Analyzing the Impact of Human Capital on Renewable Energy Penetration: A Bibliometric Reviews

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Abstract: In contributing to reducing the adverse effects of non-renewable energy sources, this paper researched how human capital can enhance the penetration level of renewable energy, which is highly abundant in Nigeria, Sub-Saharan Africa. This paper, using qualitative research methodology through Bibliometric analysis, reviewed three hundred and three (303) papers published between the year 2000 and March 2022. The bibliometric study covered publications per author, publications per country, research focus based on co-occurrence keywords, and research thread. The findings revealed that publications on how human capital can aid renewable energy penetration have been slow and in an infant stage in the past two decades. It also shows that there have been eighteen (18) papers on the subject papers in the last twenty years, showing the low level of human capital development in the energy sector. The intellectual patterns via the co-occurrence of keywords shows five (5) clusters, which are economics of renewable energy sources, human capital factors in environmental management, economic factors in energy supply and demand, sustainable energy factors, and human capital development and economy. These cluster areas revealed how human capital could be developed to increase the penetration level of the abundant renewable energy in the world. Thus, this paper recommends intensive efforts in optimizing human capital through inter-organizational collaboration on renewable energy technologies and periodic training.

Keywords: renewable energy; human capital; environmental management; energy; human capital development; renewable energy penetration

1. Introduction

Renewable energy has been pronounced a sustainable energy source without adverse effect on humans and the environment, and, thus, needs more penetration in regions where it is less utilised. Hence, the economic, social, and environmental sustainability of the earth and its resources has shifted the world’s attention to renewable energy. Renewable energy is an energy source that can be replenished, sustainable, and not harmful to humans and the environment [1,2]. According to the authors, renewable energy includes biomass, wind, solar, hydro, geothermal, and solar energy. However, despite the enormous amount of these renewable energy sources in Nigeria and Sub-Saharan Africa, there is much reliance on non-renewable energy sources, primarily fossil fuels, with their attendant consequences [3]. These consequences include the emission of carbon dioxide, which contributes to global warming, the production of acidic rainfall that harms vegetation and stationery water bodies, and the release of toxic compounds like polycyclic aromatic hydrocarbon, and benzene, among others. This is particularly evidenced in Nigeria, Africa’s most prominent black country, where massive environmental degradation hinders economic performance and decreases the standard of living [4].

According to Corfee-Morlot et al. [5], clean energy resources such as renewable energy resources aid in reducing energy poverty, enable sustainable economic growth, improve the
well-being and health of people, build resilience in societies, and foster the promotion of robust economic development. Moreover, Panshak et al. [6] stated that renewable energy resources would aid the attainment of energy security for Nigeria. Moreover, Akinbami [7] and Akuni and Okoro [1] opined that Nigeria has abundant renewable energy resources that are not fully harnessed with low penetration. According to the authors, estimates include hydropower (10,000 MW), fuelwood (13,071,464 forest land), animal waste (61 million tonnes/year), crop residue (83 million tonnes/year), solar radiation (3.5–7.0 kwh/m²/day), wind (2–4 m/s), and a bioenergy potential of 1,179,120 Joules.

These estimations also bring into perspective the current electricity generation in Nigeria. According to Ugwu et al. [2], Nigeria’s current power generation capacity is 10,480 MW but with actual generation of less than 4500 MW, which is sourced from gas turbines (37%), hydroelectric plants (38%), and gas and steam plants (25%), servicing over 200 million population of Nigeria. Compared with South Africa, with a population of almost 58 million (nearly one-third of Nigeria’s population) generates 58,095 MW of electricity, which is five times more than Nigeria’s capacity [8]. According to Falobi [9], Nigeria’s energy projection is that by the year 2020, electricity generation capacity will be at 40 GW, with an energy mix of hydroelectric (17%), coal (10%), thermal generation (69%), and renewable energy (4%). However, this projection could not be met, and in meeting this projection, Refs. [2,9] stated that abundant renewable energy would play a significant role, considering its sustainability dimensions. This was also corroborated by Ref. [10], stating that Nigeria’s enormous renewable energy can bridge the energy gap between energy demanded and energy supply.

Furthermore, this unharnessed renewable energy in Nigeria’s resources highlights the invaluable role of human capital in increasing the penetration level of renewable energy. According to Ogunjobi, Eseyin, and Popoola [11], human capital is necessary in energy resources development given its unique role in coordinating all factors of production, which invariably rely on energy. The human capital of a nation determines the level of its economic output in its utilisation of energy resources. This is as the research of Ref. [12], opined that due to the component of human capital, there is an increase in energy efficiency. In addition, according to Carraro et al. [13], human capital complements energy resources input into the economy. Huang et al. [14] opined that human capital aids technology spillover from energy resources related to foreign direct investment, especially in developing economies. Moreover, Ref. [15] highlights that energy-saving technologies and conservation mechanisms can be spread and adopted by energy consumers due to human capital development. Succinctly, human capital development is the backbone of energy optimisation and determines the energy source penetration level. That is, to get the best out of all types of all energy resources, human capital will be the driving force.

