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Towards achieving sustainable development Goal 7 (Affordable and Clean Energy) through a transition to decentralised energy systems in South Africa

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ABSTRACT

In a decentralised system, energy-producing facilities are located closer to the location of energy consumption. A Decentralized Energy system decreases the need for fossil fuels, boosts eco-efficiency, and enables the best possible use of renewable energy sources and combined heat and power. The world is moving closer to achieving Sustainable Development Goals, yet many countries in the developing world continue to face mounting power challenges resulting in constant load-shedding. This is despite the fact that energy efficiency is on the verge of advancing and renewable energy is making significant progress in the electricity industry. This study seeks to determine the role and significance of a transition to a Decentralized Energy system in achieving sustainable development goal number 7. The study found that Decentralized Energy system provides a plethora of benefits to communities, for instance, local communities under decentralised energy system have an alternative that is less expensive than the centralized national grid, and they can assist generate employment opportunities in the community. The paper concludes that even though microgrids powered by renewable energy have significantly increased access to clean energy in developing world, maintaining the microgrids' capacity to operate sustainably remains a challenge.

Introduction

Energy-producing facilities are situated nearer to the site of energy consumption in a Decentralised system (Mullarkey et al., 2015). The optimal use of renewable energy sources and combined heat and power is made feasible by a Decentralised Energy (DE) system, which also increases eco-efficiency and reduces the need for fossil fuels (Yaqoot et al., 2016). The construction of central power plants and the delivery of generating loads to consumers via massive transmission and distribution networks have historically been the focus of the electrical sector (Mullarkey et al. 2015). Power sources are moved closer to consumers by using DE systems. Additionally, because consumers are dispersed across a region, energy generation must also be decentralised to prevent inefficiencies in transmission and distribution.

Both thermal energy and electrical power can be produced in a decentralised system (Mullarkey et al. 2015). The inability of electricity to be stored and the need for on-demand generation have been key obstacles to its broad use (Wolfe, 2008). More generation sources could make it harder for power distribution systems to balance supply and demand, which they already face (Ajaz & Bernell, 2021). A few examples of technology that could store energy when supply is higher than demand and release it when demand is greatest include batteries and pumped hydro storage (Mullarkey et al. 2015). Therefore, smart grid technologies must be used to streamline grid administration in order to create a DE system (Katre & Tozzi, 2018).

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In order to overcome energy challenges, maintain the welfare of the present and future generations, and achieve the overarching goal of ensuring energy security, affordable energy supply, and environmental protection, sustainable energy generation and consumption are essential (Eberhard et al., 2016). It has become harder to justify the effectiveness and sustainability of the outdated model of centralised energy generation, transmission, and distribution, regardless of the size, security, and reliability of economies (Omer, 2008). Essentially, sustainable energy development should take into account not just cost savings but also the flexibility of switching from fossil fuels to renewable energy sources and the efficiency of energy systems (Lund, 2007). DE and smaller networks are more dependable and cost-effective alternatives to large power grids, which are prone to failure and inefficiency (Heller et al. 2018). Energy expenses for homes, businesses, and industries may be reduced by raising public understanding and acceptance of DE (Mandelli et al., 2016). The adoption of alternative energy production and consumption methods in conjunction with smart metres and other rapidly evolving demand-side response techniques has been prompted by the sharp decline in the cost of solar panels and battery storage (Mandelli et al., 2016). As stressed in SDG 7, the direction of future energy development, in this case, is towards the shift from dirty, centralised power to clean, decentralised power, which includes the development of highly renewable energies.

Recently, Europe transitioned to highly decentralised, renewable energy-based DE systems from centralised, fossil or nuclear energy-based electricity delivery systems (Heller et al. 2018). The constant use of fossil fuels in China's industry, transportation, and heating is a primary cause of the nation's high pollution rates; however, Arcos-Vargas et al. (2017) predict that broad adoption of DE systems will drastically reduce these rates. However, DE systems are still in their infancy in South Africa and the majority of the developing world, where they face several issues that limit their adoption. It is crucial to strengthen pertinent regulations, legislation, and mechanisms given the complexity of implementing DE systems, which involves elements like financial incentives, energy trade management, and environmental protection.

