Nanotechnology Status in Africa (1995-2011): A Scientometric Assessment

Patrick U. Akpan
Department of Mechanical Engineering, University of Nigeria, Nsukka.
Enugu State, Nigeria.
Patrick.akpan@unn.edu.ng; +2348102475639

Abstract

Nanotechnology is the manipulation, production, and characterization of structures which have one dimension smaller than 100nm. Although the arrival of nanotechnology in many African countries is in its early stages, one can still assess the amount of work done so far with a view to identifying where more work is required. Energy, Health and Environment are three important sectors that require nanotechnology applications. In this work, key drivers for nanotechnology application in energy, health and environment sectors were identified, factors affecting Nanotechnology development in Africa were also identified and an assessment of nanotechnology development in Africa using two scientometric indicators – number of publications and number of patents was done. The economic benefit that is accruable from the commercialization of new technologies is a major driver for nanotechnology applications in the three aforementioned areas (energy, health and environment). The results of the scientometric analysis show that 23 Africa countries produced 1,775 publications over the 1995 – 2011 periods or ~ 0.628 % of the world's publications in nanotechnology. More detailed analysis reveals that nanotechnology related research in Africa is concentrated mainly in six countries — Egypt, South Africa, Tunisia, Algeria, Morocco and Nigeria. These six countries produced 97 % of the continent's publications in peer reviewed Thomson Reuters impact factored Journals. Examination of the continent's inventive profile, as manifested in patents, indicates that Africa produced ~0.061% (41 Patents) of the world's nanotechnology related inventions. Furthermore 88 % of the continent's inventive activity is concentrated in South Africa while Egypt and Morocco share the remaining 12 %.

Keywords: Nanotechnology, Nanoparticles, Africa, Patents, Publications, Scientometrics, Energy.

Introduction to Nanotechnology

Nanotechnology is defined as the manipulation, production, and characterization of structures which have one dimension smaller than 100nm. The resultant Nanoparticles or nanomaterials possess novel properties and characteristics that differ from the same non-nanoscale material. Nanomaterials have applications in areas such as medicine, cosmetics, chemical industry, power and industrial engineering [1]. The US National Nanotechnology Initiative (NNI) highlights size, novelty, and human manipulation in its definition of nanotechnology. Nanotechnology is the creation and utilization of materials, devices, and systems through the control of matter on the nanometer-length scale that is at the level of atoms, molecules, and supramolecular structures. Shapira and Youtie [2] reported that Nanotechnology is frequently defined at the length scale of 1 – 100 nanometers (with 1 nanometer equivalent to one

billionth of a meter). However, this definition is not absolute. Novel properties are seen at critical lengths which are either smaller, for example, atom manipulation at ~0.1 nanometer, or larger, as in nanoparticle reinforced polymers at ~ 200-300 nanometers [3].
The key driver of research into nanotechnology is the enhanced properties exhibited by nanosized particles and materials. These properties have widespread potential applications across a variety of industries [4]. Research, particularly on nanomaterials will have a widespread impact in health, information, energy and many other fields where there is a major economic benefit to the commercialization of new technologies.
The objectives of this work are to: identify key drivers for nanotechnology application in Energy, Health and Environment, identify factors affecting Nanotechnology development n Africa and assess nanotechnology development in Africa using two scientometric indicators – number of scientific publications and number of patents.

Nanotechnology Application in Developing Countries

While nanotechnology has applications across multiple industries, there are no standard classifications of nanotechnology applications [2]. This explains the reason why you may find different classification of Nanotechnology applications. Applications derived from nanotechnologies are expected to make a significant contribution to diverse fields.
According to Salamanca-Buentello et al. [5], the top ten (10) applications of Nanotechnology for developing countries are presented in Table 1. Top on this list is energy storage, production and conversion. This is a prioritized list of the top ten problems in most developing countries. With energy at the top, we can see how the energy is the key to solving all of the remaining problems listed on Table 1.
Table 1 Top Ten Applications of Nanotechnology in Developing Countries [5]

1.	Energy storage, production, and conversion
2.	Agricultural productivity enhancement
3.	Water treatment and remediation
4.	Disease diagnosis and screening
5.	Drug delivery systems
6.	Food processing and storage
7.	Air pollution and remediation
8.	Construction
9.	Health monitoring
10.	Vector and pest detection and control

Key Drivers of Nanotechnology in Energy, Health and Environment in Africa
Drivers of Nanotechnology in Energy

In Figure 1, the major drivers for the uptake of nanotechnologies in the energy industry include the need for security and sustainability of energy supply, growing consumer and government awareness of the implications of climate change and the economic benefits in commercialized technology. Climate change drivers for nanotechnology R&D encompass efforts to improve energy storage in green technologies, decoupling energy production from fossil fuels and decoupling from economic growth; carbon pricing and an increased global market for alternative energy technologies.