Human capital development deals with the development and optimality of human resources in an organisation or sector. According to the author of Ref. [16] as cited by Ref. [17], human capital is described thus “the human factor in the organisation, the combined intelligence, skills and expertise that gives the organisation its destructive character. The human elements of the organisation are capable of learning, changing, innovating, and providing the creative thrust that, if properly motivated, can ensure the long-run survival of the organisation”. Refs. [18,19] opined that human capital is the skills and knowledge possessed by an individual, which they create, maintain, and utilise appropriately. Kucharacikova [17] averred that human capital is the combination of skills, knowledge, innovative capability, and the capacity of a company’s employee or human resource to meet the task given by the company. To the authors of [20], human capital is viewed as “an amalgam of factors such as education, experience, training, intelligence, energy, work habits, trustworthiness, and initiatives that affect the value of a worker’s marginal products”. The Organization for Economic Cooperation and Development (OECD) [21] stated that human capital is regarded as “the knowledge, skills, competencies, and attributes embodied in individuals that facilitate the creation of personal, social and economic well–being”. Authors of Ref. [22] summed up human capital as
the most effective form of wealth and the best indication of the current and future potentials of an individual and a country.

These descriptions, views, definitions, and definitions of human capital reflect the importance of human resources in any economic sector. It demonstrates the ability, intelligence, experience, knowledge, learning dynamics, and mental capability of individuals/human resources in a sector of the economy. The human capital depicts an individual’s knowledge level, absorptive capacity level, intellectual ability, training performance output, skills level, and mental agility [23]. Therefore, integrating the utilisation of renewable energy sources with the potential of human capital development, is crystal clear that it is a causal relationship, and mathematically, it is directly proportional to one another. The level of human capital development in the energy sector of the economy depicts the level of penetration of renewable energy, considering the abundance of renewable energy sources in Nigeria and Sub-Saharan Africa. This is highly important, considering the present view of human capital perspectives as shown in Table 1 from Ref. [24].

Table 1. Human capital Perspectives.

| Human Capital View       | Traditional View                                                                 | Present View                                                                 |
|--------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Employee                 | - Are viewed as a cost of production that needs to be controlled and closely monitored. | - Are viewed as a competitive advantage to the organisation that can be developed in their own specific way. |
| Human Capital            | - Was perceived as a costly capital that needs to be minimised.                   | - Is a source of value creation to the organisation.                          |
| The HR Function          | - Used to work as a supporting department.                                       | - Is considered as a part of strategic partner of the organisation that work on executive level. |
| Work                     | - Was functioned according to the manufacturing need based.                      | - Increasingly focused on knowledge-based and cross functional collaboration. |
| Involvement              | - HR involved in mostly setting the management budget and planning.             | - HR acts as the process function involving designing, planning as well as allocating budget. |
| Human Capital matrices   | - Only HR involved in budgeting.                                                | - Engages top executive in budgeting process.                                 |
| ROI                      | - Focused only on the input such as cost and routine practices and activities.    | - Are increasingly focused on design and metrics usage. Focuses on the impact and result to the organisation. |
| Human Capital Measurement| - Lacked know-how and true understanding of ROI                                  | - More applied and engaged ROI in order to use as the tactical tool that helps the organisation create the influential relationship between output and result. |
|                          | - Used the existing data.                                                       | - Focuses on data and information that is necessary to the organisation with proactiveness. |
| Human Capital View | Traditional View                                                                 | Present View                                                                                     |
|--------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| HR Programs        | - No alignment with business and management objectives with HR at all levels.    | - Aligned and cascaded down the goal, strategy as well as objectives of the organisations at all levels of management. |
|                    |                                                                                  |                                                                                  |
| Overall Reporting on Human Capital Technology | - Was an input-based management more than output based. | - Focuses more on output and impact to the organisation.                     |
|                    | - Tried to decrease and avoid error in human as much as it can.                 | - Promotes the mutual relationship with social system in order to enhance the high knowledge performance work system. |
| Management         | - Determined by top management and closely work with expertise in term of technical work. | - Decentralised and promoted the leadership from bottom of the structure.                  |
|                    | - Maximised shareholders benefits.                                                      | - Maximises utilities and values for all shareholders.                                |

The penetration level of renewable energy resources in Nigeria emphasises the optimal utilisation of the resources. It deals with the usage and efficiency of renewable energy resources. Renewable energy penetration entails the high usage of renewable energy, contributing to energy security. Aboumahboub et al. [25] viewed energy penetration as the optimisation of renewable energy, increasing the usage of renewable sources across different geographical locations. Alam et al. [26] viewed the penetration of renewable energy as the optimum utilisation of renewable energy, confirming with Ref. [27] that renewable energy optimisation is about delivering the least energy cost over a period of time. All these descriptions point to the fact that the penetration of renewable energy entails an increase in the utilisation of renewable energy. All these research reflect the intent of this paper to increase the usage of renewable energy sources in Nigeria.

The increase in the penetration of renewable energy sources in Nigeria through human capital development will contribute to solving the epileptic power supply in the country. According to Oyedepo [10], there is a wide gulf between energy supply and energy demand in Nigeria, as electricity supply cannot meet the growing population’s demand. Akorede et al. [28] termed this inadequate electricity supply as an energy crisis that consistently bedevils the country’s energy sector. According to the World Bank, 85 million Nigerians do not have access to electricity, representing 43% of the population, making Nigeria the country with the most energy access deficit globally, resulting in an economic loss of USD 26.2 billion [29]. Statista [30] opined that the rural areas in Nigeria are the areas that lack the most electricity in Nigeria, which, according to Ref. [31] (2014), constitutes the majority of Nigeria’s population. Akorede et al. [28] stated that the per capita energy consumption in Nigeria is one of the very lowest in the world, leading to an increasing rate of poverty in the country. Panshak et al. [6] also noted that the electricity shortage in Nigeria is overwhelming as most citizens only receive at best six (6) hours of electricity in a day, leading to an adverse effect on production in different sectors of the economy. The authors further stated that about 60 million citizens of Nigeria, according to a report from the Manufacturer Association of Nigeria (MAN), use power-generating sets, known as generators, inhaling its harmful toxins, which are not environmentally friendly, costing the citizens USD 13.35 million to fuel the generators annually. Several authors have alluded to this epileptic electricity supply to low penetration of Nigeria’s renewable energy sources. The authors include those of Refs. [1–3, 6, 28, 32–34].

