RENEWABLE ENERGY: THE CATALYST FOR A SUSTAINABLE ENERGY DISTRIBUTION SECTOR IN SOUTH AFRICA

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ABSTRACT

The purpose of this article, with practical focus, is to analyse the potential of Renewable Energy (RE) as the catalyst for a sustainable energy distribution sector in South Africa (SA) and promote collaboration between the manufacturers, government, and all relevant stakeholders. The research design was a systematic literature review. It used a qualitative research method, through a questionnaire, to evaluate the knowledge and views of professionals from the energy distribution sector, managers or leaders in the energy sector, and energy sector experts. The sample size selected was between 350 and 400 participants. The literature reviewed noted that photovoltaic (PV) energy was one of the primary RE sources for sustainable energy generation. Furthermore, installing capacity and investment continued to grow throughout SA. Of note was the value-added through distributed RE systems in respect of electricity provision. The energy poverty in SA was high, and the impact of the Covid-19 pandemic further contributed to the challenges experienced. The general conclusions were that due to global warming and increased large-scale pollution, the use of RE for power generation had become evident. The article offered the potential opportunities of RE as the catalyst for the sustainable energy distribution sector in SA. Criteria was developed to include or exclude relevant scientific literature, by identifying subject relevance, type of technology, geographic scope, intervention scale, and data type.

Keywords: Photovoltaic, Poverty, Renewable Energy, Sustainable Energy, reduction

INTRODUCTION

Due to advances in information and communication technologies, the world faces a strong evolution, placing knowledge technology based on productivity, competition and power. The world is more interconnected than ever (Vezzoli *et al.,* 2019). Renewable energy sources, such as solar energy (photovoltaic and solar thermal), hydroelectric energy, wind energy, and biomass-derived fuels, have made great contributions to the sustainability of certain countries and have brought various environmental and socio-economic benefits to countries. According to Aliyu *et al.* (2018), the greatest and broadest benefit is the contribution of renewable energy to reducing local and global pollution, thus helping to alleviate the climate change promised by industrialised and developing countries in the Kyoto Protocol. The rapid expansion of South Africa's renewable energy sector has gained local appeal and international recognition, enhancing the prospects for a low-carbon transition. This requires integrating large-scale renewable energy into national policies and goals related to energy and climate change (Davies *et al.,* 2018). In South Africa, the transition to renewable energy is intrinsically linked, to history and contemporary territorial politics, creating new territories. The renewable energy transition acquires an experimental form in the new territory, unfolding spaces and zones of political and administrative exception, allowing political and economic participants to exercise authority and commercial power (McEwan, 2017).

The year 2008, was the first time in human history that more people lived in urban areas than in rural areas, a phenomenon that had a much greater impact on developing regions of the world (such as those found in Africa and in particular South Africa (Vezzoli *et al.,* 2019). The increasing citizens involvement in the production, storage, distribution, and use of energy and potential ownership of distribution networks, participation in energy markets and energy service supply is key (Nolden *et al.,* 2020). This article analysed the transition that leads to long term RE sustainable energy systems, as the global society is faced with a shortage of supply. In so doing, the elimination of greenhouse gasses in all participating energy sectors proved beneficial for all. The relevance of the transition, to long term RE sustainability, was important in the context of the developing country for economic development. The researchers analysed the existing distribution sector, that heavily relies on the generation capabilities of large fossil fuel-based primary energy sources and presented their research on RE as the catalyst for a sustainable energy distribution sector in SA. This included the discussion of implications and the impact of the distribution sector. In particular, solar photovoltaic application systems were of focus in this article.

RESEARCH METHODOLOGY

According to Mishra and Alok (2017), research methods encompass all techniques and methods used to conduct research, and research procedures are a technique for solving research problems in an orderly manner. It is about learning properly. Therefore, the scientific method for investigations is a methodology (Mishra and Alok, 2017).

It recognises that various role players, in the energy distribution industry, articulate different views on the needs to be prioritised to mitigate climate change and increase deployment of RE technologies, as a catalyst for energy sustainability in SA. This is an attempt to review the initiatives towards the ultimate maximum utilisation of RE. In this regard, most of the published papers fell short in providing comprehensive assessment and contextual critique to address the South African scenario.