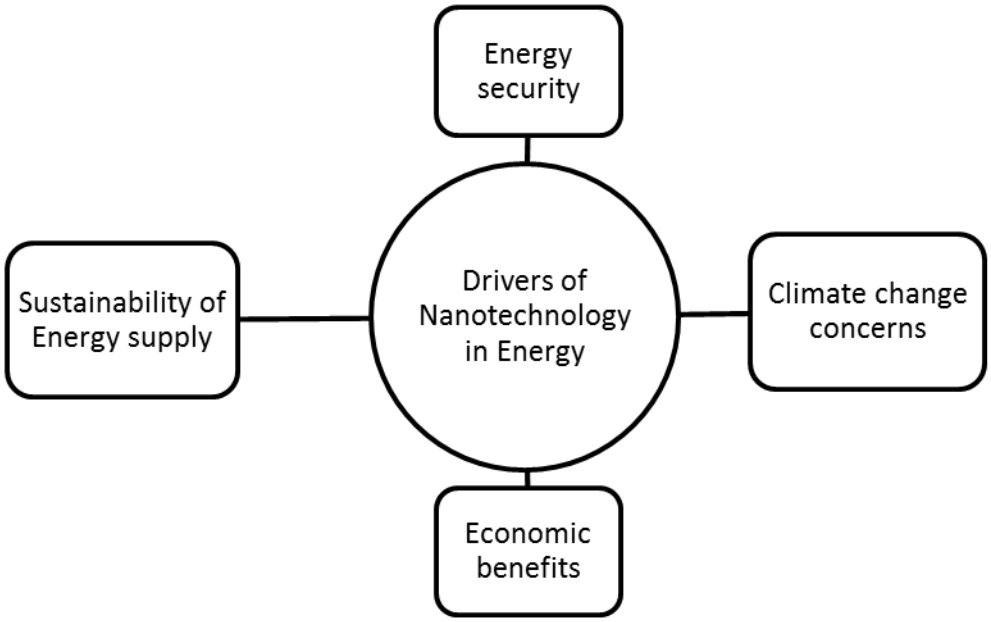


Figure 1 Drivers of Nanotechnology in Energy sector

Inefficiencies of energy supply through the current power grid also drive technological innovation. Energy industry concerns will continue to drive R&D of nanotechnologies for applications in various systems, including energy conversion (hydrogen fuel cells and thin film and organic photovoltaics), energy storage (batteries, hydrogen storage and supercapacitors), energy transmission (superconducting systems), and energy use (insulation, solid state lighting, reduction of vehicle weight and improved combustion of fossil fuels) [6]. Manufactured nanomaterials will enable the development of new energy generation systems based on nuclear, solar and renewable sources.

Drivers of Nanotechnology in Health

Some of the drivers of Nanotechnology in the health sector are presented in Fig. 2. The rapid ageing of the population will drive the uptake of nanotechnology in the development of point of care medical devices and sensors to support 'ageing in place', the ability to monitor many medical conditions in the home through the integration of point of care devices with telehealth and electronic health records management (eHealth). The increase in chronic diseases, such as diabetes, asthma, high blood pressure, etc., combined with the cost of hospital care, and risk of infections in hospital, will further drive health treatments in the home. Nanomaterials will also contribute to the development of new drugs, therapies, and cures for currently chronic and fatal illnesses. Important areas of focus will be the application of nanomaterials in tissue engineering and medical imaging. Further, the application of nanotechnologies has immense capability and promise for advanced diagnostics, improved public health and new therapeutic treatments [7].

So, nanotechnology has the potential to revolutionize disease treatment delivery system, new tools for molecular and cellular biology, new material for pathogen detection, protection of environment.