Furthermore, this paper seeks to increase the penetration level and high utilisation of renewable energy sources (RES) in Nigeria and Sub-Saharan Africa through human
capital development. Olanipekun and Adelakun [35] highlighted eight (8) challenges causing low penetration and utilisation of RES in Nigeria. The challenges include the low level of public awareness on the availability and usefulness of alternative energy systems, intermittency of resource availability, high initial starting cost when compared with other conventional energy sources in Nigeria, and inadequate fiscal and economic incentives to attract local and foreign investment in the alternative energy system. Other challenges include inadequate policy, regulation, and institutional framework for the development and adoption of alternative clean and renewable energy sources, and inadequate indigenous human capacity in the design, construction, installation, and maintenance of alternative energy systems. Others include the lack of appropriate standards and quality for modern technologies and lack of capacity for the local manufacturing of alternative energy system components, resulting in limited supply and higher cost. These challenges can be solved by developing human capital in the energy sector of Nigeria. Human capital can enhance massive public awareness of RES [36], aid energy efficiency, thereby reducing consumption costs [37], attract foreign direct investment into Nigeria’s RES system [22], enhance technology spillover in manufacturing indigenous technology for RES in Nigeria [14], and increase R&D on renewable energy [38]. Hence, increasing and improving human capital in the energy sector of the Nigerian economy will increase the usage of RES and reduces reliance on non-renewable energy sources [12].

Moreover, the research of Ref. [6] highlighted challenges causing low penetration of renewable energy sources in Nigeria, which is synonymous to the ones of Refs. [3,35]. The challenges include: a lack of adequate understanding and consciousness of the worth of renewable energy technologies, insufficient financial and fiscal inducements, dearth of human capital and infrastructural capacity, inadequacy of renewable energy data for plan implementation and investment decision, intermittency of renewable energy sources, high start-up investment outlays, and insufficient policy and organisational structures. These challenges are surmountable through the development of human capital. Human capital development will aid the technical know-how of renewable energy technologies, aid knowledge and technological transfer, simplify policy and practices, and enable a stabilised financial system in the energy sector driven by the private sectors.

In addition, this paper seeks to contribute to the increase of research on human capital development and renewable energy sources, as there is a paucity of research on the subject matter. Research such as Ref. [11] focused on human capital and energy infrastructure; Ref. [12] focused on human capital and energy efficiency; Ref. [32] explored the determinants of renewable energy consumption in Nigeria; Ref. [39] researched on renewable energy and human resources development; and Ref. [40] research on the relationship between intellectual human capital, human resources practices, and intention to use of energy resources. However, to the best of the researcher’s knowledge, there is no research or inadequate research on increasing the penetration level of renewable energy sources through human capital development. Moreover, most research focuses on the mathematical model of optimisation of renewable energy. Aboumahboub et al. [25] and Mitchell et al. [27] also utilised simulation techniques and linear optimisation modeling to achieve optimisation of renewable energy sources. However, to the best of the researchers’ knowledge, there is no research on the optimisation and penetration of renewable energy and human capital development in Nigeria using Bibliometric analysis together with qualitative research methodology.

Therefore, the cardinal aim of this paper is to analyse through a bibliometric review how human capital development can enhance the penetration level of renewable energy in Nigeria and Sub-Saharan Africa by mapping out the intellectual pattern. In achieving this aim, the bibliometric review analysed the publications from authors, publications per country, research focus based on co-occurrence keywords, and research threads based on year of publication. This will contribute to the attainment of Nigeria’s Renewable Energy Master Plan.
2. Overview of Nigeria’s Renewable Energy Master Plan

The Energy Commission of Nigeria is the government body saddled with the responsibility to coordinate activities within the energy sector and oversee the implementation of the objectives spelled out by the Energy Policy [28]. The Energy Commission of Nigeria (ECN) developed a renewable energy master plan to address the challenges of moving towards a clean, reliable, secure, and competitive energy supply in Nigeria. The main goal of this document is to reduce projected energy use by 20% by 2020 and meet 20% of the Nation’s electricity needs with Class 1 renewable energy sources like solar energy, wind energy, and fuel cell by the year 2020 [28].

The Renewable Energy Master Plan (REMP) conveys Nigeria’s vision and sets out a guide for achieving sustainable development through an increase in the role of renewable energy. The Master Plan is deeply rooted in the values, principles, and targets of the National Energy Policy, National Economic Empowerment, and Development Strategy (NEEDS), the Millennium Development Goals (MDGs), National Policy on Integrated Rural Development, and international conventions to reduce poverty and reverse global environmental change. The energy reform will unleash the potential of diversified and abundant sources of energy, including solar photovoltaic and solar thermal energy, efficient and modern applications of biomass technologies, and investments in small-scale hydro plants and wind power. Secondly, it will create an enabling environment that will assist in lowering renewable energy prices and expanding access to energy services, mainly for the poor. Finally, the renewable energy reforms will help in achieving NEEDS and MDG targets by providing opportunities to reach rural areas, industries, and improving energy services to the poor.