The review drew data and experience from extensive local and global scientific research. This article adopted a systematic evaluation method that combined empirical analysis and qualitative synthesis. To this end, this article attempted to help policymakers, researchers, and practitioners in South Africa to make use of the research outcome in pursuance of further development and deployment of renewable energy technologies.

Systematic Review

A systematic review is a process of data collection, modelling, and analysis to extract information that will aid decision-making. Depending on the industry or purpose of the analysis, there are several options for performing the analysis (Calzon, 2021). The systematic review method should locate existing research, select and evaluate contributions, analyse and synthesise data, and report evidence to draw reasonable and clear conclusions about the known and the unknown (Denyer and Tranfield, 2009).

Research Questions for the Paper

Figure 1 depicts the six research questions utilised in this review paper.

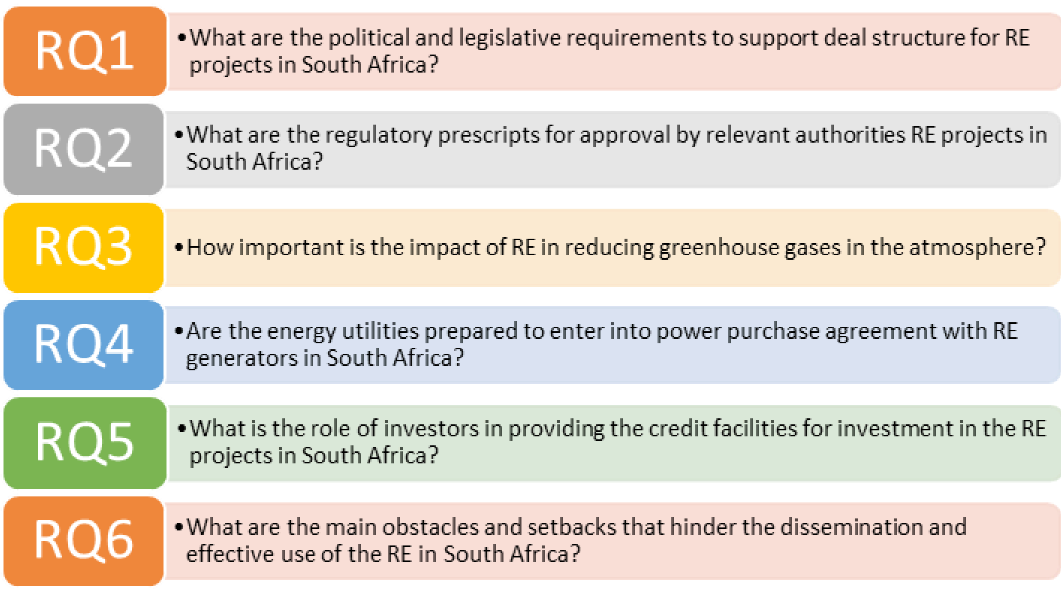

Figure 1: Research Questions *Source: Author*

Criteria for Inclusion and Exclusion

This review focused on existing literature covering RE technologies and, in particular photovoltaic that was either unpublished or published in non-commercial forms like a policy statement, government reports, and papers issued for the South African environment. A criterion was developed to include or exclude relevant scientific literature by identifying subject relevance, type of technology, geographic scope, intervention scale, and data type.

Data Sources and Search Methods

The data collection technique is imperative because the evidence gathered and its interpretation will depend on the researcher's procedures and analytical methods (Paradis *et al.,* 2016). Meho and Yang (2007), found that Google Scholar stands out for its coverage of conference proceedings and international non-English magazines. The data collected in their research found that the citations obtained through Google Scholar came from many different types of documents, including journal articles, conference papers, doctoral theses, master's theses, technical reports, research papers, chapters and books (Meho and Yang, 2007).

This observation was supported by Martin-Martin *et al.,* (2017), who concluded that Google Scholar could effectively identify frequently cited articles. This coupled with the unique coverage of Google (Martin-Martin *et al.,* 2017). Databases of internet search engines like google scholar, various academic websites, published journals of scientific nature, industry-specific experienced and knowledgeable individuals were consulted in search of data sources.