An ageing population with growing healthcare needs represents an enormous opportunity for nanotechnology products. Nanotechnology will have major applications in medicine, dentistry, pharmaceuticals and diagnostics. For example, the integration of nanotechnology within cancer research promises to increase current understanding about how cancer progresses. The identification of biomarkers will help predict disease susceptibility and precancerous lesions, while multifunctional nanoscale devices could potentially simultaneously detect and treat cancer [8].

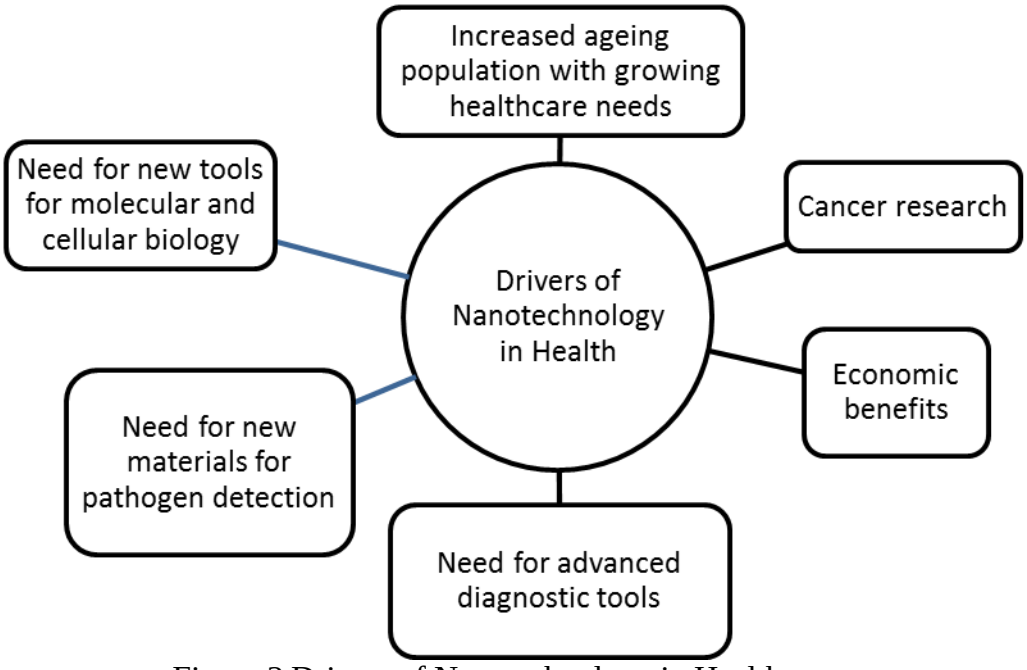


Figure 2 Drivers of Nanotechnology in Health sector

Drivers of Nanotechnology in Environment

Environment comprises the activities affecting water, land and air, therefore the drivers for nanotechnology in this sector will bother on things that affect these three areas.

Opportunities for nanotechnologies in the environmental remedial industries are numerous (see Fig. 3), with applications in environmental remediation, protection, maintenance and enhancement. From a global perspective, nanotechnology research, services and products applied to environmental protection is expected to present the largest opportunities for nanotechnologies, followed by environmental remediation [9]. Nanotechnologies applied to environmental protection will serve to facilitate and expedite ongoing remediation efforts, via the significant reduction of source pollutants. Strategies for environmental protection that include nanotechnologies encompass improved prevention and containment of toxic compound spills into soils, highly effective recycling and green technologies, along with wide-ranging and efficient improvements in energy conservation and generation [9].

