low confidence level is seen in the technology segment amongst the public, private, and finance segments.

2.2.4 High start-up investment costs

High start-up and installation costs with prolonged repayment periods pose an obstacle to the progress of solar energy technology in most emerging countries. The huge costs also show bad judgments of shareholders and a general shortage of financial tools and split financial sectors [13,16]. Imports or local manufacture of solar devices are not well supported. There are no import duties on solar PV, but when it enters the country, it is usually part of a complete solar device and entails battery storage, and this draws duties. The start-up investment cost of solar devices is therefore higher than other traditional energy sources. Another contribution to high transaction costs is that most solar projects are widely spread and are small-scale. Solar energy projects, therefore, are regarded as too pricey in the long term for regional banks to finance since the banks usually seek to recover their funds quickly and see long-term projects as higher risk. Lastly, considering that the major portion of the population falls within the low-income bracket, it becomes somewhat hard for an average individual to invest in solar energy.

2.2.5 Operation and Maintenance and costs

Solar energy technology has for many years been considered an energy supply alternative for isolated and poverty-stricken rural localities in the country. However, operational and maintenance costs are high, and this is primarily due to the scarcity of technically skilled workers. Hence, prospective technology users in rural areas may be inhibited from adopting SECs due to the fear of crises when there is a lack of technical support structures.

2.2.6 Government Policies and Encouragements

Renewable energy investment and energy efficiency need to be promoted to reduce the adverse effects of the social, economic, and environmental impacts on energy production and consumption in the country. South Africa has renewable energy in the energy mix, but this is mainly restricted to conventional biomass and off-the-grid applications. From Figure 2 it is evident that renewables contribute negligibly (11.2 %) to the total bulk electricity supply.

The government has set targets for renewable energy in the shorter term, while more impressive longer-term targets are achievable, aimed at 15 % renewable energy by 2021. To accomplish such targets requires learning from the experience of industrialized countries, for example, feed-in-tariffs (FITs) and portfolio standards.

2.2.7 Sub-standard quality control of products

A big challenge in implementing renewable energy in households is the lack of national technical standards and efficient quality control units in the country and this is caused by a lack of proper training of personnel. A country like China, for example, is responsible for most of the solar product manufacturing and exports. Firstly, these products aren’t controlled through any existing standards and specifications. Secondly, the products are without the manufacturer's trademark certificates, and thirdly most of these market products do not carry a brand name. This consequently leads to an influx of huge quantities of products with inferior quality solar components. Services and systems are also carelessly fitted by technicians with insufficient skills. Therefore, confidence levels in the technology have declined since the initial high investment costs into these products cannot be fully justified.

2.2.8 Insecurities of solar plant infrastructures

In the past, many locations that were appropriate for the expansion of solar energy systems have been subject to violent uprisings. This has affected power plant construction, infrastructure, and workers' lives (killings or kidnappings) in various regions of South Africa. Now, in the northern parts where solar insolation is in abundance, there is insecurity of the solar infrastructure which could halt future investment in large-scale grid connection.

2.2.9 Challenge with land users

If the proposed project is to be situated on land that doesn’t belong to the government, then land issues could become a big problem. A major factor to be dealt with is the location and acquisition of valid permits/licenses for solar power plants in new locations. Most rural lands are designated for agricultural purposes and held in the sole ownership of the inhabitants. The land in such cases may belong to families, close relatives, or communities. Foreign nationals are prevented from securing land ownership as communities fear they might destroy their life-long heritage. Since solar projects will include private participants on a huge scale, banning foreign nationals from taking land ownership sets up barriers to their involvement in mutual solar project development, and hence this may institute a major barrier to solar application, particularly solar PV on a huge scale.

3.0 STEPS AND POLICY MEASURES TO CONTROL BARRIERS TO SOLAR ENERGY ADVANCEMENT

Good policies and political stability are required to control the barriers and fast-track solar energy development in South Africa. However, if one or more of these barriers are withdrawn, this may become insufficient to inspire and/or push up investment in solar energy, as such acts may clash with other governmental rules. Large-scale solar energy projects require large land areas which could endanger food security in such localities. Hence to fast-track such solar energy advancements, the following steps and policy measures are recommended.

3.1 Cost reduction measures

In South Africa, although solar development is feasible from an economic standpoint, financing a project is not so easily achievable. The institutions granting finance should be motivated to grant loans to solar technology retail merchants at much more affordable rates than commercial sectors. This would ensure that retail merchants have the means to obtain capital grants for the purchase of SECs (e.g., solar PV) in wholesale supply. Institutions may also be required to offer 'soft financing' with minimum or next-to-no interest rates for the financing of solar projects.

Microcredit institutions offering micro-lending schemes should be encouraged and promoted, as they have an established track record to be very effective in encouraging renewable energy and lowering poverty in other countries [17].

3.2 Continuous awareness creation

The execution of large-scale renewable energy applications can be properly embarked requires public support [13,18]. Consciousness or awareness is an important factor in that it assists in recognizing specific solar projects and in confronting problems concerning uncertainties of solar plant infrastructures. This consciousness can be achieved by promotions and committed channels of communication mainly using workshops, media, advertisements, and meetings held with communities. However, these advertisements and meetings require financial backup from legislative and non-legislative administrations.

