Technology in Africa for Sustainable Alternative Energy Growth: An Innovative Bird Eye View

Emmanuel Emem-Obong Agbenyeku, Edison Muzenda and Innocent Mandla Msibi

Abstract**—**Over the last decade, numerous ideas have insistently emerged and triggered several social, economic and environmental discuss emanating from energy insufficiencies in Africa. A lot around energy poverty are currently argued particularly, on how chiefly Africa's industrialization is prime to its potential sustainability across all facets of growth and development. Sadly, only few member countries since post-colonialism have earnestly attempted innovative approaches towards new alternative energy schemes. Nonetheless, wasteful sums have drowned in projects of less critical nature. For this reason; an innovative bird eye view (IBEV) portrayed how member countries might augment rates of dispensable energy to increase access to electricity. Hence, versatile industrialization via renewable and greener alternative energy sources can be reached. The employed measures herein, extend past industries and research institutes to involve cultural, institutional, economic and political players of key positions in innovative process. Firstly, a conceptual idea of "learning" was conveyed as vital to IBEV, seeing innovation and production as pertinent and dynamic. On a second note, the work featured instances of trials to create renewable energy industries around the continent. Lastly, the possible transformation of research outlets such as the African Network for Solar Energy (ANSOLE) into inventions was highlighted, emphasizing how innovations might be born from inventions. A vital policy suggestion was that divisions of African "innovative force" such as a technological head like South Africa can for example; engage more with member countries involved in production or assembly while creating beneficial agreements with them. Thus, with mixed innovation schemes, more effective knowledge transfer can be groomed across the continent.

Keywords**—***Renewable energy, Electricity, Innovative learning, Sustainable development, Industrialization*

I. INTRODUCTION

THE emancipation of Africans particularly, toddling member countries is crucially tied to sustainable industrial growth and development. Presently, this can have a positive tidal impact on both residents on the continent and in diaspora. However, this is no news as it has long been established by most of the respected iconic figures with African inclination who engaged in its liberation from colonialism. Most of the experiences encountered from old times can be linked to the 19th century. Nevertheless, as recorded by [1] brighter light was cast on them in the 20th century by the likes of; Marcus Garvey, Cheikh Anta Diop, Kwame Nkrumah, Julius Nyerere and Walter Rodney. Then, for example, Marcus Garvey notably envisaged "power" as the people's only liberating route as such, advocated for the creation of an industrial superpower on the continent which was to be highly regarded by member nations and eventually could economically safeguard Africans around the globe. More to this, the late Professor Cheikh Anta Diop later provided one of the most logical and inclusive analyses on the matter of power. Here, as further reported by [1] a comprehensive breakdown of the energy resources available in Africa along with identified raw materials across diverse regions was estimated as basis for massive globalized industrial development across eight natural zones. For diverse reasons, the prominence of industrialization as a factor for independent growth and development in today's world has lost bearing as a paramount point of interest in most of Africa. A clear illustration can be seen in sub-Saharan Africa, where South Africa remains a trailblazer in semi-industrialization however, remains defined as a divided economy with technologically advanced areas and largely non-industrialized regions across opposite lines. According to [2] after the collapse of apartheid in 1994, the newly democratic South Africa adopted the National Innovation Systems (NIS) approach and formally made it a government policy in 1996. Currently, its Ten-Year Innovation Plan initiated in 2008 also uses the NIS language and drives towards matching the country from a resource-based economy to a knowledge-based one. Such that, as noted by [2] it could address its overwhelming pressures i.e., energy security, biotechnology, space technology, climate change, economic, human and social issues. Hence, this work found the need to investigate the conception of learning through the IBEV dimension. This describes the steps of acquiring skills and knowledge stressing the association between actors and organizations in a certain system towards improved technological outcomes. Also, a simplistic insight into IBEV is drawn, specifying some functional settings generally pertinent to non-industrialized areas. The study also illustrates instances the creation of alternative energy industries in different areas of the continent were undertook. Furthermore, the ideology from innovation theory was harnessed to

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explicate how the outputs/outcomes from African renewable energy researchers can eventually be turned into innovative technologies. Thereby, allowing for patent rights and strategies adopted by small firms to specifically protect their ideas, creativity, advance their innovative potential and ultimately boost and sustain overall economic, environmental and societal growth and development. Stringent policy by relevant bodies and government was finally recommended as some of the ways to hasten the cultivation of African-based greener and optional/renewable energy industries.