The overall objective of the REMP is to articulate a national vision, targets, and a road map for addressing key development challenges facing Nigeria through the accelerated development and exploitation of renewable energy. Among other things, the master plan has the following specific objectives:

- Expanding access to energy services and raising the standard of living, especially in the rural areas;
- Reducing environmental degradation and health risks, particularly to vulnerable groups such as women and children;
- Stimulating economic growth, employment, and empowerment;
- Increasing the scope and quality of rural services, including schools, health services, water supply, information, entertainment, and stemming the migration to urban areas;
- Improving learning, capacity-building, research and development on various renewable energy technologies in the country;
- Providing a road map for achieving a substantial share of the national energy supply mix through renewable energy.

According to REMP [41], there are several compelling reasons to embark on the REMP. First and foremost, in few decades to come, there will be need for a post-fossil national energy vision because petroleum-generated energy is not replaceable and would run short. Second, to create a level playing field capable of supporting ready-for-the-market renewable energy technologies such as solar, small hydro, wind, biomass, etc. Third, to reach the rural area with cost-effective alternatives (renewable energy technologies) to centralised sources of electricity. Fourth, the restructuring of the electricity supply industry will reduce subsidy and cost of electricity, competitive wholesale and retail power markets, accelerated commercialisation and privatisation, unbundling of generation, transmission and distribution, and increased self-generation end-users. Fifth, to keep Nigeria advantaged in the development of renewable energy resources and technologies like geothermal, solar, liquid biomass, hydrogen etc. Sixth, to promote better sustainable, healthy environment by reducing indoor air pollution, promoting urban air quality and the global climate are issues that are high on the national development agenda. Finally, to create a guide that will checkmate renewable energy activities and ensure they are complementarily integrated and channeled towards the same national goals.
Moreover, according to Sustainable Energy For All Action Agenda [42], it was noted that Nigeria’s renewable energy target are as follows:

- Achieve a technology-driven renewable energy sector that harnesses the nation’s resources to complement its fossil fuel consumption and guarantees energy security. Specifically, Nigeria’s target for renewable energy is:
  - By 2030, renewable energy is expected to contribute about 30% share in the available electricity mix.
  - Achieve a 20% and 19% contribution of solar energy (PV and Solar thermal) to the nation’s electricity generation mix by 2020 and 2030, respectively.
  - Achieve a 2.5% contribution of wind energy to the nation’s electricity generation mix by 2030.
  - Achieve a 27% and 20% contribution of hydroelectricity (both large and small hydro) to the nation’s electricity generation mix by 2020 and 2030, respectively.
  - Achieve a 4% power generation.

3. Methodology

In achieving the objective of this paper, the research explored qualitative research methodology and bibliometric review analysis. Qualitative research methodology, according to Adepoju and David [43], and Bhandari [44], entails the collection and analysis of empirical interactions and exploring non-numerical data in contextualising opinions, juxtaposing concepts, and understanding experiences to gain in-depth knowledge into a research problem. Hence, this paper explored relevant literature from journals, conference papers, books, and book chapters analysing human capital development and renewable energy penetration and optimisation. This empirical review of the literature was done structurally and logically to achieve this paper’s objectives.

Moreover, the bibliometric analysis was done to ascertain intellectual concentration, mapping out areas and patterns that human capital development can enhance penetration of renewable energy. According to the authors of Refs. [45–47], bibliometric analysis maps out knowledge areas and research patterns, which will be derived from reputable publications. This is adequately shown in Figure 1, outlaying the bibliometric analysis framework. Relying on the recommendations of Refs. [45,48], the research publications used for the bibliometric analysis for this paper were sourced from the Scopus database, which is a major database and indexing house often used by researchers with wide coverage in comparison to other databases. The key search word used in the Scopus database during the bibliometric analysis are “human capital” and “Renewable energy”. Publications with these search words in their title, abstracts, and keywords were extracted, with a time span from 2000 to 2022, when the Millennium Development Goals was signed by the United Nations, which covers the period of the sustainable development goals and the beginning of the fourth republic in Nigeria, where clean energy and renewable energy were popularised. The literature search was conducted in March 2022, with the initial search producing three hundred and nineteen (319) papers (documents) with the stated keywords across many related disciplines. Thereafter, the search was refined with limitation to English language and fields that covers human capital and renewable energy. The fields are Environmental sciences, energy, engineering, social sciences, economics, econometrics and finance, business, management and accounting, earth and planetary sciences, chemical engineering, agricultural and biological sciences, multi-disciplinary, biochemistry, genetics and molecular biology and chemistry. After refining, a total of 303 articles, reviews, books, book chapters, and conference papers were extracted from the Scopus database, which were then subjected to Vosviewer, a software for bibliometric analysis. Figure 1 shows the framework adopted for the bibliometric analysis.
4. Results and Discussion

4.1. Publications per Authors

In analysing the relationship between human capital and renewable energy from publications in the Scopus database, Figure 2 shows that the publications on the two subject matters are still in the infant stage from 2000. Figure 2 showed that the highest publications were in 2019–2021, depicting global and academic attention to human capital needs in the renewable energy sector. Moreover, using Vosviewer, a bibliometric analysis software, the authorship of the 303 documents shows that at least 62 authors have published more than two papers on the relationship between human capital and renewable energy. Table 2 revealed the authors, their numbers of papers/documents published, citations, and total link. Table 2 shows that Ahmad. M from the Institute for Region and Urban–Rural Development, China has the highest publications of five (5) documents on the integration between human capital and renewable energy. In addition, Table 2 revealed that Pretty J, of the center for public and policy engagement, University of Essex, UK, with two documents, has the highest citation of 1172 on the integration of human capital and renewable energy.
Table 2. Authors publications details.