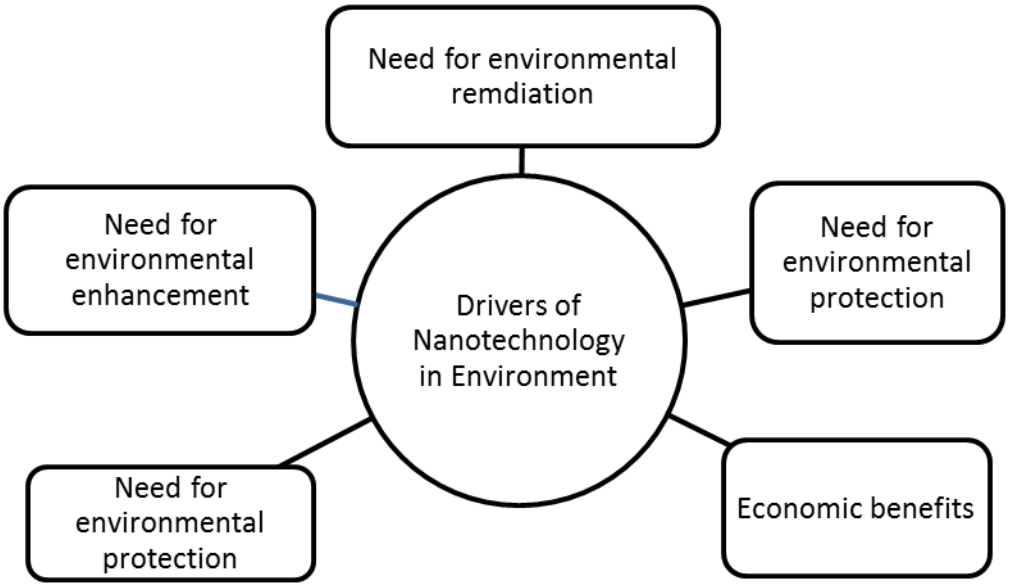


Figure 3 Drivers of Nanotechnology in Environmental sector

There is significant need in developing countries for clean, safe water, especially in rural areas, as well as in rapidly expanding mega-cities, and this is a significant potential market. Worldwide, many people are without access to safe drinking water, and more are lacking improved sanitation facilities. This imposes high human, environmental and economic costs. Nano-engineered structures, membranes and crystals have been put forward for water disinfection and cleaning as well as for desalination [10]. Growing numbers of communities are living in areas of severe water stress, driving the need to be more sustainable in their use and associated treatment of water. Driven in response to issues like these, nanotechnologies are beginning to gain greater use in water systems [11].

Climate change is also driving nanotechnology applications in the environmental remediation industry, including the water and wastewater treatment industry. Nanotechnology-based remedial applications developed for use in the environment might have important positive impacts that may directly affect human health. Air quality remediation, water quality remediation and contaminated soil remediation are areas where nanotechnology enabled solutions have numerous opportunities.

Factors Affecting Nanotechnology Development in Africa

Soleimanpour and Hosseini [12] identified some factors as affecting the development of nanotechnology development in the agricultural sector of Iran. These factors include; policy making factor, economic factor, commercial factor, infrastructural factor, human factor and educational factor. Although these factors were identified as affecting the agricultural sector, it can also be taken to affect nanotechnology developments in other sectors and in Africa as a whole. Figure 4 shows how these factors are inter-related and the effects they have on nanotechnology development. Take for instance, the effect of policy making factor on Nanotechnology development. It can be seen that it enables: the creation of national nanotechnology strategy; creation of policy framework; identification of area of concentration and the proper charting of nano- research trajectory.