II. CONCEPTUALIZATION OF LEARNING

A. Learning towards Innovative Bird Eye View (IBEV)

Conceptual learning is a prime factor to innovative thinking and is perceived is a systematic approach to technical transformation. According to [3] it is achievable by the incorporation of foreign innovations across borders directed towards improved domestic innovative techniques. For the purpose of this work, four (4) types of learning as identified by [4] are critical for innovative growth, these include;

i. learning by searching- investigative approach,
ii. learning by doing- practicalized approach,
iii. learning by using- constructive approach, and
iv. learning by interacting- knowledge exchange.

Investigative/search learning deals with the methodical hunt for new knowledge similar to research and development (R&D). While the practicalized learning process is achievable by practical encounters or the know-how required in creating a product, the constructive learning reflects the functional understanding acquired by adopting and utilizing a certain manufactured product. While interactive learning comes to play through exchange of knowledge and the continuous interactions between producers and users towards innovative achievements. In the case of crawling or non-industrialized economies, the learning processes often engaged in are via the modes of DUI (Doing, Using and Interacting). As such [5] posits a connection between the innovation of the user and the producer linked in the flow services and goods. Nevertheless, since innovation also incorporates learning, [3] noted the term 'National Learning Systems' should override 'National Innovation Systems' particularly for slow and late industrializing economies associated with technological learning over innovation [3]. For these countries, a line is drawn between passive learning- in which the technological input is simply geared towards ingestion and digestion of production capability, and an active learning- which goes afar from assimilating production capability and pushes for the mastery of both manufacturing and development capability as observed by [3]. This work therefore, posits that African countries can and should advance into the innovative phase of transformation with regards to greener alternative/renewable energy. The Innovative Bird Eye View (IBEV) which is likened to the Innovation Systems framework as recorded by [5] has two main bird eye views; (1) is a narrow view resting on mapping pointers of national specialization and performance with reference to innovation and R&D inputs, and (2) is a broader view pivoted on wider cognizance of education, environment, social institutions, macroeconomic conditions, and infrastructure development, and their impact on developing steps for learning and competence. For instance, in most of sub-Saharan African countries noted by [6] there is a prevalent supposition of clear-cut links connecting fundamental knowledge creation from educational and R&D bodies to the economic institutions applying the knowledge. A better insight is given by [6] drawn from the deprived state of industry in the region given the concrete evidence of de-industrialization from the substantial positive growth in the 1960s to fragile or negative growth in the 1980s, and a minor increase in the 1990s.

B. Learning towards Functional Innovations for Greener Alternative/Renewable Energy

With reference to a few distinct ways on the functionality of knowledge and innovation in the globalized world, a simple assessment of some international records can assist in vital illustrations. These illustrations can help display the significance and applicability of conceptualized learning and innovation to area of greener and alternative energy. A clear instance is seen in the Dutch encounter with the development of wind turbine whereby, the investigative/searching approach was its central learning mode. Hence, as recorded by [4] the traditional innovative approach was primarily tied to R&D subsidies [4]. Another demonstration can be appreciated in Denmark, where using/constructive learning mode was initiated alongside the interactive/knowledge-exchange learning mode between producers of turbines, users of turbines and the Danish Research Institute. Also, as indicated by [4] the approaches were benched on investment subsidies for the turbine manufacturers. Although, both countries ventured into wind energy development as an alternative form of power in the 1970s, by the beginning of the millennium, the Netherlands out of over 15 initial functional turbines, could account for only one turbine manufacturer. The turbine was original targeted for 2000 MW capacity however, it operated with a total installed capacity of 442 MW. While in the case of Denmark as noted by [4] had a collective installed capacity of 2340 MW with a booming industry supplying the global market with wind turbines. However, China's approach to initiating its rural electrification program ties into the innovative learning mode of DUI. Considering its small hydroelectric projects (SHPs), it was noted to have used a methodical approach as reported by [7] reliant on three discrete principles namely:

(1) self-construction (learning by doing/practicalized approach)- which ensured the general public utilized locally available materials, technology and water resources to construct functional systems;

(2) self-use (learning by using/constructive approach)- which entailed generated electricity from stations being consumed locally while disallowing competition between locally integrated markets and conventional grids; and