Unpublished Material

According to Shekelle *et al.,* (1999), the first step in gathering evidence is to check whether an appropriate and up-to-date systematic review has been published. If no systematic reviews are currently available, computer search is the usual starting point for search strategies tailored to the relevant research type. Unpublished materials usually lead to additional research, but the resources required for such activities is quite impressive. (Shekelle *et al.,* 1999). Blackhall (2007), believes that including unpublished grey literature is essential to minimise the potential impact of publication bias.

In the interest of researching the broad spectrum of renewable energy as a catalyst for sustainable energy distribution in South Africa, the data search included both published and unpublished research material available from scientific journals in google scholar, Emerald and other academic institutions databases. This was specifically done to ensure the search was robust, and reached as wide parameters as possible. Structured methods were used to search of ring-fenced related keywords, sentences, and phrases summarised to track related material.

Accessed Articles

Once the studies have been identified relevant to questions of research interest, the detection of relevance is often possible from the summary/abstract. The set of studies is reduced to those which need a more detailed evaluation. The use of explicit criteria instead of implicit must improve the reliability of the process (Shekelle *et al.,* 1999).

For this study, the literature review first sought to establish existing studies in publications published between 2016 and 2021 because renewable energy is a rapidly developing form of energy. The data search sought to access articles related to the research subject matter, that as "implementation model of photovoltaic application for sustainable energy in South Africa". In addition to the main research subject matter, articles were accessed related to the eight constructs analysed in the study. This included future technology, demand-side planning, distribution management systems, design, foresight, financial management, capacity building and regulatory environment. Unpublished studies conducted in the subject matter mentioned above were considered for a broader perspective. The primary data search was conducted on the Google Scholar link database. The main journal editors and links visited were, amongst others, from Science Direct, Springer, Elsevier and ResearchGate. In addition to Google Scholar, a secondary data search of university publications was conducted on SEALS, OpenUCT and SUNScholar databases. The keywords and phrases included in the search algorithm were:

a) Sustainable renewable energy,
b) Solar photovoltaic energy,
c) Renewable energy (future technology, demand-side planning, distribution management systems, system design, foresight, financial management, capacity building and regulatory environment)

The literature review search returned a total of 26 306 out of which 26 067 were removed for non-eligibility to the content required, thus leaving 239 records/abstracts for preliminary screening. The 239 records/abstracts were analysed and explored to determine their eligibility to the study's subject matter, thus leaving a total of 100 records included in the qualitative synthesis of this study. Figure 2 depicts the adapted PRISMA 2020 flow diagram for new systematic reviews, including searches of databases and registers for this study (Page *et al.,* 2021).