| Authors            | Documents | Citations | Total Link Strength |
|--------------------|-----------|-----------|---------------------|
| Ahmad M.,          | 5         | 108       | 14                  |
| Fatima, N.,        | 3         | 32        | 10                  |
| Jabeen G.,         | 3         | 60        | 10                  |
| Li Y.,             | 3         | 34        | 9                   |
| Celik B.,          | 2         | 18        | 8                   |
| Hawila D.,         | 3         | 69        | 8                   |
| Jorember P. T.,    | 2         | 18        | 8                   |
| Isik. A.,          | 2         | 18        | 8                   |
| Jelilov. G.        | 2         | 18        | 8                   |
| Kennedy S.,        | 4         | 69        | 8                   |
| Li X.,             | 2         | 32        | 8                   |
| Mezher T.,         | 3         | 69        | 8                   |
| Usman O.,          | 2         | 18        | 8                   |
| Ali, S.            | 3         | 75        | 6                   |
| Mondaal M. A. H    | 2         | 67        | 6                   |
| Huang Y.,          | 2         | 5         | 5                   |
| Shahzad U.,        | 4         | 64        | 5                   |
| Brown C.,          | 2         | 168       | 4                   |
| Bymes I.,          | 2         | 168       | 4                   |
| Cerqueira P. A     | 2         | 17        | 4                   |
| Devi X.,           | 2         | 16        | 4                   |
| Foster J.,         | 2         | 168       | 4                   |
| Jordan I.,         | 2         | 5         | 4                   |
| Kirikkakledi D.,   | 2         | 5         | 4                   |
| Li J.              | 3         | 58        | 4                   |
| Long X.            | 2         | 58        | 4                   |
| Luhring O.,        | 2         | 5         | 4                   |
| Mensah C. N.,      | 2         | 58        | 4                   |
| Mercado, E.,       | 2         | 5         | 4                   |
| Nadeem, A.,        | 2         | 18        | 4                   |
| Prowca, S.,        | 2         | 17        | 4                   |
| Rafique M.,        | 2         | 18        | 4                   |
| Salman M.,         | 2         | 58        | 4                   |
| Sethi N.,          | 3         | 21        | 4                   |
| Sheraz, M.,        | 2         | 16        | 4                   |
| Soukiazis, E.,     | 2         | 17        | 4                   |
| Zhang X.,          | 2         | 53        | 4                   |
| Ahmed, J.,         | 2         | 24        | 3                   |
| Alvarado R.,       | 2         | 74        | 3                   |
| Halliru, A. M.,    | 2         | 33        | 3                   |
| Khan, Z.,          | 3         | 180       | 3                   |
| Loganathan N.,     | 2         | 33        | 3                   |
| Bobylev, S. N.,    | 2         | 22        | 2                   |
| Brown M. T.,       | 4         | 142       | 2                   |
| Kubatko O.,        | 2         | 17        | 2                   |
| Kudryavtseva, O. V., | 2       | 22        | 2                   |
| Melnyk L.,         | 2         | 17        | 2                   |
| Ozturk, L.,        | 2         | 86        | 2                   |
| Shah, M. I.,       | 2         | 42        | 2                   |
| Ulgiati, S.,       | 3         | 143       | 2                   |
| Usman M.,          | 2         | 50        | 2                   |
| Sahoo, M.,         | 2         | 18        | 1                   |
| Wang, C.,          | 2         | 8         | 1                   |
| Xu, D.,            | 2         | 66        | 1                   |
| Zhang, L.,         | 4         | 83        | 1                   |
| Ganda, F.,         | 2         | 5         | 0                   |
| Pata, U.K.,        | 2         | 115       | 0                   |
| Ponce P.,          | 2         | 16        | 0                   |
| Pretty J.,         | 2         | 1172      | 0                   |
| Serino M.,         | 2         | 3         | 0                   |
| Sovacool B.,       | 2         | 16        | 0                   |
| Tang, C.           | 2         | 8         | 0                   |

4.2. Publications per Country

However, a more critical analysis of the two documents by Pretty Joules shows that it encompasses agricultural sustainability. The author’s first paper titled “Sustainable
intensification in agricultural systems” has 353 citations. The second paper, titled “Agricultural sustainability: concepts, principles & evidence” has 828 citations. Moreover, the five (5) publications of Ahmad M, from the Scopus database show the interactions between human capital and energy utilisation. All these analyses showed a low level of interaction between human capital and the penetration of renewable energy. Moreover, Figure 3 shows that the current authors on the subject matter are published between 2021 and 2022, who are Huang, Y, Kirikkaleli D., Deyi X., and Sheraz M.

Figure 3. Authors co-occurrence visualisation.

The 303 documents from the Scopus database analysed from Vosviewer on the relationship between human capital and renewable energy are from 72 countries. Using five (5) documents as the minimum number of documents per country revealed that twenty-three (23) countries met the threshold. Table 3 revealed the countries, the numbers of documents, citations, and total link strength. The countries are China (57 documents, 1208 citations), Pakistan (19 documents, 371 citations), Turkey (15 documents, 578 citations), United States (51 documents, 9718 citations), Italy (14 documents, 342 citations), Spain (15 documents, 181 citations), United Kingdom (25 documents, 1314 citations), Malaysia (11 documents, 308 citations), Bangladesh (6 documents, 74 citations), India (13 documents, 77 citations), Australia (13 documents, 408 citations), Nigeria (10 documents, 166 citations), Taiwan (5 documents, 64 citations), Ecuador (5 documents, 90 citations), United Arab Emirates (6 documents, 95 citations), France (8 documents, 9027 citations), Russian Federation (11 documents, 182 citations), Germany (9 documents, 58 citations), Sweden (6 documents, 202 citations), Indonesia (5 documents, 5 citations), Portugal (5 documents, 31 citations), South Africa (8 documents, 121 citations), and Romania (5 documents, 87 citations).