(3) self-management (learning by interaction/knowledge-exchange approach)- which permitted investors to possess and control the stations as such, preventing managerial obstruction and conserving the drive of the locals towards sustainable alternative and improved SHPs. China has since come to the frontlines of the global markets as from 2010 when it became

the largest supplier of wind turbines in the world. This shift in paradigm as reported by [8] accounted for over 50% of new wind turbines and added about 19 GW of capacity in that year alone. A plausible explanation for this speedy growth can be accounted for by the emergence of its wind industry. This industry was born out of other sectors of its varied industrial platform possessing highly significant manufacturing capability. It was also noted that China tactically utilized its licensing agreements with European companies by ensuring a joint design and collaboration instead of Foreign Direct Investment (FDI) and trade thereby, improving its innovative learning processes. Additionally, subsidiaries of domestic-controlled power generation firms as dominant wind turbine producers, created considerable in-house R&D capability. This also propelled lesser feed-in tariffs as huge merits for local service provision over foreign discharge provision.

III. POSITION OF AFRICAN INDUSTRIES ON INNOVATIVE ALTERNATIVE/RENEWABLE ENERGY

A. General Insight on the African View Point

The amount of positive impact that alternative energy potentially has in the sustainable growth and development of Africa's economic, environmental, industrial and social facets cannot be overemphasized. Yet, this knowledge is no news as earlier stated however, very little is currently been done to optimize this lingering potential. A study by the UNDP 2009, reported that only about a quarter of the population in Sub-Saharan Africa had access to electricity with 10 countries having a national access rate <10%. Moving to the rural settings, generally harboring a population ≥80%, the access rate was noted to be <3%. Countries like Zimbabwe were however exceptions as indicated by [9], as electrification rates ≥18% was recorded for its rural inhabitants whereas, South Africa's electrification plan, though principally based on coal, recorded the most exceptional results as explained by [10], discharging from a rate of access <1/3 in 1990 to ≥80% in 2009 in totality with an estimated ≥5,000,000 recently connected households. Although electrification schemes and alternative energy supplies are not yet rooted in most parts of West Africa, [11] discussed in detail the potential for a distributed generation (DG) of greener/optional energy as a definite measure to address the dire needs of people currently suffering total blackouts or insufficient power supply. This also includes a few alternative financing plans capable of utilizing DG in enhancing domestic ownership of the electricity sector. Observation by [12] shows the adoption of photovoltaics (PV) systems in Africa are higher in Southern and Eastern Africa as compared to West and Central Africa. By early millennium, South Africa and Kenya had ≥150,000 Solar Shelter Systems (SSSs) and Zimbabwe had ≥85,000, while Uganda and Tanzania recorded ≥20,000 and 10,000 respectively [12]. The prices of PV is still on the high side in Africa due to high transaction costs from importations of system parts and taxes nevertheless, on the global markets it has reduced drastically by virtue of improved innovation and economies of scale in production. In Africa however, [12] also records that Kenya still remains an exception since import tariffs and competition have reduced prices. It is noted nevertheless, that prices would be much reduced if only system parts were domestically manufactured. For these reasons, the solar PV industry in Africa indicated three crucial factors pertinent to future sustainable growth and development:

(a) technology development- by both community-level using water pumping or household electricity, and industrial-level using agro-industry and public health facilities;

(b) education; and

(c) finance. As such, these factors can also reflect on other optional/alternative energy industries as stated by [12].

B. Position of the South African Alternative Energy Industry

Till date, there have been very little attempts in the manufacture of solar system parts in Africa particularly, in South Africa, Kenya and Zimbabwe, irrespective of having most of the global manufacture of solar components situated in industrialized countries. However, as reported by [13] in 1987, Solarcomm- a solar equipment and manufacturing company in Zimbabwe with 50 head manpower had bespoken a new plant to match the quality of any imported product. Few years later, the Danish Federation of Small and Medium-sized Enterprises (DFSME) approached Solarcomm for a symbiotic commercial relationship. As reported by [13] in 1993, manufacture of the hybrid product was futile due to conflicting managerial demands. DFSME however, partnered with Solamatics (PVT) Ltd- a major competitor to Solarcomm. The fruition from the new partnership successfully yielded solar-powered navigational equipment, solar water heaters and photovoltaic vaccine refrigerators exported to other countries of the Southern African Development Community (SADC) region. Interesting lessons from this encounter in learning-exchange/technology transfer experience is the need for available local know-how at the domestic level leaning towards chances for improved training, as well as existing management enabling progressive and sustained development of technology exclusive of foreign support after knowledge transfer. Hence, available stable power supply and proper infrastructure are chief to achieving such a transformation. A clear case as recorded by [14] is seen with Prof. Vivian Alberts of the University of Johannesburg who in 2005 created a low-cost thin film solar PV technology based on Copper Indium Gallium diSelenide. However, the product was eventually licensed to Aleo Solar- a German manufacturer. This move was ascribed to the incapability of this invention to be domestically manufactured due to lack of specialized solar PV manufacturing know-how, poor institutional and legal support, and inadequate financing [15]. It is also important to note that two of the main manufacturers of PVs in South Africa; Solaire Direct and Tenesol, are both subsidiaries of French-owned companies. On the brighter side, Isivunguvungu (meaning "big wind" in both *isi*Xhosa and *isi*Zulu) as reported by [16]- a Cape Town-based company and the first wind turbine rotor blade manufacturing plant in South Africa was launched in 2011.