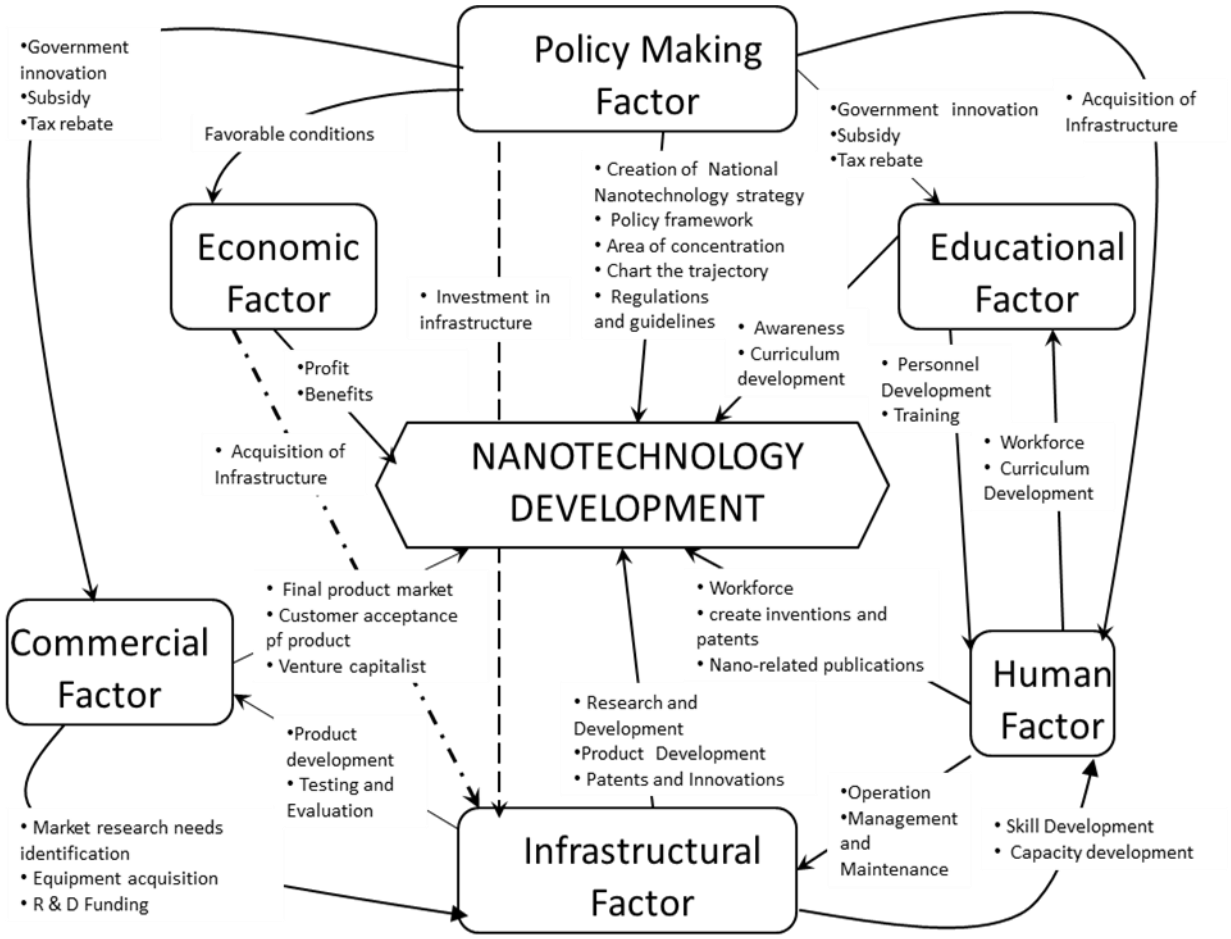


Figure 4 Factors Affecting Nanotechnology Development in Africa

Scientometric Assessment of Nanotechnology in Africa

The impact of future nanotechnologies and where these nanotechnologies will find their way to the global marketplace are reflected in the trends in global investment strategy in nanotechnology R&D and global productivity in nanotechnology R&D can be measured in terms of nanotechnology-related publications, start-ups, and patents.

Scientometrics is the quantitative study of the disciplines of science based on published literature and communication. This could include identifying emerging areas of scientific research, examining the development of research over time, or geographic and organizational distributions of research [12]. In practice, Scientometrics is often done using bibliometrics which is a measurement of the impact of (scientific) publications [14, 15, and 16]. The use of scientometric indicators for decision making is constantly on the rise resulting in the rapid growth of scientometric studies [17].

In this section, a scientometric study on nanotechnology was carried out using two scientometric indicators— number of research publications and number of patents awarded. The Scientometric analysis was carried out using data published from databases produced by

Thomson Reuters (The Derwent World Patents Index ™ and The Web of Science ™). The period under consideration is 1995 – 2011.

The analysis shows that 23 Africa countries produced 1,775 publications over the 1995 – 2011 periods or ~ 0.628 % of the world's publications in nanotechnology. More detailed analysis in Fig. 5a reveals that nanotechnology related research in Africa is concentrated mainly in six countries — Egypt, South Africa, Tunisia, Algeria, Morocco and Nigeria. These six countries produced 97 % of the continent's publications in peer reviewed Thomson Reuters impact factored Journals. Examination of the continent's inventive profile, as manifested in patents, indicates that Africa produced ~0.061% (41 Patents) of the world's nanotechnology related inventions. Furthermore 88 % of the continent's inventive activity is concentrated in South Africa (see Fig. 5b) while Egypt and Morocco share the remaining 12 %.