Figure 4 shows the map of the countries that have published at least five (5) papers on human capital and renewable energy. Integrating Table 3 and Figure 3 shows that only two African countries have published papers on renewable energy and human capital. The countries are Nigeria and South Africa, with a total of 18 papers in the last two decades, compared to other continents, which depicts a paucity of research in the continent. Moreover, Figure 5 shows that, from the Vosviewer overlay visualisation, countries currently researching on human capital development in optimising renewable energy are China, Pakistan, Turkey, Portugal, India, and Taiwan, published between 2019 and 2020. Countries that have published papers on human capital development and renewable energy between 2015 and 2019 includes Sweden, Australia, France, Germany, United States, United Arab Emirates, Russian Federation, United Kingdom, and Italy. It is noted from Figure 4 that there is no concentrated publication from Africa in the last seven (7) years on developing human capital to optimise renewable energy. This also mirrors a low level of training, poor
absorptive capacity development, and inadequate inter-organisational collaborations in optimising renewable energy for clean energy security for the continent, thus depicting a low level of human capital development in the region.

Table 3. Documents citations.

| Country               | Documents | Citations | Total Link Strength |
|-----------------------|-----------|-----------|--------------------|
| China                 | 57        | 1208      | 49                 |
| Pakistan              | 19        | 371       | 24                 |
| Turkey                | 15        | 578       | 15                 |
| United States         | 51        | 9718      | 14                 |
| Italy                 | 14        | 342       | 11                 |
| Spain                 | 15        | 181       | 11                 |
| United Kingdom        | 25        | 1314      | 11                 |
| Malaysia              | 11        | 308       | 9                  |
| Bangladesh            | 6         | 74        | 8                  |
| India                 | 13        | 77        | 8                  |
| Australia             | 13        | 408       | 7                  |
| Nigeria               | 10        | 166       | 7                  |
| Taiwan                | 5         | 64        | 7                  |
| Ecuador               | 5         | 90        | 7                  |
| United Arab Emirate   | 6         | 95        | 5                  |
| France                | 8         | 9027      | 4                  |
| Russian Federation    | 11        | 182       | 4                  |
| Germany               | 9         | 58        | 3                  |
| Sweden                | 6         | 202       | 3                  |
| Indonesia             | 5         | 5         | 1                  |
| Portugal              | 5         | 31        | 1                  |
| South Africa          | 8         | 121       | 1                  |
| Romania               | 5         | 87        | 0                  |

Figure 4. Map of countries with more than five publications.
4.3. Research Focus Based on Co-Occurrence Keywords

This section aims to identify the clusters and map out intellectual areas of concentration between the concept of human capital and renewable energy. In achieving this aim, using the Vosviewer software, the co-occurrence of keywords helps in achieving this, which is predefined at a minimum number of five (5), that is, the number of times a keyword appears across the entire publications. Aighimien et al. [45] utilised four (4) as a minimum co-occurrence while Saka and Chan [49] utilised two (2). However, a minimum number of four (4) was utilised with full counting, whereby 221 keywords were extracted for this study. This implies that 221 keywords occurred at least four (4) times, and they are source indexed keywords. The visualisation map of the keyword occurrence is shown in Figure 6, revealing five clusters, which also shows that the center keyword is renewable energy, to which all other keywords are linked.

Figure 5. Overlay visualisation of countries with publications.

![Figure 5. Overlay visualisation of countries with publications.](image)

Figure 6. Co-occurrence Keywords.

![Figure 6. Co-occurrence Keywords.](image)
Cluster 1: Economics of Renewable Energy Sources

This cluster is depicted by the red region in Figure 5, containing seventy-six (76) keywords. The keywords describe the economics of renewable energy sources. It includes the following keywords: anaerobic digestion, biodiversity, biofuel, biogas, biomass, capital costs, capital investment, climate change, comparative study, controlled study, cost, cost-benefits analysis, costs, decision making, desalination, economic analysis, economic aspect, economic performance, ecosystems, electric generation, electric power generation, electricity, electricity generation, energy, emission control, energy, energy conversion, energy resource, and energy-generating resource. Other keywords are: energy-generating resource, environmental impact, equipment, energy, fossil fuel power plants, fossil fuel, fuels, gas emissions, gasification, geothermal energy, geothermal power plants, global warming, greenhouse gases, hydroelectric power, hydroelectric power plants, hydrogen, hydropower, investment, lifecycle, lifecycle analysis, lifecycle assessment, and non-renewable resources. Others are: nuclear energy, nuclear fuel, optimisation, photovoltaic system, policy making, recycling, renewable resource, sensitivity analysis, solar energy, solar power generation, waste disposal, waste management, waste resources, water resources, water supply, and wind power.

These keywords depict the economics of renewable energy, that is the economic evaluation of generating electricity from renewable energy. It entails the cost–benefits analysis of renewable energy mix and the techno-economic analysis of renewable energy sources. According to Ref. [50], renewable energy economics entails the cost advantage, cost comparison, capital intensity, and marginal cost of renewable energy sources. The authors opined that the cost of generating fossil fuels is less than the cost of generating renewable energy sources. In addition, according to the authors, the economics of renewable energy sources also factors in the timeline in developing renewable energy. The authors gave the below illustration depicting large amount of fossil fuels sources in comparison to renewable energy sources. This is because most renewable energy sources cannot be generated in a day, as the sun does not shine daily, nor does the wind blow all the time.