C. View Point of the West African Optional Energy Industry

The Sustainable Power Electric Company (SPEC) of Senegal initiated the first solar panel production line in West Africa established and announced in 2011. A 15 MW solar production line was bought as described by [17] from the Swiss company 3S Modultec alongside comprehensive training packages, service and maintenance contracts and the certification of the panels to be produced. SPEC, as explained by [17] had a technology and innovation center specialized in solar energy for development of major projects. It looked to expand the production line to 25 MW and intended to potentially merge automated and semi-automated production phases. Experts from 3S Modultec planned on augmenting the capacity of the local SPEC team by monitoring the project throughout the projects planning, ramping-up, launching and certification stages. In the course of time in 2011, the Nigerian National Agency for Science and Engineering Infrastructure (NASENI) established a partnership with an unnamed foreign firm to establish a 7.5 MW solar module factory that would manufacture PV panels for small-scale off-grid applications throughout Nigeria [16]. Hence, building a solar cell factory that can produce solar panels using locally grown silicon ingots as explained by was the ultimate plan [16]. However, with certain destabilizing and militating factors, particularly in Nigeria, and the present political dispensation, it is unsure how far the project has come.

IV. INNOVATIVE RESEARCH IN AFRICA FOR SUSTANABLE GROWTH AND DEVELOPMENT IN ALTERNATIVE/RENEWABLE ENERGY

A. Uniting Research and Innovation for Sustainable Energy

In 2010 the African Network for Solar Energy (ANSOLE) was founded to drive policy informed education and training at various skill levels, encourage research activities among resident African scientists and those in diaspora. As well as propel the awareness and use of optional/solar energy in Africa even via African languages and dialects towards a hastened environmental conservation, economic and societal growth. Many researchers in this network which now holds a hand full of members as stated by [14] do not believe Africa can survive in the already advanced field of silicon-based PV. However, in compensation for its currently low efficiency, is attracted to organic polymer-based solar cells due to their relative ease of processing, flexibility and affordability. Although the interactions between researchers created by ANSOLE will lead to inventions being protected by patents, increase the ability to transform these inventions into innovations to manufacture more beneficially for both the producers the users. The process involves creating a social system that has to nurture technical ideas, make investments in risky situations, and arrange the division of benefits so that both investors and personnel are motivated to develop the competences to execute all necessary tasks [16]. In cases where this situation is inexistent and international hands are required, arrangements should be made in ways that develop beneficial and essential capacity in the host/learning country. As such, FDI is way more likely to yield substantial knowledge transfers between countries with related interests and close economic development ties rather than in circumstances between industrialized and non/less industrialized countries. Generally, trial and error have remained the basic drive towards innovative successes. However, advances in theoretical and practical knowledge, more firms possess prospects of initiating and introducing more innovations. Nonetheless, the technical inputs needed for problem solving could be costly and inaccessible for utilization in a virgin project. Hence, abstract knowledge exchanged by networks should incorporate problem-solving capabilities of toddling firms such that innovative solutions can be born. Finally, in patenting strategies, [16] stated that broader patents can increase the rate of technological progress by propelling and promoting small firms or innovators with little or no size and downstream capabilities in the face of larger markets.