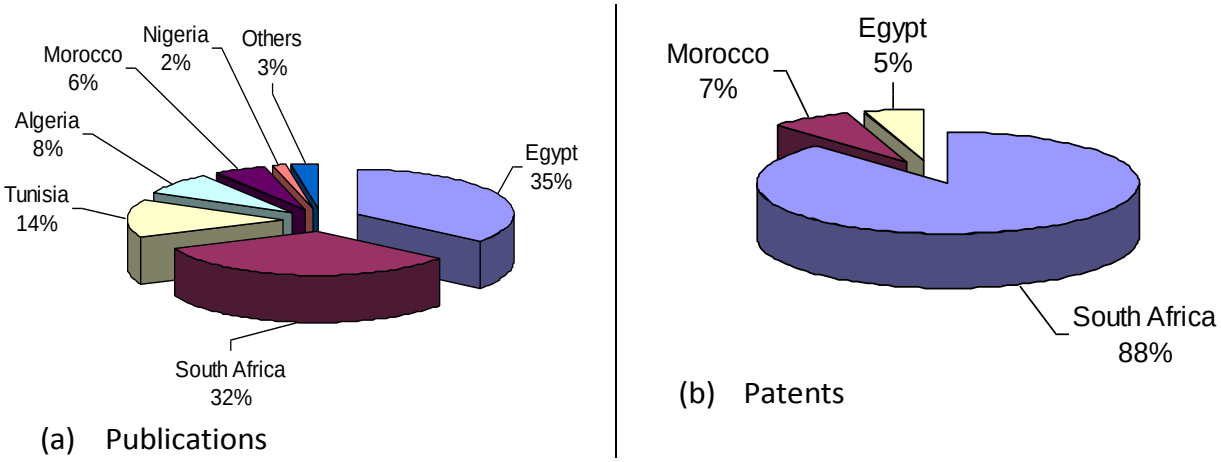
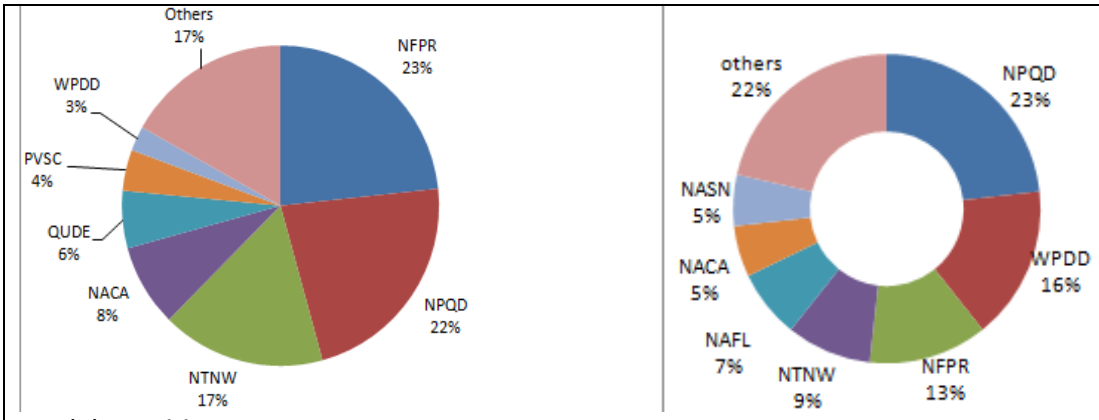


Figure 5 Major Contributors to Nanotechnology in Africa (1995-2011).

In Fig. 6a, the top seven most published areas of nanotechnology in Africa are; Nanofabrication and Processing (NAPR), Nanoparticle and Quantum Dots (NPQD), Nanotubes and Nanowires (NTNW), Nanocatalyst (NACA), Quantum Devices (QUDE), Photovoltaic and Solar cells (PVSC), Water purification, desalination and decontamination (WPDD). In the Patents category, the top seven areas of nanotechnology patents in Africa were (see Fig. 6b) Nanoparticle and Quantum Dots (NPQD), purification, desalination and decontamination (WPDD), Nanofabrication and Processing (NAPR), Nanotubes and Nanowires (NTNW), Nanofiltration (NAFL), Nanocatalysts (NACA) and Nanosensors (NASN).



(a) Publications (b) Patents

Note:

NFPR-Nanofabrication and Processing
NPQD-Nanoparticles and Quantum Dots
NTNW-Nanotubes and Nanowires
WPDD-Water Purification, Desalination and Decontamination
QUDE-Quantum Devices
PVSC-Photovoltaic and Solar Cells
NACA-Nanocatalyst
NAFL – Nanofiltration
NASN- Nanosensors

Figure 6 Seven Most-Prolific Areas of Nanotechnology in Africa (1995-2011).