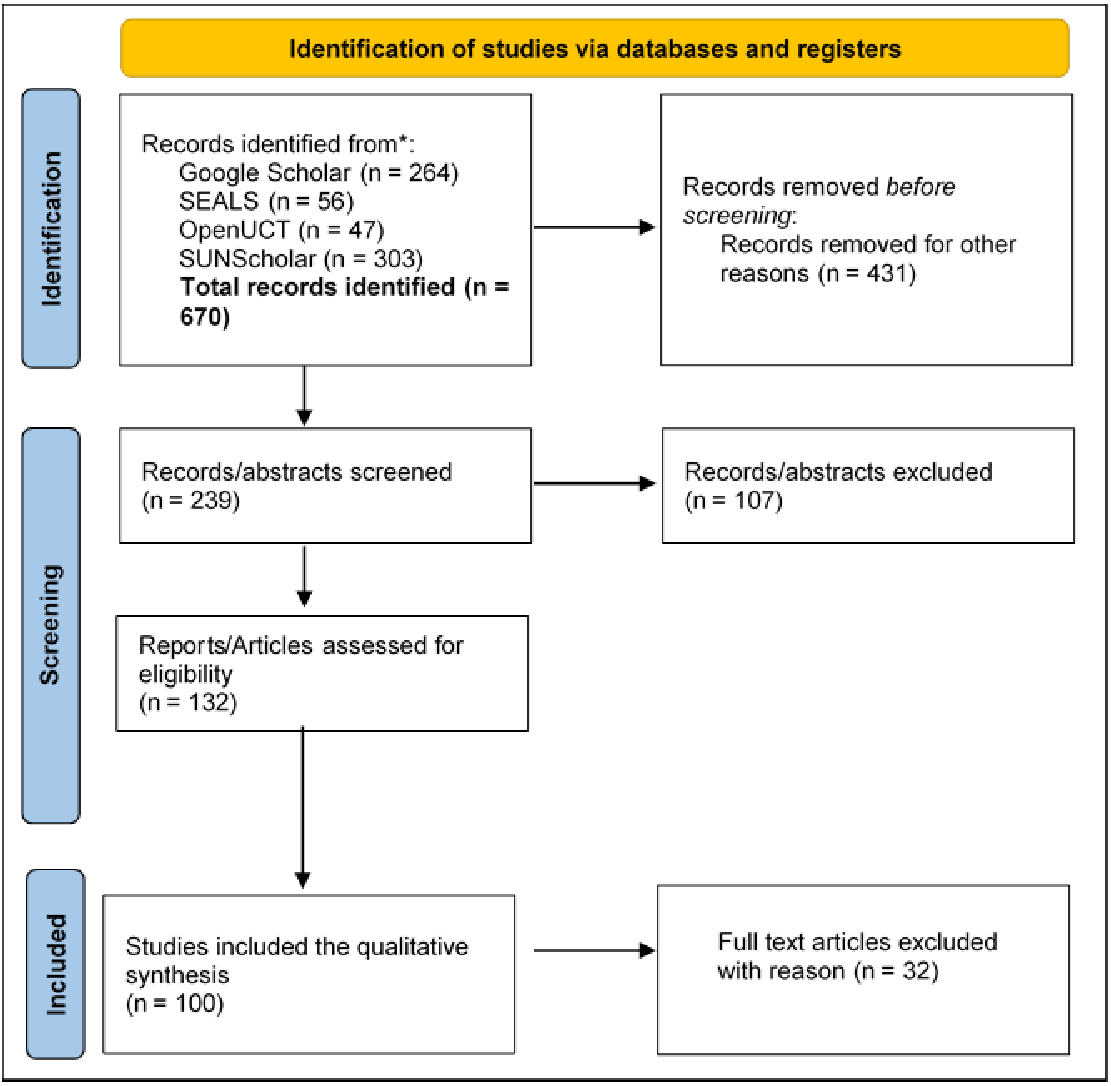

Figure 2: Flow diagram for new systematic reviews *Source: Author*

DISCUSSION

The discussion focused on regulatory parameters, including the role of Small-Scale Embedded Generation (SSEG) within the energy mix, environment management, and its impact on reducing Green House Gases (GHG), its benefits, and sustainability in SA.

Role of Renewable Energy as Part of the Energy Mix

According to Barth *et al.* (2017), the increase in the proportion of renewable energy generation in the power system, has brought major challenges, such as the volatility of renewable energy. In order to meet these challenges, demand-side management is a frequently mentioned remedy (Barth *et al.,* 2017). Therefore, integrating increasingly dispersed renewable energy, in the energy system, is one of the two most important research areas in energy informatics (Goebel *et al.,* 2014; Barth *et al.,* 2017). Therefore, an optimal supply strategy can be achieved by providing greater flexibility on the demand side (Barth *et al.,* 2017).

Reduction of Green House Gases in South Africa

In Yusuf, Abubakar and Mamman (2020: 1), environmental degradation remains a serious challenge in Africa, especially oil-producing African countries. Aliyu, Modu and Tan (2018: 4**)** postulate that the SA's renewable energy resources have enormous and significant potential and contribute to its energy sector, society, and economy. The cost of energy is an important factor in determining the profitability of renewable energy technologies.

Benefits of Roll-Out of Small-Scale Embedded Generation

Klaaaren *et al.* (2019), states that the impact of the roof PV programme depends on the three factors. These includes the potential for Solar Resources of a Specific Area, the technical possibility of systems from the number of kilowatts of electricity that electricity can generate and the performance of available solar resources and their specific system and the economy of the programme. In terms of whether it is an economic meaning for SSEG clients and practical/local governments.