Ajaz and Bernell (2021) examined the many factors that help microgrids establish themselves in the electric power industry using the Multi-Level Model (MLP) framework. This was done in order to identify the elements that help microgrids take off. The study's conclusions indicate that the infrastructure's vulnerability to harsh weather forced the states of New York and California to build new infrastructure that is more dependent on decentralisation. Ajaz and Bernell (2021) also found that the success of these systems depends on the government's assistance in the development of microgrids. This is because new technologies emerge and evolve quickly and because there is a need for various types of government intervention, which is typically met by the application of rules and regulations. The results of a study by Kainiemi et al. (2019) show that both the public and private sectors need to exert greater effort to promote the development of microgrids in order to achieve a smooth transition. The study's conclusions state that in order to determine whether or not there are signs of a potential paradigm shift, it is also crucial to analyse the state of the energy regime at the moment. Kainiemi et al. (2019) looked into the potential for facilitating innovation as part of the energy transition using the TIS framework. The results corroborated those of studies by Ajaz & Bernell, (2021), which discovered that policy has a key role in accelerating system changes.

Sustainable Development Goal 7: Affordable and Clean Energy

Sustainable development goal 7 seeks to ensure access to affordable, reliable, sustainable and modern energy for all. The goal has five targets that are spelt out in table 1;

Table 1: SDG 7 and Its Targets

Target	Explanation
7.1	To ensure universal access to affordable, reliable and modern energy services
7.2	To increase substantially the share of renewable energy in the global energy mix
7.3	To double the global rate of improvement in energy efficiency
7.A	To enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
7.B	expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

Independent Power Projects in Africa

Nearly 600 million people in Sub-Saharan Africa do not currently have access to electricity at any given time, which serves as evidence of the region's power shortage (Eberhard et al., 2016). In order to boost generation capacity and help provide energy to those who need it most, African governments need to promote more private investment. As a result, the majority of African nations are already at their limit in terms of their capacity to meet the needs of the electrical industry. Case studies from countries in the region with the most IPP experience, including Kenya, Nigeria, South Africa, Tanzania, and Uganda, were used by Eberhard et al. (2016). The authors sought to find ways to make the region's investment climate better. Eberhard et al. (2016) also concentrated on the difficulties faced by policymakers and outlined the components that could encourage more sustained investment in the electricity sector. According to the authors, in order to draw in the private sector, governments must establish an atmosphere that is conducive to investment and business. Additionally, sub-Saharan African governments must adopt more competitive procurement practices. Eberhard et al. (2016), assert that this must entail promoting long-term contracts by using a competitive bidding process. As a result, it may be possible to negotiate lower prices and help avoid additional problems, such as the potential for challenging contracts.

An enabling environment for IPP investment is provided by policies, institutions, and regulatory frameworks that are open and supportive of the energy sector (Eberhard et al., 2016). Supportive policy frameworks are crucial for managing the power sector because they help to identify the best solutions for supply or demand management and accurately forecast future electricity demand (Eberhard et al., 2016). The White Paper on Energy Policy (ESI) 1998 of South Africa is a detailed plan for restructuring and liberalising the electricity delivery sector. Municipalities and Eskom, South Africa's national energy utility, show little interest in restructuring their operations, and it is obvious that the numerous concerned ministries have little in common.

Current Energy Outlook in South Africa

Given its contribution to the growth of the South African economy and the creation of new jobs, the energy sector has been a crucial part of the country's development (IEA, 2019). It is also crucial to emphasise how good for the nation's economy lower energy costs are. 85 per cent of the people in South Africa receive their electricity from the national grid, however, the country is unable to develop renewable energy sources due to capacity issues (IEA, 2019). The majority of South Africa's energy business is made up of coal, which is recognised as the energy source with the lowest cost per unit in the entire globe. In 2016, coal constituted the majority of the nation's energy supply, making up 62% of the total, followed by crude oil (14%), renewable energy (11%), nuclear power (3%), and natural gas (3%), in that order (IEA, 2019). Eskom, the nation's state-owned utility corporation, is South Africa's main source of power. It is in charge of producing over 90% of the nation's total electricity (IEA, 2019). Two examples of extra energy sources are private and public generators. Eskom also owns and runs a number of other power plants (IEA, 2019). The Department of Energy, a department of the South African government, is in charge of regulating the laws and regulations pertaining to energy in South Africa. Additionally, it contributes to the creation of policies that will enable the country to meet its energy needs.

The ever-rising expenses related to running and maintaining the nation's electrical transmission network provide a substantial problem for South Africa (Longe et al., 2017). Currently, Eskom is unable to secure the finance required to rebuild the grid (Ajaz & Bernell, 2021). Many customers and independent power producers are unable to connect to the national grid as a result of the current difficulties. This includes crucial enterprises like those situated in South Africa's industrial development zones (IEA, 2019). Due to the numerous barriers preventing the grid's rollout, low electrification rates have been noted in South Africa's more rural areas.