Illustration: “For example, a gallon of gasoline contains about 37 kwh (kilowatt-hours) of potential energy. An average person running for an hour burns about 0.13 kwh, showing that a person has to run for 285 h or almost 12 days continuously to expend the amount of potential energy in just one gallon of gasoline. A typical 3 × 6 solar PV panel can generate about 0.2 kwh in one hour of bright sunshine. The sun would need to shine on such a panel for 185 h (about a month, assuming six hours of bright sun per day) to provide the same energy as a gallon of gasoline”.

Moreover, Energypedia [51] averred that the economics of renewable energy entails calculating the levelised cost of energy (LCOE), which measures the lifetime cost, which includes the building and operation of a power plant divided by lifetime energy production/output. According to IRENA [52], LCOE entails the following cost metric analysis: factory gate equipment, on-site equipment (transport cost import levies), and total installed cost (project development, site preparation, grid connection, working capital, auxiliary equipment, non-commercial cost, working capital, operations and maintenance, weighted average cost of capital, resource quality, capacity factor and lifespan.

However, this cluster introduces that the economics of renewable energy cannot be completed without the major factor of production–human capital [53]. The development of human capital for the efficiency and utilisation of renewable energy can be achieved through concentrated financing via trainings, conferences, inter-organisation partnerships, intra-organisation collaborations and investment in Research and Development (R&D). Furthermore, to boost human capital development for renewable energy penetration, the organisation climate, working conditions, and organisation culture must be human resource-friendly. This will enable the adequate utilisation of all the finance channeled towards renewable energy.
Cluster 2: Human Capital Factor in Environmental Management

This cluster is depicted by the color green in Figure 6, comprising of fifty-seven (57) items amalgamating into human factors in environmental management. The items include: alternative energy, assessment method, capital, carbon dioxide, carbon emission, carbon footprint, CO2 emission, conceptual framework, cross-sectional studies, ecological footprint, economic development, economic growth, empirical analysis, energy consumption, energy use, environmental degradation, environmental economics, environmental Kuznets, environmental management, environmental quality, environmental sustainability, financial development, foreign direct investment, fossil fuel, fuel consumption, globalisation, Granger causality test, gross domestic product, gross national product, human, and human capital. Other keywords include: human development investment, humans, incomes, innovations, institutional quality, invention, investment incentives, Kuznets curves, national resource, panel data, personnel, policy, productivity, public policy, regression analysis, renewable energy, renewable energy consumption, renewable energy use, research and development technological innovations, technology, theoretical model and trade openness. These keywords depict human capital factors in environmental management. That is, they are the factors that enhance human capital in the management of the environment, which is very key in the exploitation of renewable energy, as a properly managed environment can increase penetration of renewable energy. From the keywords, human capital factors include incomes, innovations, GDP, GNP, FDI, Kuznets curve, productivity, public policy, trade, and technology. This reflects factors of human capital indicated by Refs. [54,55].

All these factors aid in the management of the environment. According to Ref. [56], environmental management is a concept that entails practices and procedures that make an organisational entity reduce its environmental impact, with a focus on aiding the green environment. This is also the objective of increasing the penetration of renewable energy in reducing carbon emission, environmental degradation, and energy consumption. Therefore, the cluster confirms the research of [57–60], that human capital developments enhance environmental sustainability. The authors opined that human capital development affects the environmental performance index (EPI), such as the environmental health index (air quality, drinking water and sanitation, and heavy metals), and ecosystem vitality index (biodiversity and habitat, forest, fisheries, climate and energy, air pollution, water resources and agriculture). These show that the environment must be managed optimally in optimising renewable energy, which cannot be done without proper human capital development.

Cluster 3: Economic Factors in Energy Supply and Demand

This cluster is shown in the color blue in Figure 6, comprising forty-seven (47) keywords. These keywords highlight the relationship of economic factors in the demand and supply of energy, thus bridging the gap that renewable energy can fill. The keywords are: air pollution, behavioral research, building, commerce, competition, economic and social effect, economics, education, electric utilities, electricity supply, employment, energy conservation, energy efficiency, energy market, energy planning, energy policy, and energy poverty. Other keywords include: energy resources, energy security, energy transitions, environmental technology, finance, human capital, human resource management, incentive, low carbon economy, natural resources, planning, population statistics, renewable energy resource, renewable energy policy, renewable energy, renewable energy technologies, rural areas, rural population, socio-economic, solar power, spatiotemporal analysis, sustainable development, urban area, urban growth, urban planning, urbanization, and use of renewable energy. These keywords show that economic factors such as population, urban planning and growth, socio-economic activities, urbanization, human capital, education and economics aids in budgeting the gap between energy demand and supply. This will lead to energy security, thus reducing energy poverty and aiding the transition to renewable energy. This confirms the research of Ref. [61] on the causal relationship between the economy and energy, which will lead to investment in the sector. The research of Khanna and Rao [62] shows that economic factors affect electricity consumption, including GDP,
prices, income, economic activities, and urbanisation. This also bring into perspective that energy efficiency is a factor that must be considered to increase the penetration of renewable energy, as the authors of Ref. [63] justified that there is a relationship between energy efficiency, income level of household and energy consumption. Therefore, to increase the penetration level of renewable energy, economic factors must be considered optimally.