Renewable Energy as a Catalyst for Sustainable Development

The signing of the Kyoto Protocol, enabled many countries to reduce fossil fuel-related energy and switch to alternative energy sources (Baloyi *et al.,* 2016). This strengthens the search for more sustainable energy systems to reduce our high dependence on fossil fuels (Baloyi *et al.,* 2016).

Theoretical Model of Rolling out a Solar Embedded Generation

Some steps that apply to the implementation of the SSEG installation, through the development of procedures and systems, to incorporate photovoltaic solar energy in the municipal energy distribution business include:

Regulatory Environmental Awareness;

(a) Understanding of the technical standards that govern SSEG (NRS 097 series among others);

(b) In addition to the existing NRS097 and other NRS standards, clarify any technical issues or conditions that the municipal government wants to raise against SSEG clients;

(c) Establish rates for SSEG to protect municipal revenues (whether necessary depends on the central buyer NETFIT1 SSEG Possibility of compensation plan going into effect);

(d) Modification of the billing system to adapt to net power generation (if net power generation is allowed);

(e) Develop the necessary documents: SSEG Prospective Applicant Guide / Request SSEG Customer Form / Contract (Supply Contract) and

(f) Municipal Staff Competency: Train municipal staff to handle installation requests and inspections (if applicable) to provide clear explanations to the political leadership (SAMSET, 2014).

Analysis of Validity and Reliability of the Constructs

Validity is the grade to which a measure's mark signifies its predictable variable. However, how do researchers make such judgments? The researcher considered a cause that they considered: reliability. When a measurement has good test-retest reliability and internal steadiness, researchers should be more self-confident that these marks embody their expectations (Chiang *et al.,* 2015). In quantitative research, reliability refers to the steadiness, solidity, and repeatability of outcomes. If dependable outcomes are found under the same situations but different situations, the researcher's results are reliable (Twycross and Shields, 2004; Mohajan, 2017). Construct validity refers to the gradation to which researchers transform or transform the perception, knowledge, or behaviour of a paradigm into functional and operational realism and operationalisation (Taherdoost, 2016).

Future Technology

Van der Merwe (2017), pointed out that limitation issues are more empirical than theoretical ones because different social technology sectors have different views on the functions of social systems. The benefit of clearly observing the socio-technical system is that the co-evolution of technology and society, arrangement and purpose has become the attention of devotion (Geels, 2004; Van der Merwe, 2017). Therefore, it is recommended that municipal renewable energy regulatory agencies, that have the fiscal capability to grow or procure such systems, continue developing such systems. In turn, regulators or municipalities can allow the community (renewable energy developers and property holders) to contact the web-based system and resolve whether it is exposed or exclusive data (Adeleke, 2018).

Demand Planning

Komlanvi (2018), concluded that more research and experimental work is needed to take full advantage of the capabilities of the developed renewable energy system, and its unique control system. The scale of the system should reach almost all the possibilities. The topography of the artificial intelligence system, is integrated with a single control system, in its architecture to make it mobile and promote use by end-users (Komlanvi, 2018). If the artificial intelligence system can realise automatic adjustment and system stability, then it has various requirements for charging and automatic evaluation of the system for maintenance purposes (Komlanvi, 2018). Renewable energy investments and demand-side energy efficiency improvements play a key part in decreasing greenhouse gas releases (Barbose *et al.,* 2013; International Energy Agency, 2014; Callaway, Welfare and McCormick, 2018).

Distribution Management

Current energy schemes are not intended to care for large-scale amalgamation of photovoltaic energy, and respond to grid codes (Mansouri, Lashab, Guerrero and Cherif, 2020). The bid of able and online control methods, is very important for improved coordination between the various parts of modern electrical systems (Mansouri *et al.,* 2020; Chihota, 2019). In grid-connected mode, collaborative energy management is where microgrid participants can cooperate and use resources effectively (Oladejo, 2018). If each participant's peak energy demand and consumption patterns differ, it will bring more benefits (Oladejo, 2018).