Furthermore, it is predicted that South Africa will shut down coal-fired power plants totaling about 24,100 MW by the year 2050, which will result in a significant change in the nation's overall energy mix (Longe et al., 2017). On the economy, it is anticipated that this will have a negative impact. To lessen the negative effects that the plant retirement programme will have on the local community, the government must implement efficient interventions and programmes (Integrated Resource Plan, 2019). Decentralised small grids could be used by the country as an alternative to the centralised Eskom method as the main supplier. Mini-grids, as opposed to the main grid, which is a network of transmission and distribution facilities, are decentralized and can be run by individuals or groups, while the main grid is made up of a collection of these facilities (Ajaz & Bernell, 2021).

Despite the fact that different parts of the continent face different opportunities and challenges, it is expected that Africa will continue to develop using a model that relies less on carbon consumption. The continent's energy consumption is expected to increase as a result of the expanding availability of renewable energy sources and natural gas (CSIR, 2017). The South African energy crisis may be resolved by the use of renewable energy. South Africa has a variety of underutilised energy resources, including wave energy, geothermal energy, wind energy, hydropower, and solar energy (Ouedraogo, 2019). However, the global literature on renewable energy has pointed out that some obstacles must be overcome before renewable energy projects can be successfully implemented.

Transition to Decentralised Energy Systems

Implementing DE systems can reduce or even do away with the need for large, centralised power plants and energy grids. On the other hand, these systems get their energy from a wide range of places that are all located close to where power is needed geographically. In order to design a system that is not only easy to implement but also has the potential to be extremely beneficial to all parties involved, it is necessary to have a thorough understanding of the relationships between technology, economics, and societal concerns (Fabrizio et al., 2018; Mandelli et al., 2016). To show the commercial viability of decentralised energy systems and linkages to small grids in South Africa, pilot projects must be carried out. This will make it possible to fully realise these technologies' potential. Investor support for the projects is still anticipated, despite the fact that the lack of existing business models and precedents in the country has hampered the development of these systems (CSIR, 2017). Due to their modest energy requirements and isolation from other places, rural settlements become the perfect candidates for DE systems and small grid connections. National grid extensions, on the other hand, are expensive and therefore unaffordable for isolated settlements (CSIR, 2017).

Nations all around the world are looking into the opportunities offered by DE systems. In an effort to address the energy issues that affect low- and middle-income regions of the world, numerous nations on every continent are hard at work building their very own power systems. Mini-grids can meet the needs of the most remote communities by offering services that are almost on par with those provided by standard grids (Kainiemi et al., 2019). Decentralised systems can deliver electricity to a single user or a small group of consumers simultaneously. The difference between mini-grids and stand-alone systems can often be seen in the amount of consumers who are connected to the systems (Mandelli et al., 2016). Systems that only supply electricity to a single consumer are referred to by the former term, while systems that also supply power to multiple customers are referred to by the latter term. For instance, a collection of homes in a village could use a mini-grid to distribute electricity to the various commercial and residential establishments in the area.

Barriers to Effective Implementation of Decentralised Energy Systems

The main barriers to the successful deployment of DE systems are the multiple issues that prevent them from reaching their full potential. These include the accessibility of resources, the planning and implementation of the system, and the need for a certain level of skill on the part of those who will be operating it (Yaqoot et al., 2016). The availability of resources is seen as a barrier in the process of putting in place DE systems even though renewable energy sources like wind and solar are widely available and occasionally may not provide enough power to meet demand (Kainiemi et al., 2019). Additionally, the amount of energy produced by renewable energy sources is typically less than that produced by fossil fuels due to the variety of characteristics of these sources (Yaqoot et al., 2016). As a result, they are prone to underperformance and intermittent intervals of performance. Additionally, the use of energy storage systems can improve the ability of these technologies to dispatch energy (Mandelli et al., 2016). The availability of skilled labourers is a crucial factor that must be considered when it comes to the design and installation of DE systems. Due to the fact that this issue prevents the general use of these technologies, this component is vitally crucial.

Economic roadblocks that prevent the widespread implementation of DE systems were noted by Ajaz & Bernell (2021). These financial obstacles include the expense of starting up renewable energy plants and the availability of subsidies for traditional fuels. These two elements work together to prevent the use of DE systems. Economic impediments can include things like the absence of environmental externalities from the cost of conventional energy, protracted payback times, the advantages of other fuels, and the failure of some biogas plants (Kainiemi et al., 2019). Institutional obstacles can include things like a lack of knowledge about the many government policies and procedures relating to the creation and application of DE systems, which has an impact on their broad adoption. DE systems are being developed and put into place as a result of these policies and procedures (Brisbois, 2020). The macroeconomic instability and the lack of involvement of the private sector in decision-making are additional causes of these issues. Reports state that a lot of nations favour nuclear energy and fossil fuels in their policies. DE systems face significant barriers in the form of inadequate legal and regulatory frameworks and legal and regulatory limitations.