V. CONCLUSIONS

This paper indicated the importance of the versatility of industrialization via renewable and greener alternative energy sources towards the growth, development and sustainability of Africa. It emphasized how appropriate measures beyond industries and research institutes alone but inclusive of cultural, institutional, economic and political strategies can promote innovative process. As well as how the idea of conceptualized "learning" remains pertinent in the African context for sustainable greener/optional energy growth. As such, the following conclusions were drawn:

- The need for alternative energy in Africa has become enormous due to shortages of conventional energy/electricity supply.
- This predicament can project Africa towards developing greener/optional industries which can offer effective and appropriate solutions to its need.
- How conceptualized learning can generally promote innovative views guiding the process of industrialization towards generation of alternative energy in Africa.
- Additionally, regardless of the countries where adoption of optional energy is growing, largely in solar PV applications, the need for domestic industries to fully offer these technologies is of key concern as they are scarcely involved in this much needed service.

In summary, the paper posits that outputs from webs of scientists such as ANSOLE be incorporated into user and manufacturer alternative energy technologies such that, their knowledge can be transformed into inventions and subsequently, convert the inventions into affordable and tangible. It is emphasized however, that the process involved may need rational technology policies of licensing and patenting strategies and agreements. Recommendations herein are such that for instance, a country like South Africa, with its research base may utilize active learning strategies in collaborating with Zimbabwean firms with manufacturing experience to yield fruitful research outcomes. Equally, West African or East African firms for example, may get licensing agreements with Southern African firms to reinforce their production capacities via passive learning strategies. Furthermore, tertiary and secondary educational institutions in myriad communities may train more young people towards developing and managing dispersed renewable energy systems. Thereby, enhancing sustained technological learning, growth, development and competence all geared towards building and improving Africa's innovative capacity.

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REFERENCES

[1] Diop C.A. 1987. Black Africa - The Economic and Cultural Basis for a Federated State: Lawrence Hill Books.

[2] Maharajh R. 2011. Innovating beyond Racial Capitalism: A Contribution towards the Analysis of the Political Economy of Post-apartheid South Africa, in Research Policy Institute, Lunds University: Lund, Sweden. p. 294.

[3] Viotti E.B. 2002. National Learning Systems: A New Approach to Technical Change in Late Industrializng Economies and Evidence from the Cases of Brazil and South Korea. Technological Forecasting and Social Change, 69(7).

[4] Kamp L.M., Smits R.E.H.M. and Andriesse C.D. 2004. Notions on learning applied to wind turbine development in the Netherlands and Denmark. Energy Policy, 32: p. 1625-1637.

[5] Lundvall B.Å. 2009. Innovation system research and developing countries, in Handbook on Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting, B.-Å. Lundvall, et al., Editors.

[6] Adeoti J.O. 2002. Building technological capability in the less developed countries: the role of a national system of innovation. Science and Public Policy, 29(2): p. 95-104.

[7] Yao X. and Barnes D.F. 2007. National Support for Decentralized Electricity Growth in Rural China, in The Challenge of Rural Electrification: Strategies for Developing Countries, D.F. Barnes, Editor, RFF Press: Washington, DC. p. 225 - 258.

[8] Lema R. 2011. Competition and Cooperation between Europe and China in the Wind Power Sector. IDS Working Paper, 2011(377).

[9] Karekezi S. and Kithyoma W. 2002. Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa? Energy Policy, 30: p. 1071-1086.

[10] Bekker B. 2008. South Africa's rapid electrification programme: Policy, institutional, planning, financing and technical innovations. Energy Policy, 36: p. 3115-3127.

[11] Soumonni O. 2010. A Bottom-up Approach to Energy Policy Planning in West Africa: The Case of Distributed Generation of Renewable Electricity. in Proceedings of the 4th International Conference on Appropriate Technology. Accra, Ghana.

[12] Moner-Girona, M. 2006. Decreasing PV Costs in Africa. Refocus, 7(1): p. 40-45.

[13] Mollat M. 2009. The Denmark-Zimbabwe Technology Partnership Projects in Solar Equipment Manufacturing. UNCTAD Technology for Development Series.

[14] Ottery C. 2012. The solar researchers aiming to light up Africa. The Science and Development Network; Available from: http://www.scidev.net.

[15] Perrot R. 2012. SA's low-carbon entrepreneurs need much greater support, in Business Day, BDFM Publishers (Pty) Ltd.: Johannesburg, South Africa.

[16] Soumonni O. 2012. Towards a technology policy for renewable energy development in africa: an innovation systems Proc. 05th International Conference on Appropriate Technology, Pretoria, 109-116.

[17] Knaus A. 2011. 3S Modultec Sells Integrated Solar Panel Production Line to West Africa. Available from: http://www.meyerburger.com.