System Design

Statistical technologies were evaluated in the proposed 1 MW PV system energy performance estimates installed in South Africa PE, PE and South Africa NMMU Summer Strand South Campus (Clohessy, 2017). These components and intervals, scattered within the tolerances, suggested that they are used to evaluate the energy generation process of the ready PV systems. The evaluation of the energy generation process of the photovoltaic system, that uses an acceptable range was not carried out before (Clohessy, 2017). The modelling of renewable energy systems is a great computational challenge, due to increasing the height of the offer and demand time series (Kotzur, Markewitz, Robinius and Stolten, 2018).

Foresight

Incorporating this development perspective, into government policy and practice frameworks to promote energy democracy, will require ongoing partnerships of knowledge and practice (Davies, 2021). Therefore, deepening the social logic of renewable energy development will allow public institutions such as state companies, public services, community cooperatives, or municipalities to play multiple roles in the energy transition to support the deployment of the renewable energy infrastructure (Davies, 2021).

Financial Management

Ducie (2017), stated that unlocking investment requires cooperation. Therefore, local governments, the private sector and communities can help unlock investment potential. The key is knowing when to promote these processes directly and only those processes (Ducie, 2017). While the public sector will always be the main driver of infrastructure development, various financing mechanisms and applicable financial partners and investment bases are needed to solve future sustainable urban problems (Ducie, 2017).

Capacity Building

Regarding the commitment of the Comprehensive Renewable Energy Producer Programme (REPPP) to include a gender perspective by empowering women with socio-economic empowerment, unlike the traditional PPI, REIPPPP risks the development of an independent energy producer (IPP) led by women (Keown, 2019). There is nothing to lose in the renewable energy industry, but it has gained a lot. It is necessary to replicate and amplify the good experience gained in the mining industry. It is a crime for the renewable energy industry to repeat the same mistakes, mainly from a social perspective. This funding aims to train our future leaders (Keown, 2019).

Regulatory Environment

Roux (2018), questioned how, in his case, urban transformation affects or restricts the country's transformation. What impact will the limited transformation of the city have on impoverished regions and cities? Who is excluded from the benefits of the reconfiguration process by defining the transition along the city line? The impact of the energy policy has prompted the need to determine the policy recommendations necessary to help achieve sustainable development and the objectives of various energy policies in South Australia (Julius, 2018). There is a need to raise the awareness of local communities/regions of the benefits of green energy. Thereafter, include and implement access to green energy in the housing policy, and improve existing houses that do not have access to green energy (Julius, 2018).

CONCLUSION AND RECOMMENDATIONS

In conclusion, from the literature, it can be concluded that there is substantial room to grow the deployment of renewable energy in South Africa. Renewable energy provides a much-needed solution to energy diversity and could directly contribute to a better energy mix. An increase in renewable energy deployment will offset the use of fossil fuels in electricity production. In turn, this will directly contribute to improved environmental management, and realise the associated benefits. Furthermore, an improvement in the energy mix will also reduce the dependency on a single supplier for the bulk energy requirements in the country. Renewable energy, therefore, will reduce energy costs, and assist in hedging against the predicted energy tariff increase path. The latter will be of great value not only to the economy but also to low-income customers.

The percentage of energy provided to the respective networks in South Africa, is relatively low compared to the energy supplied from fossil fuel power stations. The window of opportunity, to accommodate renewable energy without significant system stability risks is now. Deploying renewable energy and energy storage closer to load nodes will improve network voltage levels from a technical perspective. This will further contribute to better load management, improved load profiles and the reduction of technical losses. The factors referred to above are challenges confronting many distributors of electricity in South Africa.

Recommendations, based on the research done and having considered relevant inputs, it is recommended that:

1. Municipalities are encouraged to promote the use of renewable energy;
2. The regulator incentivises the deployment of SSEG and energy storage in the electricity distribution networks;
3. Municipal by-laws are aligned to encourage end customers to become prosumers, i.e. that they install renewable energy solutions, remain grid-tied and feed surplus energy back into the network;
4. Energy wheeling from renewable energy installation through established networks be promoted;
5. Micro-grids supplied from renewable energy sources be advanced;
6. Personnel are trained to manage and meet the renewable energy transitional requirements effectively, and
7. Renewable energy solutions, be leveraged as a catalyst for a sustainable energy distribution sector in South Africa.

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