Some scholars (Ajaz & Bernell, 2021; Kainiemi et al., 2019), assert that switching from a centralised to a DE system might unleash innovation, drive economic growth, and create new job possibilities. The monitoring and upkeep of client accounts are only a few examples of the services that can assist the operation of small grids. DE systems can help create jobs in the local community and offer local communities a cheaper alternative to the centralised national grid (Ajaz & Bernell, 2021). They can also help with the provision of energy in areas that are not already covered. By reducing the necessary number of connections, they also offer the additional benefit of lowering the overall cost of grid expansion. In contrast to a power plant, a decentralised microgrid can be quickly set up and provide access to electricity to remote locations without interfering with the operation of the main grid (Ajaz & Bernell, 2021). Due to their remote location, renewable energy sources like wind and solar power have the potential to provide a higher level of energy security, making them better for the environment and usable in microgrids (Ajaz & Bernell, 2021). In addition to being able to provide communities with electricity, mini-grids also have the potential to assist enhance the overall quality of life in these communities by lowering the cost of energy and enhancing the health of the people who live there. They also assist small businesses to expand by making it easier for them to run their operations properly.

In South Africa's Eastern Cape and KwaZulu-Natal regions, researchers investigated whether or not the installation of a microgrid may make getting access to energy easier. The vast array of factors that affect the feasibility of microgrids within the electric power business were examined using the HOMER programme (Motjoadi et al., 2020). The study examined the numerous advantages provided by various microgrid configurations as well as the technical difficulties they raise. According to research by Motjoadi et al. (2020), one of the main challenges to the development of rural microgrids is the lack of a comprehensive and integrated framework. Motjoadi et al. (2020), identified this as one of the main roadblocks to their success. It also investigated the effects that they would have on society and the environment. In addition, the study discovered that although rural microgrids that use a variety of renewable energy sources are technically feasible, in order for them to be economically sustainable, they will require help from either the government or non-governmental organizations.

The Home Energy Management Model was used in a study by Teske et al. (2020) to investigate the practicality of DE systems for residential applications. The research's goal was to build a linear-mixed integer model in order to solve the question of how a sustainable energy system might work. It was able to calculate the operational costs of different systems by accounting for the energy flows that were most effective for those systems. Additionally, it was determined when the best time would be to implement the system using a realistic daily planning horizon. Katre and Tozzi (2018) acknowledge that research on the viability of DE systems is comparative and focuses on the socioeconomic and technological aspects of how they operate. The authors claim that because of this sustainability, there is a dearth of understanding regarding how to evaluate a model's sustainability and whether it can be replicated or not. In order to assess the viability of various models for energy access on an individual basis, Katre and Tozzi (2018) created a framework. This was accomplished by fusing the Multi-Tier Framework with the multi-dimensional study of sustainability across five distinct dimensions.

Conclusions

Even though microgrids powered by renewable energy have significantly increased access to clean energy in developing nations, maintaining the microgrids' capacity to operate sustainably remains a challenge. They frequently need an energy tariff that appropriately represents their costs. Furthermore, there is still a lack of widespread acceptance of the financial viability of microgrids using renewable energy. This is because there aren't enough case studies that provide in-depth details about how these systems work and their ongoing financial viability. DE systems offer a wide range of advantages to local communities. For instance, they give them an affordable alternative to the centralised national grid and can help create job opportunities in the area. They can also help with the provision of energy in areas that are not already covered. By reducing the necessary number of connections, they also offer the additional benefit of lowering the overall cost of grid expansion.

Since distributed generation encourages multiple entities to become power producers, the existence of state-controlled electricity markets hinders the development of a DE system. For individuals who are creating connected ventures, there are difficulties in the legal and administrative spheres in addition to financial ones. To provide services for off-grid and mini-grid systems, ownership mechanisms and pricing frameworks must be developed. Pricing energy should consider the consumers' financial status and their willingness to pay for it, in addition to the cost of operating the system or gadget. Widespread deployment of distributed generating could lead to unstable voltage profiles if sufficient planning is not done. Planning carefully can help to prevent this volatility. The operating criteria for power systems will need to be rethought and updated in order to manage developing technologies like smart grids, renewable energy sources, and energy storage. When compared to large central plants, distributed producing sources frequently have a higher capital cost per kW. This is particularly true when the expenses involved in tying the various sources together are taken into account. In light of the high cost of construction and the lengthy lifespan of the current transmission and distribution equipment, it is challenging to make infrastructure modifications to make it more efficient. In order to preserve the stability of the system, it is crucial to take into account how newly added grid-connected distributed generating sources will interact with the current transmission and distribution infrastructure.

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