3.3 Conflict with land uses

Most large-scale solar projects (e.g., PV farms, wind turbines, windmills, etc.) involve competition for uses of large tracts of land. The cultivatable lands in most rural communities are primarily used for agriculture. There is growing concern regarding land use for large-scale energy harvesting [13,19,20]. Economic compensation scheme policies need to be implemented by the government and passed on to the concerned population for the possession of their land for solar energy development, as this land is their only source of income. Also, by educating and training the people in skills acquisition in the solar technology field, other job options could be created.

3.4 Establishing and enforcing quality standards for solar equipment

Obstacles related to inferior-quality solar systems have led to deterioration in some of the solar energy projects in the country. It is up to the governmental agencies to set up proper manufacturing standards and specifications and to rigorously abide by them, instead of being solely dependent on countries abroad to do so. Policy methods and enticements should be set up in the country to inspire local manufacturers to build solar devices. The breakdowns with regards to solar energy equipment and its related appliances are mainly related to inferior sizes and designs, arising from an absence of quality and other climatic data.

4.0 CONCLUSIONS AND RECOMMENDATIONS

In summary, solar energy resources, their present applications, and broad-range use in South Africa have been presented. The motivators (drivers) and obstacles (barriers) to solar energy applications and advancements combined with policy methods required to counteract the identified barriers have been discussed. To expand solar energy resources abundantly in the country, good policies with robust political will are required in the following areas:

- The workforce needs to be properly trained with all the necessary skills and knowledge about solar energy technologies.
- The necessary financial support or funding needs to be provided for research, data collection, and analyses.
- Finance and subsidized incentives must be available to individuals, communities as well as private businesses that volunteer to invest their capital in solar energy development technologies.
- All monies need to be reimbursed to all those communities whose land was acquired by the government/investors for solar project development.
- Communities need to be trained with the necessary skills in solar project development.
- Community participation and ownership of solar energy projects need to be encouraged for the security and protection of the infrastructure.

REFERENCES

[1] Mugnier, Daniel; Jakob, Ulis (2015): Status of solar cooling in the World. Markets and available products. In WIREs Energy Environ 4 (3), pp. 229–234. DOI: 10.1002/wene.132

[2] OECD/IEA (2018): The future of cooling. Opportunities for energy-efficient air conditioning. Edited by IEA Publications, International.

[3] South African Department of Energy. info@energy.gov.za http://www.energy.gov.za

[4] S. Tamseel and S. Alam, "Analysis of solar-powered DC air conditioning system," *International Journal of Scientific and Research Publications for Buildings and Industry,* vol. 6, pp. 461-463, 2016.

[5] https://quintongreenfreak.wordpress.com/2012/06/04/solar-power-and-solar-irradiation-in-south-africa-2/

[6] By Periwinklewrinkles -Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=94056965

[7] National Energy Regulator Act of 2004. https://www.gov.za/documents/national-energy-regulator

[8] https://www.news24.com/citypress/news/sa-population-to-rise-by-18.7-million-by 2040-20200815

[9] Energy Commission of Nigeria and the United Nations Development Programme (ECN-UNDP). Renewable Energy Master Plan (REMP): final draft report. Available

online: ⟨http://www.iceednigeria.org/workspace/uploads/nov.-2005.pdf⟩; 2005 [accessed 26.10.13].

[10] https://loadshedding.eskom.co.za/loadshedding/description.

[11] Nnaji B. Power sector outlook in Nigeria: government renewed priorities. Securities and Exchange Commission. Available online: ⟨http://www.sec.gov.ng/files/Prof%20Nnaji%20Presentation.pdf⟩ [accessed 29.03.13].

[12] Iwayemi A. Investment in electricity generation and transmission in Nigeria: issues and options. Int Assoc Energy Econ 2008: 37–42 (First Quarter).

[13] Labo HS. Current status and future outlook of the transmission network. Investor's Forum for the Privatisation of PHCN successor companies. Available online: ⟨http://www.nigeriaelectricityprivatisation.com/wpcontent/uploads/downloads/2011/02/Transmission_Company_of_Nigeria_Investor_Forum_Presentation. pdf⟩; 2010 [accessed 29.03.13].

[14] https://www.timeanddate.com/sun/@8335359

[15] https://www.opml.co.uk/blog/south-africa-s-crippling-electricity-problem

[16] Karekezi S, Kithyoma, W. Renewable energy in Africa: prospects and limits. In: Republic of Senegal United Nations Workshop for African Energy Experts on Operationalizing the NEPAD Energy Initiative, Dakar, Senegal, 2–4 June; 2003. Available online: ⟨www.un.org/esa/sustdev/sdissues/energy/op/nepad karekezi⟩ [accessed 29.03.13].

[17] Mondal MAH, Kamp LM, Pachova NI. Drivers, barriers, and strategies for implementation of renewable energy technologies in rural areas in Bangladesh-an innovation system analysis. Energy Policy 2010; 38(8): 4626-34.

[18] Brunnschweiler CN. Finance for renewable energy: an empirical analysis of developing and transition economies. Environ Dev Econ 2010; 15(3) : 241-74.

[19] Soker M. von Zitzewitz E. Renewable energy and the clean development mechanism: potential barriers and ways forward- a guide for policymakers. Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) Public Relations Division; 11055 Berlin; 2007.

[20] UNEP FI. Financing renewable energy in developing countries. Drivers and barriers for private finance in Sub-Saharan Africa; 2012.