Cluster 4: Sustainable energy factors

This cluster comprises of sixteen (16) keyword items, as shown in the yellow region of Figure 5, which reflects factors that aid energy sustainability. The keywords are: agricultural productivity, agriculture, conservation of natural resources, developing world, ecology, ecosystem services, environment, environmental assessment, environmental protection, food supply, green economy, natural capital, social capital, sustainability, and technological development. The research of Prasad et al. [64] opined that energy sustainability is about optimising renewable energy. According to Ref. [65], sustainable energy is a form of energy that can be utilised again and again without the worry or concerns regarding expiration, depletion, and vanishing of the source of energy. Hence, in accordance with the research of Ref. [66], there are influencing factors that must be considered in ensuring sustainable energy. In conjunction with the keywords of this cluster, the following factors have a pendulum effect on achieving sustainable energy; agricultural products waste, ecosystem services, environmental impact assessment, food security dimensions, indicators of green economy, capital formation, and technology [48,67–72].

Cluster 5: Human capital development and the economy

This cluster is shown in purple with nine (9) keyword items: carbon, economic growth, energy utilisation, environmental policy, human activities, human capital development, international trade, non-renewable energy, and pollution. The keywords depict a relationship between human capital and the economy in renewable energy penetration in conformance to Refs. [73–75]. This can also aid in optimising the locational marginal price (LMP) or nodal prices to generate more electricity from the renewable energy [76]. According to the authors of [76] and [19], the intellectual capital of artificial neural networks and support vector machines can be deployed in increasing the penetration of renewable energy through economic parameter of nodal prices.

4.4. Research Thread Based on the Year of Publication

The co-occurrence keywords have revealed divergent keywords revolving around human capital development and renewable energy. However, Figure 7 shows the overlay visualisation map of the co-occurrence keywords in the relevancy of their year of publication. Figure 7 shows that between 2014 and 2016, publications revolved around hydropower, energy, renewable energy, biomass, conservation of natural resources, energy efficiency, and solar energy, among others. This depicts the popularisation of different renewable energy sources. Moreover, between 2016 and 2018, the publications center around the following keywords: environmental impact, economic and social effects, urban area, economic analysis, renewable energy, and investment. These publications center on the role of economic factors in increasing the penetration of renewable energy.

Moreover, publications from 2018 to 2020 revolve around economic development, globalisation, Kuznets curves, environmental quality, empirical analysis, alternative energy, capital, human, personnel, and inventions. These recent areas of publication around the underlying impact of human capital in the relationship between economic factors and renewable energy. These keywords show the current areas that need more research for the optimal development of human capital in optimising renewable energy both quantitatively and qualitatively.
5. Research Gaps and Future Opportunities

This paper has revealed major gaps in this area of research, which are future opportunities for research exploration. Firstly, there is a paucity of research on the symbiotic relationship between human capital development and the penetration of renewable energy in Nigeria and Sub-Saharan Africa. However, this paper has contributed to filling this gap and has mapped out intellectual areas of focus to enable human capital to speed up the penetration and usage of renewable energy through bibliometric review. Another gap is the high cost of renewable energy penetration, which is reflected in the low human capital in the sector, as shown in this paper. Future research should focus on the absorptive capacity of human capital in energy organisations both in the private and public sectors. Furthermore, this paper has brought to light the need for substantial research on the economics of renewable energy penetration. Hence, future research should focus on renewable energy penetration dynamics considering the local and national economy of the place, especially on material acquisition, engineering economy, and human capital development. In addition, there are possible overlapping of these research findings as the bibliometric analysis stems from only the Scopus database, without other databases. Hence, future research can compare the bibliometric analysis of different database along the aim of the research.

6. Policy Recommendations

To achieve high penetration, adoption, and utilisation of renewable energy, government involvement is inevitable. Hence, we present the following policy recommendations:

a. There should be a private–public partnership (PPP) on renewable energy penetration, especially on the most abundant renewable energy sources vis-a-vis areas of need.
b. There should be a dedicated annual budget for Research and Development (R&D) on the optimisation and penetration of renewable energy.
c. There should be a partnership through a Memorandum of Understanding (MoU) between government and research institutions on the appropriate energy mix in organisations, factories, and residential buildings.
d. There should be appropriate harmonisation in developing human capital in energy-related organisations with local content mechanisms of renewable energy.
e. Periodic training, conferences, and workshops on renewable energy penetration should be institutionalised in energy-related organisations.

f. Energy efficiency guidelines should be formulated on energy usage in government agencies and residential buildings to reduce the environmental impact of the use of non-renewable energy.

7. Conclusions and Recommendation

The cardinal objective of this paper was to map out areas of intellectual patterns and research focus in the development of human capital for optimising renewable energy in achieving the Renewable Energy Plan of Nigeria. The extracted papers published between 2000 and March 2022, almost 22 years indexed in Scopus database, identified areas of intellectual concentration that will aid human capital development in increasing renewable energy. These areas include the economics of renewable energy, the influencing factors of human capital in environmental management, the economic factors in bridging the demand and supply of energy, the pendulum effect of factors affecting energy sustainability, and the human capital as a moderating factor in the relationship between economic development and renewable energy utilisation. Moreover, the paper reviewed that the research on the two concepts is relatively low in sub-Saharan Africa, giving the high energy poverty in the region with about 600 million people having no access to electricity [77]. This is despite the massive amount of renewable energy potential in Africa. The contribution of this study to the body of knowledge entails the identification of research gaps and research focus, which will stimulate the development of human capital to increase renewable energy penetration in Nigeria and Sub-Saharan Africa. This will salvage the epileptic power supply and low electricity access in the region.

Therefore, this study recommends intensive efforts in optimising human capital in Nigeria’s energy sector, through periodic training on renewable energy, and inter-organisational collaboration on renewable energy technologies that will undoubtedly aid technology transfer, knowledge transfer, and spur foreign direct investment. Moreover, the study recommends the decentralisation of energy sources to aid energy mix by incorporating renewable energy sources, thereby enhancing energy efficiency among energy consumers, and meeting different energy demands.

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