CONCLUSION

Nanotechnology is indeed an important technology engineered to solving problems by manipulating matters at the nanoscale. In this work, key drivers for nanotechnology application in energy, health and environment sectors were identified, factors affecting Nanotechnology development in Africa were also identified and an assessment of nanotechnology development in Africa using two scientometric indicators – number of publications and number of patents was done. The economic benefit that is accruable from the commercialization of new technologies is a major driver for nanotechnology applications in the three aforementioned areas (energy, health and environment). The scientometric assessment shows that Africa's contribution in Nanotechnology is abysmally low.

REFERENCE

[1] Masoka, X., Utembe, W., Sekobe, G., Gulumian, M. Nanotechnology Research and Occupational Health and Safety in Africa. *African Newsletter on Occupational Health and safety* Volume 22, number 3, P. 56 -60. 2012.

[2] Shapira, P. and Youtie, J. The Economic Contributions of Nanotechnology to Green and Sustainable Growth. A paper presented at OECD/NNI International Symposium on Assessing the Economic Impact of Nanotechnology Background.27-28 March 2012, Washington DC.

[3] NSTC/NSET (Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Council Committee on Technology). The National Nanotechnology Initiative strategic plan. Washington, DC.

http://www.nano.gov/html/res/pubs.html., 2010.

[4] Frost & Sullivan, Opportunities for Nanotechnologies in Electronics–Technology Market Penetration and Road mapping*, Technical Insights, 2011.*
Salamanca-Buentello F, Persad DL, Court EB, Martin DK, Daar AS, Singer PA.
[5] Nanotechnology and the developing world*. PLoS Med*, 2005; 2(5): e97.
[6] Lu, M., & Tegart, G., Energy and Nanotechnologies: Strategy for Australia's Future, Academy of Technological Sciences and Engineering (ATSE), 2008.
[7] GENNESYS Whitepaper, A New European Partnership between nanomaterials science and nanotechnology and synchrotron radiation and neutron facilities, Max-Planck-Institut für Metallforschung, Stuttgart, 2009.
[8] Barton, C. Nanotechnology: Revolutionizing R&D to develop smarter therapeutics and diagnostics. *Business Insights*, 2007.
[9] Boehm, F. Nanotechnology in Environmental Applications*: The Global Market,* BCC Research, 2009.
Shannon, M.A., Bohn, P.W., Elimelech, M., Georgiadis, J.G., Mariñas, B.J., and Mayes, A.M..
[10] *Science and technology for water purification in the coming decades*. Nature, 2008. 252, 20, 301-310.
[11] OECD Fostering Nanotechnology to Address Global Challenges*: Water.* 2011.
[12] Soleimanpour, M. R., Hosseini, S. J., and Mirdamadi., S. M. Exploring the model of nanotechnology development In agriculture sector of Iran. *Arpn journal of agricultural and biological science* vol. 7, no. 12, December 2012 pp. 1002 – 1006.
Glossary of Thompson scientific terminology. The Thompson Corporation.
[13] http://science.thomsonreuters.com/support/patents/patinf/terms/. Accessed on 2014.
Hullmann A. and Meyer M. Publications and patents in nanotechnology: An overview of
[14] previous studies and the state of the art. *Scientometrics*, 2003, 58(3), 507-27.
Schummer J. The global institutionalization of nanotechnology research: A bibliometric
[15] approach to the assessment of science policy. *Scientometrics*, 2007, 70(3), 669-92.
Guan, J. & Ma N. China's emerging presence in nanoscience and nanotechnology. A comparative bibliometric study of several nanoscience 'giants'. *Research Policy*, 2007,
[16] 36(6), 880-86.
Dutt, B., Garg, K.C., and Bali, A., Scientometrics of the international journal Scientometrics.
[17] *Scientometrics*, 2003. *56*(1), 81-93.

ABBREVIATIONS

NFPR	Nanofabrication and Processing
NPQD	Nanoparticles and Quantum Dots
NTNW	Nanotubes and Nanowires
WPDD	Water Purification, Desalination and Decontamination
QUDE	Quantum Devices
PVSC	Photovoltaic and Solar Cells
NACA	Nanocatalyst
NAFL	Nanofiltration
NASN	Nanosensors